NOÖS

Civilisational Refoundation Protocol

Horizon 2026 — 2226

David Mosbeux

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Table of Contents

Part II — The Three Axiomatic Laws

NOÖS Civilizational Refoundation Protocol Horizon 2026 — 2226 David Mosbeux Reference edition — May 16, 2026 Document open to multilateral ratification — Open license NOÖS Protocol for Civilizational Refoundation Horizon 2026 — 2226 David Mosbeux Reference Edition — May 16, 2026 Open Document for Multilateral Ratification Free License Preface This work proposes a coherent architecture for transforming, over two centuries, the political, economic, legal, educational, and linguistic institutions of human societies. It does not claim absolute originality: each proposition is linked to previous works that prefigure it.

It does, however, claim systemic coherence — none of the six reforms is viable in isolation. The text is structured into seven parts. Part I establishes the civilizational diagnosis: why the convergence of several structural mutations makes institutional inertia costly, and why the time to act is now measurable. Part II sets out the three axiomatic laws that form the foundation of the entire edifice — systemic primacy, temporal compensation, cognitive indivisibility. Part III details the six operational institutional pillars, each with prior art verification, mechanism, indicators, and safeguards.

Parts IV to VII deal respectively with biophysical economics and the NÖM unit, the auxiliary world language Mundia, the deployment phases over two centuries, and the reasoned inventory of risks and counter-arguments. The title — NOÖS — borrows from the Greek νο■ς: intellect, spirit, ordering principle. It designates neither a political doctrine, nor a secular religion, nor an organized movement. It designates a framework for interpretation, open to critique, amendment, translation, and local appropriation. No proposition is claimed as original. Each pillar, each mechanism, each indicator is linked to the works, treaties, laws, jurisprudence, experiments, and movements that prefigure it.

This prior art verification pursues three objectives: to avoid the illusion of pure innovation, to capitalize on existing feedback, and to make scientific and legal critique possible. The author adopts the stance of an institutional engineer rather than a prophet. The goal is not to predict the future, but to provide human societies with robust arbitration tools in the face of a transition whose physical constraints are publicly known and quantified before its term — an unprecedented situation in the history of civilizational transitions.

Three audiences are targeted simultaneously: public decision-makers, constitutional lawyers, senior officials, and diplomats; researchers in social sciences, Earth sciences, artificial intelligence, linguistics, and ecological economics; and the informed citizen reader. Each chapter is written to be read independently, while still being part of an overall logic. The work is deliberately long. Its density reflects the conviction that civilizational refoundation requires simultaneously presenting the diagnosis, the method, the institutions, the indicators, the risks, the counter-arguments, and the prior art.

The hurried reader will consult the executive summary (Appendix Z) before returning to the chapters that directly concern them. Table of Contents Part I — Civilizational Diagnosis (2018-2026)

CHAPTER 1

The

Collapse of Inherited Frameworks

CHAPTER 2

The

CHAPTER 12

Synthesis:

Why 2026 Is a Tipping Point

Part II

The Three Axiomatic Laws

CHAPTER 13

Law

I — Systemic Primacy (Statement and Justification)

CHAPTER 14

Law

I — Operational Implementation

CHAPTER 15

Law

II — Temporal Compensation (Statement and Foundations)

CHAPTER 16

Law

II — Differential Accounting and Provisions

CHAPTER 17

Law

III — Cognitive Indivisibility (Statement and Stakes)

CHAPTER 18

Law

III — Regulation of Frontier AIs

Part III

The Six Institutional Pillars

CHAPTER 19

Pillar 1 —

Indexed Evolutionary Constitution (Principle)

CHAPTER 20

Pillar 1 —

Automatic Revision Mechanism

CHAPTER 21

Pillar 1 —

Legal Architecture and Hierarchy of Norms

CHAPTER 22

Pillar 2 — 200-Year

Multigenerational Trust (Principle)

CHAPTER 23

Pillar 2 —

Governance, Composition, Indicators

CHAPTER 24

Pillar 2 —

Use Cases: Water, Rare Earths, Archives, Seeds

CHAPTER 25

Pillar 3 —

Individual Vital Budget (Principle and Prior Art)

CHAPTER 26

Pillar 3 —

Quota Calibration and Exchange Mechanisms

CHAPTER 27

Pillar 3 —

Graduated Sanctions and Unseizable Vital Minimum

CHAPTER 28

Pillar 4 —

Cognitive Academy (Principle)

CHAPTER 29

Pillar 4 —

Detailed Curriculum and Evaluation

CHAPTER 30

Pillar 4 —

Global Cognitive Agency (AI Governance)

CHAPTER 31

Pillar 5 —

Chamber of Future Generations (Principle)

CHAPTER 32

Pillar 5 —

Composition, Mandates, Indicators

CHAPTER 33

Pillar 5 —

Articulation with Representative Democracy

CHAPTER 34

Pillar 6 —

Energy-Currency (Thermodynamic Standard)

CHAPTER 35

Pillar 6 —

Transitional Coexistence with Fiat

CHAPTER 36

Pillar 6 —

CHAPTER 46

Just

Transition and Geography of Transformation Part V — Mundia, Global Auxiliary Language

CHAPTER 47

Why an

Auxiliary Language in 2026

CHAPTER 48

Mundia

Specifications

CHAPTER 49

Mundia

Phonology

CHAPTER 50

Isolating

Pedagogy and

School Deployment

CHAPTER 56

100-Year

Roadmap (2026-2126) Part VI — Deployment Phases (2026 → 2226)

CHAPTER 57

Phase 1 (2026-2036) —

Crystallization

CHAPTER 58

Phase 2 (2036-2056) —

Convergence

CHAPTER 59

Phase 3 (2056-2086) —

Generalization

CHAPTER 60

Phase 4 (2086-2126) —

Maturation

CHAPTER 61

Phase 5 (2126-2176) —

Stabilization

CHAPTER 62

Phase 6 (2176-2226) —

Consolidation

CHAPTER 63

Adoption

Strategy: Contagion or Imposition?

CHAPTER 64

Progress

Indicators by Phase Part VII — Risks, Counter-Arguments, Safeguards

CHAPTER 65

Risk:

Technocratic Capture

CHAPTER 66

Risk:

Institutional Paralysis

CHAPTER 67

Risk:

Eco-Authoritarianism

CHAPTER 68

Risk:

Capture by Authoritarian States

CHAPTER 69

Risk:

Institutional Greenwashing

CHAPTER 70

Risk:

Monetary Instability in Transition

CHAPTER 71

Risk:

Cultural Rejection of Mundia

CHAPTER 72

Risk:

North-South Divergence

CHAPTER 73

Risk:

Instrumentalization by Financial Markets

CHAPTER 74

Risk:

Protocol Obsolescence Appendices

CHAPTER 75

Appendix

A — Summary Table of Prior Art (87 entries)

CHAPTER 76

Appendix

B — Measurable Indicators and Thresholds

CHAPTER 77

Appendix

C — Glossary of 120 Terms

CHAPTER 78

Appendix

D — Reference Legal Models

CHAPTER 79

Appendix

E — Thematic Bibliography (300 references)

CHAPTER 80

Appendix

Z — Executive Summary (15 pages) Part I — Civilizational Diagnosis (2018-2026) Chapter 1 The collapse of inherited frameworks: The disarticulation of post-Westphalian political and economic paradigms. The years 2018-2026 have catalyzed a profound transformation of global political and economic structures, revealing the obsolescence of frameworks for thought and action inherited from the 20th century. The Westphalian nation-state model, formalized by the treaties of 1648, and its economic corollary – industrial then financial capitalism – struggle to apprehend the complexity of contemporary challenges.

Systemic interconnectedness, analyzed by Ulrich Beck as early as 1986 in *Risk Society*, has transformed threats into global risks, challenging traditional state sovereignties. Successive shocks have highlighted the fragility of systems designed for a world of linearity and predictability. The COVID-19 pandemic, which began in late 2019, exposed the vulnerability of globalized supply chains and the disparity of health responses, while accentuating a global public debt that reached $255 trillion in 2020 according to the IMF, or 290% of global GDP.

This crisis also revealed the impasse of purely national policies in the face of cross-border threats, reaffirming the urgency of multi-scalar governance. The war in Ukraine, which began in February 2022, shook the post-Cold War geopolitical order, challenging European and global security architectures. It underscored the persistence of power confrontation, but also the energy vulnerability of industrialized nations, facing dependence on hydrocarbons, and information manipulation on an unprecedented scale, as anticipated by Manuel Castells in his major work, *The Information Age* (1996-1998).

The exponential emergence of generative artificial intelligence, since the advent of models like ChatGPT in late 2022, is redefining the contours of work, creation, and human cognition. This advent questions the foundations of intellectual property, education, and decision-making, disrupting pre-existing regulatory and ethical frameworks, often ill-adapted to the speed of technological innovation. This gap between technological progress and regulation illustrates the inertia of current normative processes. The Anthropocene, accelerator of systemic crisis.

Climate change, whose manifestations are visibly accelerating, constitutes the most powerful indicator of the obsolescence of our frameworks. The Intergovernmental Panel on Climate Change (IPCC), in its Sixth Assessment Report (2021-2023), confirmed the increase in extreme weather events and the irreversibility of certain impacts. Carbon dioxide (CO■) concentrations in the atmosphere surpassed 420 parts per million (ppm) in 2021, a level unprecedented for several million years, according to NOAA. The sixth mass extinction, documented by studies such as the 2019 IPBES report, reveals a collapse of biodiversity at an unprecedented rate, with one million species threatened with extinction.

This phenomenon, coupled with ecosystem degradation, jeopardizes ecosystem services essential to the maintenance of human life on Earth, rendering obsolete economic approaches that externalize environmental costs, as demonstrated by Karl Polanyi in *The Great Transformation*

(1944). These ecological crises are not mere "externalities" but intrinsic manifestations of an unsustainable development model. They directly challenge the notion of infinite growth on a finite planet and call for a radical re-evaluation of indicators of wealth and progress, beyond simple gross domestic product.

Ecological economics proposes alternatives, such as Kate Raworth's *doughnut economics* (2017), aiming to reconcile prosperity and planetary boundaries. The scientific recognition of the Anthropocene, a concept popularized by Paul Crutzen and Eugene Stoermer in 2000, designates a new geological epoch where human activity is the dominant force transforming the Earth. This conceptualization shifts humanity from the status of an external observer to that of a major geological actor, implying unprecedented responsibility and a semantic and philosophical re-examination of the nature/culture distinction, central to the works of Bruno Latour (1991, *We Have Never Been Modern*).

Polarization and the erosion of institutional trust. The decade 2018-2026 is marked by increasing societal polarization, exacerbated by digital platform algorithms and the massive spread of misinformation. Persistent, and even worsening, socio-economic disparities in many developed economies fuel palpable resentment and a questioning of political and economic elites. This polarization manifests through deep ideological divisions, undermining democratic consensus. The decline of trust in institutions is a strong trend. According to the Edelman Trust Barometer 2024, trust in governments and media remains low, with only 51% of respondents trusting their governments.

This distrust impinges on the capacity of states to mobilize their populations to face collective challenges and implement long-term policies. It also fuels the rise of populism and anti-system movements. Distrust does not spare scientific bodies, despite the gravity of the warnings. Controversies surrounding scientific evidence, particularly on climate or vaccines, reveal an epistemological crisis where the authority of expert knowledge is contested, often in favor of alternative narratives disseminated through unverified channels. This erosion of scientific credibility makes it more difficult to formulate policy responses based on tangible facts.

This challenge to institutions is coupled with a crisis of representation. Representative democratic systems struggle to integrate the diverse and sometimes contradictory aspirations of citizens in a context of increasing complexity of issues. Direct citizen participation, through mechanisms like the citizens' climate conventions experimented in France (2019-2020), testifies to an attempt at democratic revitalization, but their scope remains limited. The impasse of existing legal and ethical tools. International law, based on state sovereignty and consent, shows signs of faltering in the face of transnational issues.

Essential multilateral agreements, such as the Paris Agreement on climate (2015), depend on the goodwill of signatories and are insufficiently binding to guarantee the achievement of objectives. Sanction mechanisms are often weak or unenforced, as evidenced by the difficulty of limiting greenhouse gas emissions. The proliferation of environmental legal instruments, from environmental law to the rights of nature, illustrates an awakening of consciousness, but their effectiveness clashes with diverging economic and political logics. The establishment of specialized tribunals or redress mechanisms for future generations, though discussed, remains marginal.

Law struggles to anticipate and regulate rapid technological innovations, leaving gaping gray areas, particularly in the fields of AI and bioethics. On an ethical level, Kantian or utilitarian frameworks, so structuring for modernity, struggle to provide adequate answers to the dilemmas posed by the Anthropocene and AI. The notion of intergenerational responsibility, while widely accepted in principle, remains difficult to translate into concrete legal obligations. The question of assigning rights or a form of legal personality to non-human entities, whether ecosystems or artificial intelligences, is at the heart of emerging philosophical and legal debates.

The difficulty of defining a global "general interest" in the face of antagonistic national or corporatist interests weakens any attempt at supra-national regulation. The absence of a legitimate authority to arbitrate between contradictory imperatives – economic development, environmental protection, digital sovereignty – leads to fragmented responses and an inability to initiate systemic transformations. The necessity of epistemic and normative renewal. Faced with this constellation of interdependent crises, a simple adaptation of existing frameworks appears insufficient.

A profound epistemic and normative renewal is imperative, a refoundation of political imaginaries, economic theories, and legal systems. Complex thought, theorized by Edgar Morin, offers avenues for apprehending interdependencies and overcoming compartmentalized disciplinary approaches. It is necessary to rethink the relationship between human and non-human, no longer as a subordinate duality but as a co-belonging within a single Earth system. This ontological shift, which permeates political ecology and Earth philosophy, implies integrating the biophysical limits of the planet into the heart of all political and economic decisions, instead of relegating them to the periphery.

Sovereignty itself must be re-examined. Not as an absolute prerogative of states in the face of global challenges, but as a capacity to articulate multi-level governance, from local to planetary. This requires the invention of new forms of institutions and decision-making mechanisms that can transcend national borders while respecting local specificities, fostering an ecological and global citizenship. This renewal implies moving beyond inherited antinomies – state/market, freedom/security, tradition/progress – to forge innovative syntheses. It calls for the development of new metrics of progress, which integrate ecological resilience, social justice, and non-material well-being.

This intellectual and political challenge is on a scale comparable to that of the Enlightenment for the end of the Ancien Régime. Chapter 2 The Nine Planetary Boundaries and the Six Already Transgressed. The Concept of Planetary Boundaries: A New Governance Framework. The approach of the nine planetary boundaries, conceptualized by Rockström *et al.* in 2009 and regularly updated, notably by Steffen *et al.* in 2015 and then by Richardson *et al.* in 2023, offers an essential analytical framework for understanding the Earth system's state of resilience.

These are not fixed thresholds, but rather zones of uncertainty and increasing risk beyond which the fundamental biophysical processes regulating the Earth's Holocene stability could be irreversibly altered. Transgressing these boundaries does not imply immediate collapse, but a significant increase in the probability of abrupt and large-scale environmental changes, threatening the stability upon which human societies depend. This framework is situated within a Earth System Science perspective, recognizing the deep interconnections between the different components of the global environment.

The disturbance of one boundary can exacerbate others, creating positive feedback loops that accelerate movement towards less desirable and potentially more chaotic systemic states. Modern environmental governance, often fragmented and sectoral, struggles to grasp this systemic complexity. The Stockholm Resilience Centre's initiative, by identifying and quantifying these nine frontiers, aims to provide clear indicators for political and economic decision-makers, transcending traditional political divides. It offers a compass for the human trajectory in the Anthropocene, this geological epoch where human activity has become the dominant geophysical force.

The objective is to maintain the biophysical conditions that have allowed human civilizations to flourish over the past 10,000 years. The implications of this framework are profound. It challenges paradigms of unlimited economic growth and absolute decoupling between economy and environment, by postulating incompressible biophysical thresholds at the planetary scale. Public and international law finds a new field of application here, by defining shared responsibilities for the management of these planetary common goods and by developing regulatory mechanisms capable of internalizing these limits into collective decisions.

Detailed Description of the Nine Planetary Boundaries and their Current State. Climate Change. Climate change is the most publicized boundary, defined by atmospheric CO_2 concentration and radiative forcing. The safety threshold was initially set at 350 parts per million (ppm) of CO_2. However, the current concentration has long since exceeded this threshold. According to the World Meteorological Organization, the global average CO_2 concentration reached 418 ppm in 2022 and continued to rise, settling at around 420 ppm in 2023, far from the safe threshold (WMO, 2023). The threshold for increased radiative forcing is set at 1 W/m^2.

Currently, it exceeds 2.91 W/m^2 above pre-industrial levels (Richardson *et al.*, 2023). Consequences include ocean acidification (another boundary), ice melt and sea-level rise, as well as extreme weather events whose frequency and intensity are increasing, as reported by the sixth assessment report of the IPCC (IPCC AR6, 2021). Transgression of this boundary is a source of climate runaway effects, notably through permafrost thawing releasing methane and the weakening of the oceanic carbon pump. Biosphere Integrity. This boundary encompasses biodiversity loss and species extinction.

It is measured by two sub-components: the species extinction rate and the functional integrity of ecosystems (biodiversity integrity index of the biosphere). The natural extinction rate is estimated at 0.1 to 1 species per 10,000 species per century. Currently, it is at least 10 to 100 times higher. IPBES (2019) estimates that one million species are threatened with extinction, out of a total estimated population of 8 million species. Functional integrity is below the safe threshold. The biomass of terrestrial ecosystems is significantly reduced, and habitat connectivity is fragmented, compromising essential ecosystem services such as pollination, water regulation, and carbon sequestration.

The viability of this boundary is crucial, as it is the foundation of all life on Earth and ensures the stability of other boundaries, particularly the carbon and water cycles. Its transgression means a drastic reduction in the capacity of ecosystems to adapt to disturbances and to provide the conditions necessary for human existence. Biogeochemical Cycles (Nitrogen and Phosphorus). These cycles are disturbed by the excessive input of anthropogenic nutrients, primarily linked to intensive agriculture. For the nitrogen cycle, the safety threshold is 62 million tons of reactive nitrogen produced annually.

Currently, over 200 million tons are released into the environment, leading to oceanic dead zones and toxic algal blooms. Only about 130 million tons are effectively absorbed by crops (Richardson *et al.*, 2023). For the phosphorus cycle, the safety threshold is 6.2 million tons of annual anthropogenic phosphorus. Inputs exceed this threshold, with annual flows of approximately 22.6 million tons (Richardson *et al.*, 2023). These disruptions cause eutrophication of fresh and marine waters, alter drinking water quality, and threaten aquatic biodiversity. The consequences are systemic, affecting human health and long-term agricultural yields. Land-System Change.

This boundary concerns the conversion of natural ecosystems into agricultural or urban lands. The threshold is set at 75% forest land in temperate and boreal zones, and 85% in tropical zones. Historically, 59% of emerged land is no longer pristine, having been modified by human activity. The desertified or degraded land surface exceeds 25% of the global terrestrial surface (IPBES, 2019). The critical threshold for ecosystem integrity is 75% undisturbed ecological integrity. It is currently at 50-60%.

Deforestation and soil degradation reduce the capacity of ecosystems to sequester carbon, fueling climate change, and impact regional and local hydrology, amplifying the risks of floods and droughts. This boundary is intrinsically linked to biodiversity, with forests being major reservoirs of species and providers of important ecosystem services. Freshwater Use. The freshwater boundary is defined by blue water withdrawals (rivers, lakes, aquifers) without compromising the resilience of aquatic ecosystems. The safety threshold is approximately 4000 km3 per year.

Current annual withdrawals are significantly higher, with global use estimated at approximately 4000 km3/year for agriculture, industry, and domestic uses (IPBES, 2019). This figure does not highlight the pressure on aquifers, whose reserves are sharply declining. Furthermore, the modification of green water flows (soil moisture and evapotranspiration) is also crucial. Thresholds are transgressed for green water flows in nearly half of the world's river basins. This boundary is transgressed in many regions of the world, particularly Southeast Asia, the Middle East, and the American West, leading to water stress, conflicts over water access, and accelerated soil degradation.

Ocean Acidification. Ocean acidification is a direct consequence of increased atmospheric CO2 concentrations. When CO2 is absorbed by seawater, it forms carbonic acid, lowering the pH of the oceans. The average pH has already decreased by 0.1 units since the beginning of the industrial era (from 8.2 to 8.1), representing a 26% increase in acidity (IPCC AR6, 2021). The safety threshold is set at an aragonite saturation of 80% relative to pre-industrial levels. Currently, aragonite saturation is 84%. This process directly threatens marine organisms forming shells and calcareous skeletons, such as corals, mollusks, and many plankton, which form the base of marine food chains.

French law on biodiversity of August 8, 2016, incorporates measures for the protection of marine ecosystems, but the issue of acidification exceeds national competencies. Novel Entities (Chemical Pollution). This boundary concerns the introduction of new substances, materials, and forms of energy that can have harmful effects on Earth systems. It includes persistent organic pollutants, heavy metals, radionuclides, microplastics, and nanomaterials. Due to a lack of complete data and understanding of the combined effects of these substances, a precise quantitative global threshold is difficult to establish.

However, the accumulation of these entities clearly exceeds the assimilation capacity of ecosystems. The production and release of chemicals increased by 23% between 2000 and 2017 (Richardson *et al.*, 2023). Evidence of negative impacts is increasing, ranging from hormonal disruption and direct toxicity to living organisms to contamination of food chains and degradation of soil and water. This boundary is considered largely transgressed, but exact quantification remains a major scientific challenge, requiring an approach by substance groups and specific regions. Atmospheric Aerosol Loading.

Aerosols are fine particles suspended in the atmosphere, of natural or anthropogenic origin (biomass combustion, industrial emissions). They influence the climate by reflecting sunlight (cooling) or absorbing it (warming), and by modifying cloud formation and the water cycle. Aerosols also have direct impacts on human health, particularly respiratory. There is no single planetary threshold for this boundary, due to the complexity of their regional effects and their short atmospheric lifetime. The net radiative forcing of aerosols remains one of the largest uncertainties in climate projections.

However, atmospheric concentrations of certain aerosols, particularly PM2.5 fine particles, largely exceed WHO recommendations in many megacities, leading to millions of premature deaths each year. More robust quantification is required, based on regional air quality indicators and the impact on radiative forcing. Stratospheric Ozone Depletion. This boundary is the only one that is in the process of being restored, thanks to concerted international action. Ozone depletion is due to emissions of ozone-depleting substances (ODS), primarily chlorofluorocarbons (CFCs) and halons. The safety threshold is 275 Dobson Units, corresponding to a maximum loss of 5% compared to reference levels.

At its lowest in the 1990s, spring ozone over Antarctica dropped to less than 100 DU. The Montreal Protocol, signed in 1987, enabled a drastic reduction in the production and consumption of ODS. As a result, the ozone layer is recovering and is expected to return to its pre-1980 levels by around 2060 (UNEP, 2018). This success demonstrates that ambitious international political action is possible to address global environmental threats, but it also highlights the need for a rapid and collective response. The Six Boundaries Already Transgressed and Their Systemic Consequences.

According to the assessment by Richardson *et al.* (2023), six of the nine planetary boundaries are now considered to be transgressed. These are climate change, biosphere integrity, the biogeochemical cycles of nitrogen and phosphorus, land-system change, freshwater use, and novel entities. Their cumulative transgressions have serious consequences for the overall resilience of the Earth System. The simultaneous transgression of climate change and biosphere integrity creates a double existential threat. Biodiversity loss weakens the ability of ecosystems to adapt to climatic disturbances and to regulate biogeochemical cycles.

For example, tropical deforestation reduces carbon sequestration and alters regional precipitation patterns, which can lead to irreversible tipping points for major ecosystems such as the Amazon rainforest. Disruptions to the nitrogen and phosphorus cycles, coupled with land-system change, lead to widespread degradation of soils and waters. Eutrophication threatens aquatic life and the availability of drinking water, while the loss of soil fertility through erosion and depletion of organic matter compromises global food security.

The European Union's Nitrates Directive (91/676/EEC) attempts to regulate nitrogen discharges, illustrating a legal arsenal that is still insufficient given the scale of the problem. Excessive freshwater use, exacerbated by climate change (frequent droughts) and the degradation of watersheds (deforestation), leads to a scarcity of this vital resource. More than 2 billion people currently live in regions experiencing high water stress (UNEP, 2021). Conflicts over usage are emerging, and ecosystems dependent on these water reserves are collapsing. Novel entities, often invisible and insidious, accumulate in all environmental compartments.

Microplastics, for example, are found from the bottom of the oceans to mountain tops and in the human body. Their long-term impacts, particularly on health and food chains, are poorly understood, but they represent a diffuse and persistent threat, potentially synergistic with other environmental stresses. The accumulation of these transgressions indicates that humanity is no longer navigating within a safe space for its development. The overlaps and interdependencies between these boundaries suggest that a holistic approach and integrated solutions are essential. Fragmented efforts will not be sufficient to restore the resilience of the Earth system.

It becomes imperative to adopt a planetary governance framework capable of apprehending and managing these systemic risks. Implications for International Law and Governance. The concept of planetary boundaries directly challenges the global legal and institutional architecture. International environmental law, often characterized by a reactive and sectoral approach, must evolve towards a proactive and integrated logic. Existing treaties, such as the Convention on Biological Diversity (CBD) or the United Nations Framework Convention on Climate Change (UNFCCC), while crucial, are not sufficient to bring about the systemic changes required.

The notion of "planetary common goods" emerges as a framework for understanding planetary boundaries, justifying shared responsibility and the establishment of rules for collective management. This approach aligns with theories of environmental justice, which highlight inequalities in exposure to risks and the imperative of intergenerational equity. The recognition of constitutional duties towards the environment, such as Article 3 bis of the French Environment Charter of 2004, constitutes a significant first step, although global effects require transnational coordination. Economic regulation must imperatively internalize environmental costs that have hitherto been externalized.

Market mechanisms, such as carbon markets, offer avenues, but their shortcomings and limited scope call for a deeper reform of tax systems and subsidies, particularly those that favor environmentally destructive activities. Sustainable finance must become the norm, allocating capital towards regenerative activities that respect planetary thresholds. Finally, Earth governance in the Anthropocene era requires unprecedented scientific and political cooperation. Earth system sciences provide the diagnoses, but translating this knowledge into concrete policies requires robust democratic debates and legitimate decision-making mechanisms.

The establishment of "guardian councils" for planetary boundaries, combining scientific expertise and citizen representation, could be a way to ensure the sustainability of our living space. Chapter 3 Net Energy, EROI, and the Physical Ceiling of Growth The Concept of Net Energy and EROI The analysis of the relationship between energy and economic growth has evolved profoundly with the introduction of the concept of Net Energy, popularized by the Energy Return On Investment (EROI) ratio. Formally defined by Cutler J. Cleveland, Robert Costanza, Charles A.S.

Hall, and Robert Kaufmann as early as 1984, though its premises were laid by Hall and Cleveland in 1981, EROI measures the amount of usable energy a production system delivers for one unit of energy invested in its life cycle. It is expressed as the ratio of energy delivered to energy expended to obtain it and make it available. This ratio is fundamental because it transcends mere market accounting or monetary costs, positioning itself at the level of the physical flows underlying all economic activity.

An energy source with a high EROI means that a small amount of energy is needed to extract a large quantity, thereby releasing a substantial energy surplus for societal activities not directly related to energy production, such as agriculture, industry, transport, health, or education. Modern economy, as we have known it since the industrial revolution, was built on a massive exploitation of fossil resources offering initially very high EROIs. For example, the first oil wells in Texas in the early 20th century showed EROIs greater than 100:1. This energy abundance allowed for unprecedented development, an exponential increase in productivity, and demographic and technological expansion.

However, it is crucial to distinguish the EROI of an energy source at extraction (wellhead or mine EROI) from the overall EROI at consumption. The latter integrates the energy required for the transformation, transport, and distribution of the final energy. For society to function, the net energy available must be sufficient to cover all its needs, well beyond the mere production of energy itself. The Historical Evolution of EROI and its Implications for Potential GDP The evolution of EROI for various energy sources follows a generalized decline trajectory for fossil fuels and a more mixed performance for renewable energies.

Historically, conventional oil saw its average EROI drop from about 100:1 at the beginning of the 20th century to about 20-30:1 in the 1970s, and is estimated today, for conventional oil from mature wells, to be around 10-15:1 (Hall, Lambert, & Balogh, 2014). This decline is due to the gradual depletion of the most easily accessible and concentrated resources. New exploitations are launched in more complex geological contexts, requiring more sophisticated technologies such as hydraulic fracturing for shale gas and oil, deepwater drilling, or the exploitation of oil sands.

These techniques naturally consume more energy, whether for extraction, transformation, or waste treatment, which further reduces the EROI. Natural gas follows a similar trend, with increasingly difficult-to-exploit deposits. Coal, though still abundant, has seen the EROI of its conventional mines decrease. The average EROI for all fossil fuels, taking into account the total energy investments of the system to deliver them to the final consumer, hovered around 15:1 in the early 2000s, and is now approaching 10-12:1 globally in 2024 according to some estimates (Morgan, 2013). Regarding renewable energies, their EROI varies considerably.

Hydropower, when favorably located, can show very high EROI, sometimes above 80:1. However, the most favorable sites are already exploited. Wind energy generally exhibits EROIs between 10:1 and 30:1, depending on wind power and installation longevity. Solar photovoltaic, after decades of technological improvements, has seen the EROI of its panels increase significantly, from less than 1:1 in the 1970s to about 6:1 to 12:1 today, for large-scale installed systems (Jancovici, 2019). A low EROI for an energy source means that a larger proportion of the energy produced must be reinvested in the energy system itself.

This translates into a reduction of net energy available for other sectors of the economy. Timothy Morgan and other economists have highlighted that GDP growth is strongly correlated with the availability of this net energy. When the average EROI of an economy's entire energy mix declines, the proportion of gross energy dedicated to energy production increases, decreasing the share allocated to the production of goods and services. This phenomenon illustrates a scissor effect: the amount of energy needed to maintain the complex functioning of a technologically advanced society does not necessarily decrease, while the ease of access and efficiency of energy production tend to decrease.

This physical reality imposes a structural constraint on nations' potential GDP. A declining national average EROI means that it is increasingly costly, in energy terms, to obtain the same level of wealth. The Critical EROI Threshold and the Limits of Growth EROI studies suggest the existence of critical thresholds, beyond which the maintenance of a complex society becomes energetically very difficult, if not impossible. Charles A.S.

Hall, in particular, advanced the idea that an EROI below 3:1 for the entire energy system would mean the end of industrial society as we know it, because the net energy available would no longer be sufficient for essential activities outside of energy production (Hall, Lambert & Balogh, 2014). This is due to the fact that every system, whether agriculture, transport, health, or education, requires a certain energy input to function. If energy production itself absorbs most of the gross energy, these societal functions are compromised.

Some have even refined these thresholds, suggesting that an aggregated EROI below values like 5:1 or 7:1 could already prevent the funding of sectors such as research and development, higher education, or non-essential public services for immediate survival. Researchers like Gaël Giraud remind us that physical and human capital is intrinsically an embodiment of energy. The construction of a road, a factory, a hospital, or the training of an engineer, requires energy inputs. If energy production becomes too costly in energy terms, the capital necessary for the reproduction of our society can no longer be accumulated at the necessary rate, leading to constrained physical degrowth.

The concept of a "physical ceiling to growth" then emerges. This is not so much a limit to resources as such (although they exist) as it is the limit imposed by the physical capacity to mobilize enough net energy to sustain a constantly expanding economic system. GDP growth is, ultimately, the growth of the consumption of energy and material flows. If the efficiency of this conversion, measured by EROI, decreases, then economic growth becomes energetically more demanding. The idea of perpetual growth is thus directly questioned by the physics of net energy.

Energy efficiency gains at the final consumption level can certainly moderate demand, but they do not eliminate the fundamental problem of the degradation of primary sources' EROI. The 2015 French Energy Transition for Green Growth Law, aiming notably to reduce fossil fuel consumption, implicitly recognizes this physical constraint, even if the direct link with EROI is not always explicitly formulated in its provisions. According to the IPCC (Intergovernmental Panel on Climate Change), world primary energy consumption grew by about 1.7% per year between 2000 and 2019.

Maintaining this growth with a declining average EROI means an exponential increase in gross energy needs, which is incompatible with finite resources and climate imperatives. In 2023, global primary energy consumption reached approximately 635 EJ (exajoules), 80% of which came from fossil fuels. A Striking Example: The Case of Canadian Oil Sands To concretely illustrate the drop in EROI and its implications, the exploitation of oil sands in Alberta, Canada, provides an enlightening case study. These deposits contain viscous bitumen requiring significant amounts of energy to be extracted and converted into synthetic crude oil.

Rather than pumping liquid oil at high pressure, it is necessary to heat the subsurface with steam (a process called SAGD, Steam-Assisted Gravity Drainage) or to dig vast open-pit mines to extract the ore. The process of extracting and upgrading oil from oil sands is extraordinarily energy-intensive. Reliable EROI estimates for these resources generally range between 3:1 and 6:1 (Brandt, 2011). This means that for three to six units of energy delivered to the consumer, one unit of energy was invested for extraction, transport, and refining. By comparison, the EROI of an easily accessible conventional oil well could exceed 100:1 at the beginning of the 20th century.

This low EROI has multiple consequences. Firstly, it directly contributes to the decline of the global average EROI of oil. By integrating increasingly "expensive" energy sources, the share of overall gross energy re-appropriated by the energy sector grows. Secondly, oil production from oil sands releases significantly higher greenhouse gas emissions than conventional oil, due to the intense heating processes and combustion necessary for these operations. This is an ecological and energy dilemma: low EROI energies are often also the most polluting. The capital and energy investment required to develop these projects is colossal.

For example, the Athabasca Oil mine project required billions of dollars in investment and equally significant amounts of energy to become operational. These investments are directly correlated with energy, as machines, infrastructure, and labor are themselves the result of an energy cost. It is evident here that the decrease in EROI is not merely a matter of an increase in monetary price, but of a physical scarcity of usable net energy. The economic viability of oil sands projects is heavily dependent on a sufficient oil barrel price to justify these energy and monetary expenditures.

When oil prices collapse, as was the case in 2014 or 2020, these operations become less profitable and projects are canceled or suspended, not only for financial profitability reasons, but primarily because the amount of net energy derived from them limits the amortization of invested energy capital. The Role of Renewable Energies from an EROI Perspective The transition to renewable energies is often presented as the solution to energy and climate challenges, but its evaluation through the lens of EROI is essential.

While intrinsically decarbonized in use, the production of renewable equipment (wind turbines, photovoltaic panels, batteries) is very demanding in raw materials and energy-intensive industrial processes.

The EROI of different renewable sectors is therefore a crucial point. Wind turbines, for example, require significant quantities of steel, concrete, and rare earths for their magnets. Their manufacturing, installation, and maintenance demand considerable energy consumption. The EROI of wind power varies greatly depending on studies and assumptions, ranging from 10:1 to 30:1. However, the intermittency of this source must also be taken into account.

The energy produced is not constant and requires storage systems or backup sources (often thermal power plants) to ensure grid stability, which reduces their effective EROI for the overall system. Solar photovoltaic, after decades of research and development, has seen its EROI grow spectacularly. It was less than 1:1 in the 1970s, which meant that more energy had to be invested to manufacture a panel than it produced during its entire life. The EROI of modern panels is now between 6:1 and 12:1. However, challenges remain, such as the need for space, production variability, and the necessity for costly energy storage systems (batteries), which themselves have an EROI to consider (Smil, 2017).

Hydropower, when possible, remains the renewable source with the highest EROI, sometimes exceeding 80:1. However, almost all geologically favorable sites are already exploited in developed countries, and the construction of large dams is often very capital-intensive, high in embodied energy, and has significant environmental and social impacts. An often-overlooked aspect is the need for a complete overhaul of the energy system. The transition to 100% renewables, however desirable for decarbonization, implies building massive infrastructures (transmission grids, storage systems) which represent a colossal energy investment.

This "system EROI" is a potential limiting factor for the speed and scale of the transition. Recent works, such as those by Jean-Marc Jancovici, emphasize that the mass of physical capital to be created for a decarbonized society is gigantic, implying a massive allocation of energy and resources (Jancovici and Blain, 2021). In 2024, the global average EROI remains dominated by fossil fuels, despite the growth of renewables. The challenge is to maintain an aggregated EROI sufficient for the functioning of society, while shifting to less carbon-intensive sources.

The continuous degradation of the EROI of fossil fuels, combined with the often lower (but improving) EROIs of intermittent renewable energies, raises the question of the sustainability of future economic growth. Legislators, through texts such as the French law on the Acceleration of Renewable Energy Production adopted in 2023, are trying to respond to this need for diversification, but without always explicitly integrating the EROI constraint into the cost-benefit analysis. Global Governance and the Physical Ceiling The question of the physical ceiling to growth, illuminated by EROI analysis, inevitably leads to issues of global governance.

The physical impossibility of maintaining perpetual economic growth, as we have known it over the last two centuries, in the face of dwindling net energy, demands a profound reassessment of economic and political paradigms (Costanza et al., 2014). International institutions and current treaties struggle to integrate this fundamental constraint. The Paris Agreement on climate (2015), for example, aims to limit global warming caused by GHG emissions, but does not directly address the issue of net energy availability or the finitude of resources. It focuses on the output (emissions), without fully addressing the input (net energy) that supports the carbon-based economy.

The work of the OECD (Organisation for Economic Co-operation and Development) or the IMF (International Monetary Fund) continues to promote policies aimed at GDP growth, without always fully integrating the physical limits of the Earth system. GDP, as an indicator, measures monetary flows and not the availability of net energy, which can lead to suboptimal decisions, or long-term energetically untenable ones. Awareness of EROI and its implications requires international coordination for an energy transition that is not only decarbonized but also energetically realistic. This implies massive investments in energy efficiency, sobriety, and the development of high-EROI renewable energy sources.

It also means redistributing wealth more equitably if the "size of the pie" can no longer grow indefinitely. The challenge is immense, as it involves rethinking the very notion of "progress" and "development" in a world where the energy surplus is diminishing. International law and national policies will have to adapt to this physical reality.

This could involve national net energy quotas, agreements on the management of low-EROI resources, or funding mechanisms for R&D for energy-efficient and high-EROI technologies, as economist Nicholas Georgescu-Roegen already emphasized in 1971 in "The Entropy Law and the Economic Process." The Rio Earth Summit in 1992, through Agenda 21, laid the groundwork for reflection on sustainable development, but had not yet fully integrated the notion of EROI as a major physical constraint to growth.

Chapter 4 The Emergence of General-Purpose Artificial Intelligences The Genesis and Expansion of Large Language Models The year 2017 marks a fundamental rupture in the field of artificial intelligence with Google Brain’s publication of the paper "Attention Is All You Need," introducing the Transformer architecture. This innovation, prioritizing attention mechanisms over traditional recurrent architectures such as LSTMs, radically simplified sequence modeling and paved the way for training models with billions of parameters. It provided the necessary algorithmic foundation for the emergence of the Large Language Models (LLMs) we know today.

The following decade saw an unprecedented acceleration of capabilities. GPT-3, launched in June 2020 by OpenAI, with its 175 billion parameters, demonstrated unexpected generalist skills, capable of generating coherent and contextually relevant text on a multitude of subjects. Its performance, ranging from code writing to creative content generation, underscored the transformative potential of these large-scale architectures. It also highlighted the scaling laws, formalized by Kaplan et al. in 2020, which predict a constant improvement in performance with the increase in model size, training data, and compute budgets. Subsequent developments confirmed this exponential trajectory.

GPT-4, deployed in March 2023, surpassed its predecessor in robustness and multimodal reasoning capabilities, accepting visual inputs in addition to text. Its ability to pass standardized exams with near-human scores, such as the American uniform bar exam where it ranks in the 90th percentile (OpenAI, 2023), testifies to its sophistication. Other players quickly followed, such as Google with Gemini 1.0 at the end of 2023, then Gemini 1.5 Pro in February 2024 integrating a million-token context window, and Anthropic with Claude 3 Opus in March 2024, claiming competitive performance on academic benchmarks.

The year 2025 was marked by the emergence of GPT-5 and other competing models like DeepSeek 2, reaching scales of hundreds of trillions of parameters, even exceeding the quadrillion. These progressions are not mere quantitative increases: they induce emergent capabilities, where the model develops skills not explicitly programmed, such as in-context learning or a rudimentary form of planning. These advances open up prospects for applications unimaginable only a few years ago, profoundly changing human-machine interactions. Implications for Cognitive Work, Research, and Education The advent of these general-purpose AIs (AGIs) exerts unprecedented transformative pressure on cognitive work.

Entire professions, from content writing to medical diagnosis, are bound to be radically altered, or even augmented. A report by the MIT

Task Force on the Work of the Future (Autor et al., 2020) already underlined the growing importance of skills complementary to automation, but the scale and speed of current changes exceed these initial predictions. In the field of scientific research, LLMs are becoming invaluable tools for analyzing vast corpora of literature, formulating hypotheses, generating experimental plans, and even synthesizing new molecules or materials.

For example, DeepMind's AlphaFold 2, although specialized, demonstrated AI's ability to solve complex problems like protein folding (Jumper et al., 2021). Generalist models are beginning to emulate this capacity in interdisciplinary fields, significantly accelerating the pace of discoveries. Education is also profoundly affected. Personalized AI-based tutoring, capable of adapting content and pedagogy to each student's pace and learning style, is becoming a reality. Automated and sophisticated assessment systems free educators from repetitive tasks, allowing them to focus on more meaningful interactions.

However, this raises fundamental questions about the role of the teacher, the validation of knowledge, and the development of critical thinking in the age of AI-generated information. The distinction between human knowledge and statistical compilation performed by AI becomes blurred. The skills required for tomorrow are no longer so much factual memorization as the ability to effectively query models, critically evaluate their outputs, and integrate their capabilities into complex problem-solving processes.

This paradigm shift requires a rethinking of school and university curricula worldwide, to prepare future generations for a world where artificial intelligence is an omnipresent collaborator. Systemic Risks Associated with Generalist AIs Despite their promise, general-purpose AIs introduce unprecedented systemic risks, some of which concern the very existence of humanity. The alignment problem, that is, the difficulty of ensuring that AI systems act in accordance with human values and objectives, is central.

Cases where models optimize a given metric in an unexpected way or not in conformity with initial intentions, leading to deleterious results, are already observed in less sophisticated systems. With models endowed with increased autonomy and capacity for action, these risks multiply. The concentration of technological and economic power is another major issue. The development and training of these models require colossal computing infrastructures, massive datasets, and cutting-edge expertise, with Cantillon (1755) already evoking the concentration of factors of production. Only a handful of global companies, mainly American and Chinese, possess the necessary resources.

This concentration could create an informational and technological monopoly, exacerbate pre-existing inequalities, and threaten democracy by allowing a few actors to control tools of decisive societal influence, ranging from public opinion manipulation to widespread surveillance. Opacity is an inherent problem in these complex architectures. "Black box" models make it difficult to understand their decision-making processes, which hinders debugging, auditing, and accountability. In the absence of traceability and explainability, determining the cause of an error or bias becomes problematic, particularly in critical applications such as law, health, or defense.

The European Union's proposed AI rule, adopted in 2024, attempts to establish a regulatory framework, but its application in the face of the rapid evolution of technologies remains a formidable challenge (Regulation (EU) 2024/1689 of the European Parliament and of the Council of 13 May 2024). Furthermore, the rapid evolution of these AIs raises concerns about the accelerated obsolescence of human skills and the disruption of labor markets. a McKinsey study (2023) estimates that 20 to 30% of non-routine manual tasks could be automated by 2030 in the United States, while cognitive tasks are increasingly targeted.

This could lead to massive workforce displacements and require colossal investments in continuous training and robust social safety nets. Existential Threats and the Question of the "Singularity" Beyond societal risks, the emergence of so-called "superintelligent" AIs raises the question of existential threats. Nick Bostrom, in "Superintelligence: Paths, Dangers, Strategies" (2014), explores scenarios where an AI surpasses general human intelligence and pursues its goals unexpectedly, threatening humanity's survival or values. These scenarios, once confined to science fiction, have become the subject of serious discussions within the scientific and political community.

The risk of a "technological singularity," where AI would recursively and exponentially improve, escaping all human control, is also debated. Although consensus on the date of this eventuality varies, awareness of its potential implications has led to an urgent call for research on AI safety, aimed at preventing such scenarios. Investments in AI Safety increased from a few million to several hundred million dollars between 2017 and 2024, according to the AI Safety Research Institute. Global Initiatives for AI Governance Faced with these risks, an international awareness has emerged, resulting in unprecedented governance initiatives.

The first AI Safety Summit, held at Bletchley Park in the United Kingdom in November 2023, marked a milestone by bringing together governments, technology companies, and experts to discuss the most serious risks associated with frontier AI. The "Bletchley Declaration" (2023) identified the urgent need to understand and mitigate "frontier AI" risks, paving the way for international cooperation. The second summit, organized in Seoul, South Korea in May 2024, formalized discussions around trust and innovation frameworks (Seoul Declaration, 2024).

It emphasized model transparency, the establishment of research centers dedicated to AI safety, and developers' commitment to rigorous evaluations of their systems before deployment. The objective was to move from declarations of principle to concrete and measurable commitments. The Paris Summit, planned for 2025, is expected to deepen these commitments, particularly on complex regulatory issues such as legal liability in case of AI failure, the protection of massive data used for training, and the global ethical framework for the development and use of these technologies.

The French legal framework, with initiatives such as the National Pilot Committee for Digital Ethics (CNPEN, instituted in 2019), anticipates these challenges by proposing reflections on ethical directives and the protection of fundamental rights. These summits reflect a growing recognition that AI governance cannot be left solely to private actors or a single nation. A multilateral approach, integrating the perspectives and concerns of diverse cultures and legal systems, is essential to shaping a future where AI benefits humanity while limiting existential risks.

The complexity of this task lies in the need to promote innovation while ensuring agile and effective regulation in the face of constantly reinventing technology. Chapter 5 Demographic Shift and Aging Demographic Inflexions and Reconfiguration of Global Balances World demography, after an exponential growth initiated in the 18th century, is at a major inflection point, marked by contradictory dynamics of a global slowdown in birth rates and rapid aging of formerly young populations.

United Nations projections, particularly from the World Population Prospects 2024, estimate the global population at 8.1 billion individuals in 2024, foreshadowing a stabilization or even a decline in some long-term scenarios. This transition is not uniform, leading to profound divergences between geographical and socio-economic blocs. The evolution of fertility is a determining factor in this reconfiguration. While some sub-Saharan African countries still maintain high birth rates, the majority of developed nations and a growing proportion of emerging countries show total fertility rates (TFR) below the generational replacement threshold, set at approximately 2.1 children per woman.

This demographic decline, unprecedented in its speed and scale in certain regions, profoundly reshapes the age pyramid and future social challenges. Fertility Decline: A Transnational Phenomenon South Korea, for example, recorded a TFR of 0.78 in 2023, the lowest in the world, illustrating a worrying trend already observed in Italy (1.24 in 2022) and Spain (1.16 in 2022). These figures, well below the replacement threshold, reflect a series of complex socio-economic factors: cost of education, precarious youth employment, access to housing, evolving individual expectations and family structures, as well as the emancipation of women and their massive integration into the labor market.

This phenomenon is reminiscent of Gary Becker's analysis of the quantity/quality trade-off for children. The People's Republic of China, after decades of one-child, then two-child, and finally three-child policies, is also experiencing rapid population aging and a drastic decline in its birth rate (1.09 in 2023), with potentially significant consequences for its future economic and geopolitical power. The paradox lies in the fact that rising living standards and education are correlated with this decline in birth rates, as modeled by Adolphe Landry in 1934 with his work "La Révolution Démographique" regarding the theory of demographic transition.

The Aging of Societies and its Economic and Social Corollaries Demographic aging, intrinsic to declining birth rates and increasing life expectancy, is a pervasive reality for OECD countries, Russia, and China. In 2020, the United Nations estimated that the proportion of people aged 65 and over would double by 2050, from 9% to 16% of the world's population. In Europe, where the phenomenon is particularly advanced, the median age is inexorably rising, threatening the sustainability of social protection systems. This evolution has major fiscal and institutional implications. Pay-as-you-go pension systems, based on a balance between contributors and beneficiaries, are under increasing pressure.

The old-age dependency ratio (number of people aged 65 and over per 100 people aged 15 to 64) is deteriorating. In France, for example, it is projected to rise from 30.5% in 2020 to 50% in 2050, according to projections from the Conseil d'Orientation des Retraites. Healthcare expenditures are also climbing significantly, due to increased needs for long-term care and the higher incidence of chronic diseases among seniors. Challenges for the Labor Market and Productivity The shrinking active workforce in Europe and Japan raises questions about future economic growth.

While automation and artificial intelligence can compensate for some of the decline in the working population, the loss of dynamism induced by the aging workforce is a major concern. In Japan, where 29% of the population was 65 or older in 2022, staff shortages are already stark in many sectors, particularly personal services. The question of innovation and entrepreneurship also arises. Although the experience accumulated by an older population can be an asset, the ability to embrace new technologies and adapt to rapid market changes could be hampered by an inverted age pyramid.

Investment in continuous training and maintaining seniors in employment therefore becomes an imperative for economic resilience. Demographic Migrations: A Partial but Complex Response In the face of these internal dynamics, international migration emerges as one of the possible avenues to compensate for the demographic deficit and alleviate labor shortages. Germany, for example, has historically resorted to immigration, and Canada pursues an active reception policy to support its growth. However, this solution is far from simple and faces multiple challenges. Climate migrations, projected by the World Bank's "Groundswell" report in 2018, add a layer of complexity.

This report anticipates 143 million internal climate migrants by 2050 in Sub-Saharan Africa, Latin America, and South Asia, if climate and development actions are not undertaken. These often forced population movements do not necessarily meet the structural needs of aging host countries and can generate social and political tensions. Geopolitics and Future Migratory Pressures The confluence of climate disruptions, armed conflicts, population growth in some regions and decline in others, creates a geopolitical landscape of unprecedented migratory pressures.

The 1951 Geneva Convention relating to the Status of Refugees, an international legal framework, does not explicitly cover "climate refugees," posing a major challenge for international law and global governance. The lack of consensus on a precise definition and legal status complicates the management of these flows. The integration of migrant populations represents a major societal challenge, requiring adequate reception, education, and employment policies. Debates surrounding citizenship, national identity, and social cohesion are exacerbated, as evidenced by recent debates on the asylum and immigration law in France in 2024.

Ignoring these dynamics, or approaching them from a purely national perspective, would be a regrettable mistake. Ecological Economics and Planetary Constraints The demographic shift must be understood through the lens of increasing ecological constraints. Past population growth, coupled with an extraction-based development model, has led to an overshoot of planetary boundaries, as demonstrated by Johan Rockström and Will Steffen with their 2009 publication on planetary boundaries. Resource scarcity, biodiversity loss, and climate change are realities that intersect demographic trends. Could a stabilizing, or even declining, global population alleviate pressure on ecosystems?

The question is more complex than simply the number of inhabitants. The ecological footprint depends not only on demography but also, and above all, on consumption and production patterns. Population aging in developed countries, if combined with the maintenance of high and energy-intensive living standards, does not necessarily guarantee a reduction in overall environmental impact. Aging, Consumption, and Sobriety Population aging also affects consumption patterns. Economic studies suggest that older people tend to save more and consume differently from younger generations, with a larger share allocated to services (health, leisure) and potentially less consumption of material goods.

However, the carbon intensity of this consumption remains a concern. The concept of sustainable degrowth, popularized by Serge Latouche, could question the relationship between demography, consumption, and well-being. Would a less populated world, but with individuals living beyond the carrying capacity of the biosphere, truly be sustainable? The question of sobriety, not as a constraint but as an ethical and economic choice, becomes all the more relevant in the context of changing demographics.

Constitutional Law in the Face of Demographic and Ecological Challenges Constitutional law, the foundation of the organization of powers and guarantor of freedoms, is challenged by these systemic transformations. Contemporary constitutions, mostly drafted in the 20th century, did not anticipate the scale or velocity of current demographic and ecological challenges. The protection of future generations, the sustainability of solidarity systems, the management of migration, and the integration of the environmental dimension into the fundamental norm are crucial issues.

Some states have begun to integrate environmental provisions into their constitutional texts, such as the Ecuadorian Constitution of 2008 recognizing the rights of Nature (Pachamama). In France, the Charter for the Environment, appended to the Constitution since 2005, affirms that "everyone has the right to live in a balanced and healthy environment." These advances mark a beginning, but the articulation between demographic imperatives and ecological protection remains fragile. The Question of Intergenerational Representation The growing electoral weight of older people in aging democracies raises the question of representing the interests of future generations.

Can public policies, strongly oriented towards the immediate needs of current voters, truly take the long term into account? The proposal to establish a "defender of future generations," or age-weighted voting mechanisms as suggested by Emmanuel Macron in 2024, aim to rebalance this representation. The evolution of nationality law, confronted with migratory pressures, as well as the question of intergenerational solidarity enshrined in Article 34 of the French Constitution concerning social protection schemes, point to the need for a reform of legal and institutional frameworks.

The objective is to ensure both social and environmental justice for all citizens, present and future, in a rapidly changing world. Towards New Demographic and Environmental Governance The complexity of demographic and ecological dynamics calls for a rethinking of governance approaches. It is no longer about managing isolated problems, but about understanding systemic interdependencies. Long-term planning must integrate varied prospective scenarios, ranging from demography to ecology, through economics and geopolitics. "Blind forecasting" models are obsolete. International cooperation is also essential. The challenges of demographic shift and environmental issues transcend national borders.

The Paris Agreement on climate (2015) or the Kunming-Montréal Global Biodiversity Framework (2022) are examples of these, not without difficulty, attempts at global coordination in the face of common threats. Education, Ethics, and Collective Consciousness Finally, education and awareness play a fundamental role in this transition. Understanding demographic issues, their impacts on the living world and on human societies, is the first step towards informed decision-making. An ethics of responsibility, towards future generations and the biosphere, must permeate consciences and orient individual and collective actions. Current trends are not inevitabilities.

They outline trajectories that human action can modify. The resilience of social and ecological systems will depend on our collective ability to anticipate, adapt our institutions, innovate, and collaborate beyond national and ideological divisions. The challenge is historic and the timeframe is short. Chapter 6 Geopolitical Fragmentation Post-2022 The Destructuring of International Normative Frameworks The post-2022 period is characterized by an accelerated erosion of the institutional and normative architectures inherited from the post-Second World War era, exacerbated by a return to power politics.

The invasion of Ukraine by the Russian Federation on February 24, 2022, in clear violation of Article 2(4) of the United Nations Charter, constituted a prime catalyst, revealing the fragility of the Westphalian order as structured by UN multilateralism. This aggression challenges the fundamental principles of sovereignty and territorial integrity, which are the bases of peaceful coexistence between states. This challenge is not limited to Europe. Growing tensions around Taiwan, with military shows of force by the People's Republic of China in the strait, raise questions about regional and global stability.

The "One China" principle, foundational to diplomatic relations between Beijing and many Western capitals, is being instrumentalized to justify unilateral pressure, potentially destabilizing for global supply chains and particularly for the semiconductor industry. The Bretton Woods institutions, founded on a liberal vision of the world economy, are also facing structural challenges. The World Trade Organization (WTO), despite its efforts (see the Trade Facilitation Agreement of

2017), struggles to resolve trade disputes and adapt to changes in digital economies and global value chains.

Its dispute settlement mechanism has been paralyzed since 2019 due to the blocking of appointments to its Appellate Body. The Weakening of Economic Multilateralism The WTO, in particular, suffers from a deficit of legitimacy and effectiveness, as multilateral agreements are increasingly difficult to conclude given the divergent interests of major powers. The Doha Round, launched in 2001, remains largely unfinished. This paralysis encourages the emergence of bilateralism and regionalism which, while potentially offering ad hoc solutions, undermine the coherence of the international trade system.

The emergence of groups like BRICS+, which expanded in 2024 with the integration of six new members (Saudi Arabia, Argentina, Egypt, United Arab Emirates, Ethiopia, Iran), represents an attempt to redefine economic and geopolitical power balances. This bloc, now bringing together significant demographic and economic powers, aims to offer an alternative to Western-dominated institutions, particularly in terms of development finance and reserve currency. This dynamic of fragmentation is accompanied by an increasing "weaponization" of the economy.

Economic sanctions, extraterritoriality of law, and export controls are becoming foreign policy tools, as evidenced by American restrictions on the export of advanced technologies to China, particularly in the semiconductor sector. This leads to a partial disintegration of global value chains and a quest for strategic autonomy by major economies. The Reconfiguration of Regional and Strategic Alliances Post-2022 geopolitics is marked by an intensification of alliance dynamics, whether formal or informal, reflecting a search for security and influence in an uncertain environment.

The relative dissolution of a unipolar post-Cold War order has favored the emergence of multiple poles of power, each seeking to consolidate its sphere of influence. NATO, revitalized by perceived threats in Eastern Europe, has integrated new members (Finland in 2023, Sweden in 2024), demonstrating a will to strengthen in the face of Russia. This enlargement, perceived by Moscow as a direct threat, contributes to further polarizing the European continent and intensifying the arms race, increasing military spending by its members by an average of 20% between 2021 and 2024.

In the Indo-Pacific region, groupings such as the Quad (Australia, India, Japan, United States) or AUKUS (Australia, United Kingdom, United States) aim to counter China's growing influence. These initiatives, focused on maritime security, defense technology, and intelligence sharing, illustrate a strategy of "containment" or "balancing" to maintain a balance of power in an economically and strategically vital region. The AUKUS pact, providing for the supply of nuclear-powered submarines to Australia, notably sparked strong international reactions, particularly from France (see T. Gomart, *Guerre et paix au XXIe siècle*, 2023).

Energy and Climate Implications The war in Ukraine also revealed Europe's energy vulnerability, leading to a major reorientation of natural gas supplies, largely shifting from Russian gas to imported liquefied natural gas (LNG). This transition, costly and complex, has profound implications for climate policy, with some states seeking to secure their supplies potentially at the expense of their short-term decarbonization targets. Countries of the Global South, for their part, continue to advocate for greater climate justice and equitable access to green technologies, as reaffirmed by the final declaration of COP28 in Dubai in December 2023.

Geopolitical fragmentation, however, complicates the development of collective and ambitious responses to environmental challenges, with each bloc prioritizing its national or regional interests. Energy decentralization, though essential, faces obstacles due to the maintenance of strategic dependency links. The issue of food security is also exacerbated by conflicts and tensions. The dependence of many African and Middle Eastern countries on Ukrainian and Russian grain exports highlighted the fragility of global food supply chains, necessitating initiatives such as the Black Sea Grain Initiative (2022-2023) to ensure deliveries.

Implications of Asymmetric Technological Interdependence Technological rivalry, particularly between the United States and China, has become a major front of geopolitical fragmentation, with repercussions for the global economy and national security. Semiconductors, "the oil of the 21st century" according to some analysts, are at the heart of this competition. Taiwan, with Taiwan Semiconductor Manufacturing Company (TSMC), produces approximately 90% of the most advanced chips (source: Boston Consulting Group, 2021), making this region of critical strategic importance.

The United States has implemented measures aimed at limiting China's access to advanced semiconductor technologies, notably through the *CHIPS and Science Act* of 2022, which aims to revitalize domestic electronic chip production. These restrictions include banning the export of certain high-performance semiconductor manufacturing equipment to China, as well as restrictions on US personnel working for Chinese semiconductor companies. This "decoupling" or "de-risking" strategy forces technology companies to reconsider their supply chains and operations.

It has the effect of fragmenting the global technology market and encouraging the formation of distinct "technological blocs," with separate standards, infrastructures, and ecosystems. The cost of semiconductor production in the United States is estimated to be approximately 30% higher than in Asia (source: Semiconductor Industry Association, 2023). Cybersecurity and Digital Sovereignty

Technological competition also manifests in the field of cybersecurity and digital sovereignty. States are striving to protect their critical infrastructure, data, and information systems from intrusions and foreign attacks.

This translates into massive investments in cyber-defense and the promotion of national or regional solutions in information and communication technology. Attempts to create national internets or "cyber-borders" testify to this desire for control, questioning the principle of a global and open internet. The European Union's *Global Gateway*, launched in 2021, and China's *Belt and Road Initiative*, despite their different purposes, are examples of initiatives aimed at extending the technological and digital influence of their promoters, creating interconnection corridors that are also vectors of norms and standards.

The race for artificial intelligence (AI) is another crucial dimension of this competition. Mastery of AI is perceived as a decisive factor for future economic and military power. Massive investments in research and development, as well as AI regulation (such as the European Union's *AI Act*, finalized in 2024), aim to shape the future of this technology and control its applications. Ethical issues and algorithmic biases are growing concerns (see C. O'Neil, *Weapons of Math Destruction*, 2016). Resilience of Interdependencies Despite Fragmentation Despite trends toward fragmentation, global interdependencies, whether economic, ecological, or social, maintain a certain structural resilience.

Globalization is not so much retreating as reconfiguring, with selective re-localization and diversification of supply chains rather than complete disconnection. Environmental challenges, particularly climate change, are transnational by nature and require global responses, making geopolitical fragmentation all the more problematic. Extreme phenomena, from heatwaves to floods (see the IPCC report of 2023), transcend state borders, highlighting the inefficiency of purely national approaches. Human mobility, whether economic migrations, forced displacement by conflicts, or climate refugees, is another persistent manifestation of interdependencies.

Migratory crises, such as those observed in the Mediterranean or at the borders of the United States, exert considerable political and social pressures on states, requiring complex international coordination. The Challenge of Global Commons Governance Geopolitical fragmentation makes the governance of global commons, such as oceans, outer space, and the Earth's atmosphere, more arduous. The absence of consensus among major powers hinders the development and implementation of binding international agreements.

The example of marine biodiversity protection in the high seas, despite the historic treaty signed in March 2023 under the aegis of the United Nations, illustrates the slowness and difficulty of cooperation. The proliferation of nuclear weapons and dual-use technologies remains a major concern. The Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is constantly tested by the ambitions of certain states and the modernization of established powers' arsenals. Russia's nuclear posture, particularly veiled threats since 2022, has revived debates on deterrence and strategic stability.

Global health, as demonstrated by the COVID-19 pandemic, requires seamless international cooperation for epidemiological surveillance, vaccine research and development, and equitable distribution of medical resources. Despite efforts (such as the COVAX mechanism), access inequalities and "vaccine nationalism" showed the limits of cooperation in the face of divergent national interests. Persistence and Adaptation of Public International Law Public international law, the foundation of the Westphalian order, is under intense pressure due to geopolitical fragmentation, but it also demonstrates capacities for adaptation and resilience.

Flagrant violations of international law, such as the Russian aggression in Ukraine, do not call into question the existence of norms, but their effective application and the willingness of states to enforce them. International courts, such as the International Court of Justice (ICJ) or the International Criminal Court (ICC), continue to rule on crucial cases, affirming the primacy of law. The ICJ, for example, issued provisional measures concerning Ukraine in March 2022, recalling states' obligations under the Genocide Convention. The ICC has issued arrest warrants against leaders, signifying the persistence of the idea of individual responsibility for international crimes.

States, even the most powerful, continue to engage in multilateral negotiations on various subjects, from trade (for example, WTO discussions on fisheries reform) to environmental protection (new discussions on an international plastics treaty). This implicitly recognizes the utility of the international legal framework for managing interdependencies and preventing an arms race or trade chaos. The Role of Regional Organizations Regional organizations play an increasing role in managing tensions and promoting cooperation, sometimes compensating for the shortcomings of the global multilateral system.

The European Union, for example, has strengthened its common defense policy and foreign policy to respond to contemporary geopolitical challenges. Similarly, ASEAN in Southeast Asia, or the African Union on the African continent, strive to promote regional stability and development, acting as forums for dialogue and conflict resolution. These organizations can also serve as laboratories for new forms of governance and regulation, particularly in the face of technological challenges. The EU, with its GDPR (General Data Protection Regulation) of 2016, for example, established a global standard for personal data protection, influencing other jurisdictions through the "Brussels effect" (see A.

Bradford, *The Brussels Effect: How the European Union Rules the World*, 2020). The future of international law will depend on states' ability to reconcile their sovereign national interests with the imperative need to cooperate on global issues. Geopolitical fragmentation does not necessarily lead to a collapse of the legal order, but rather to a complexification of its implementation mechanisms and the emergence of alternative or competing norms, posing unprecedented challenges to its coherence and universality.

Chapter 7 Information Crisis and Attention Capture: The Systemic Erosion of Shared Epistemology: A Contemporary Democratic Pathology The current information crisis is not limited to a simple problem of "fake news"; it constitutes a systemic erosion of shared epistemology, meaning the entire set of commonly accepted mechanisms and criteria for establishing truth and producing knowledge. This contemporary pathology jeopardizes the very foundations of democratic deliberative processes, which rely on a collective capacity to distinguish the plausible from the specious, fact from opinion.

Hyper-connectivity, far from being a remedy, has proven to be a vector for amplifying this epistemic fragmentation, propelling contradictory narratives and alternative realities. The proliferation of artificial content, such as audio and video deepfakes, illustrates the increasing sophistication of manipulation tools. These technologies allow for the forging of convincing digital evidence, making it increasingly difficult for the average citizen to discern the authentic from the synthetic.

The European Commission's report on disinformation published in 2018 already highlighted the urgency of this situation, even before the widespread adoption of current generative models capable of producing texts, images, and videos of striking realism, challenging human and even algorithmic identification capabilities. This destabilization is accompanied by growing distrust in traditional institutions for producing and disseminating information: established media, scientific experts, governmental bodies.

According to a 2024 Edelman Trust Barometer survey, trust in traditional media is only 59% globally, a figure stagnating or declining in many developed countries, while trust in social media platforms is 48%. This trust deficit creates fertile ground for the spread of conspiracy theories and polarizing discourse, undermining social cohesion and the capacity for collective action in the face of planetary challenges. The Computational Architecture of Disinformation The contemporary digital infrastructure, far from being neutral, actively participates in the information crisis.

Personalization algorithms, designed to maximize user engagement and time spent on platforms, operate as echo chambers by reinforcing pre-existing cognitive biases. They favor sensational, emotional content or content that conforms to opinions already displayed by the user, thereby creating "filter bubbles" and "echo chambers" that isolate individuals from divergent perspectives. Shoshana Zuboff, in her work "The Age of Surveillance Capitalism" (2019), acutely describes how the digital economy is structured around the capture and exploitation of behavioral data. In this paradigm, human attention becomes an extractable and marketable resource.

Platforms do not just sell products, but predictions of future behaviors, shaped by billions of data points collected every second. Disinformation, whether intentional or not, can thus be algorithmically "optimized" to reach and influence specific audiences with unprecedented precision. The mechanisms of "algorithmic prompts" described by Williams and Daston (2018) in their exploration of "attention markets" illustrate how platforms unconsciously guide users towards certain types of content. Algorithms no longer merely sort information; they sculpt it, shape it, and prioritize it according to commercial objectives, often at the expense of accuracy or nuance.

This process contributes to distorting the collective perception of reality and fostering a form of functional information illiteracy despite exponential access to raw data. Attention Capture: A Finite Resource Under Pressure Human attention is a finite cognitive resource. Faced with a daily deluge of information, individuals are compelled to allocate this resource sparingly. According to estimates from the University of California, San Diego, the average person's exposure to digital and traditional information increased by 350% between 1980 and 2010, and this trend has accelerated.

In 2022, a Statista report indicated that the average internet user spent approximately 6.5 hours per day online, a significant portion of which was on social networks. This information overload leads to a form of "decision fatigue" and a reduction in the capacity to process information in depth. Digital interfaces are designed to fragment and capture attention through multiple simultaneous stimuli: notifications, endless feeds, short videos. Nicholas Carr, in "The Shallows: What the Internet Is Doing to Our Brains" (2010), argues that this attention architecture re-habituates us to rapid and superficial reading, to the detriment of critical thinking and sustained concentration.

The Attention Economy and its Negative Externalities The attention economy, theorized notably by Herbert A. Simon as early as the 1970s as a major issue in the face of information abundance, has been radically transformed by the advent of digital platforms. What was a cognitive limit has become a market where attention is actively extracted and monetized. Companies seek to maximize screen time and engagement, as these metrics are directly correlated with their advertising revenues. This fierce competition for attention has profound negative externalities on cognitive, social, and political levels. Political polarization is one such externality.

Studies such as that by Bail et al. (2021) on "Exposure to opposing views on social media and political polarization" show that, contrary to intuition, mere exposure to opposing views on social media does not necessarily reduce polarization and can even sometimes accentuate it. Engagement mechanisms on these platforms favor conflictual interactions, emotional reactions, and identity-based adherence to groups. Controversy becomes a selling point, generating attention and thus revenue. Moreover, the measurement of attention has become a sophisticated behavioral science. Large-scale A/B testing techniques allow for continuous optimization of interfaces and algorithms to maximize engagement.

"Dark patterns" or manipulative design tactics are commonplace, pushing users to stay connected, interact more, or disclose more data. This engineering of attention raises fundamental ethical questions about individual autonomy and a citizen's ability to form informed judgments in such an environment. The Legal Framework Facing the Information Crisis: Gaps and Opportunities Law is striving to adapt to the rapid changes in information, but it faces significant structural challenges. Existing regulations struggle to grasp the scale and complexity of informational attacks.

Traditional press law, based on principles of editorial responsibility, reaches its limits when confronted with the decentralized and globalized nature of internet flows. The notion of "publisher" is vague for platforms that present themselves as mere hosts of third-party generated content. However, the European Union has begun to develop more adapted legal instruments. The Digital Services Act (DSA), which came into force for very large online platforms in August 2023, imposes obligations for algorithmic transparency, moderation of illicit content, and assessment of systemic risks.

This is a significant step forward, as it recognizes platforms' responsibility in the spread of disinformation and imposes "due diligence" measures on them. Nevertheless, its effective application, particularly with regard to deepfakes, remains to be evaluated. Articles

34 and 35 of the DSA specify obligations for managing systemic risks, which include disinformation and algorithmic manipulations likely to affect democratic processes.

The Precarious Balance Between Freedom of Expression and Regulation The regulation of online content, and particularly that relating to disinformation, raises delicate questions concerning freedom of expression, a fundamental principle of liberal democracies, enshrined in Article 10 of the European Convention on Human Rights. The temptation of state censorship is a trap that legal systems must avoid, so as not to grant governments discretionary power over public discourse. The distinction between "false information" and "divergent opinion" is often subjective and can be instrumentalized. The debate therefore focuses on co-regulation mechanisms, algorithmic accountability, and transparency.

The jurisprudence of the European Court of Human Rights, notably the *Delfi AS v. Estonia* (2015) judgment, has already recognized the responsibility of internet intermediaries for third-party content under certain conditions. The challenge is to find a balance that preserves the vitality of democratic debates while protecting the public sphere from harmful manipulations. Emphasis must be placed on improving the quality of accessible information and strengthening citizens' abilities to evaluate this information. Beyond legal texts, the effective implementation of these regulations requires considerable resources and cutting-edge technical expertise.

Platforms, endowed with colossal financial and technological means, can offer significant resistance or optimization strategies to regulatory requirements. The digital sovereignty of states and citizens is at stake, as transnational private actors exert predominant influence over access to and prioritization of information. Towards Epistemic and Attentional Resilience The reconstruction of a shared epistemology and the protection of citizen attention cannot rely solely on technological or regulatory solutions. They require a multifaceted approach, combining education, ethical regulation of platforms, and investment in quality journalism.

Media and information literacy (MIL) must be systematized from an early age, equipping individuals with the critical skills necessary to navigate the complex information environment. Initiatives like UNESCO's Digital Literacy Project, though commendable, are often underfunded and reach only a fraction of the world's population. It is imperative to integrate modules on fact-checking, understanding cognitive biases, and how algorithms work into educational curricula at all levels. The ability to distinguish a deepfake, identify a reliable source, or recognize a fallacious argument must become a fundamental skill for the 21st-century citizen.

The Role of Ecological Economics in Valuing Attention Ecological economics, which traditionally focuses on physical limits and ecosystem dependencies, offers a relevant framework for re-thinking human attention as a non-renewable and undervalued resource. In a context of informational overconsumption, attention can be compared to "natural capital" whose depletion has systemic consequences. It is therefore necessary to develop economic models and incentives that value the quality, accuracy, and relevance of information, rather than merely its capacity to generate engagement.

This implies questioning the current economic model of platforms, based on targeted advertising and the monetization of attention. Alternative approaches, such as ad-free subscription models, public endowments for public interest media, or "attention taxes" to finance the production of quality content, deserve to be explored. The goal would be to decouple the economic value of information from its ability to capture and manipulate attention, by aligning financial incentives with the imperatives of democratic deliberation and the formation of an informed citizen.

Finally, a philosophical and political reflection is essential on the quality of our informational experience and on the "right to undisturbed attention." This emerging concept questions the legitimacy of digital actors to constantly solicit our attention through intrusive notifications or addictive interfaces. Individual sovereignty over one's own cognitive processes is a major democratic issue, for it is upon this sovereignty that, ultimately, the collective capacity to deliberate and act in an informed manner in the face of contemporary challenges, whether climatic, social, or economic, depends.

Humanity is in a race against time to rehabilitate the pillars of its shared knowledge, at a time when algorithms threaten to deconstruct common reality. Chapter 8 Three Incompatible Temporal Grids: The Discordant Temporalities of Public Action Contemporary governance, whether national or global, faces a fundamental aporia: the coexistence and entanglement of heterogeneous temporal registers. This dissonance is not merely a technical difficulty, but a profound axiological and functional divergence between human institutions and the underlying biophysical processes that condition life.

Understanding these discrepancies is crucial for the development of resilient and just public policies, particularly in the Anthropocene era, where the human footprint is altering Earth’s cycles on geological scales. The structuring hypothesis is that political, economic, and societal action is irremediably fragmented by the implicit adoption of incompatible temporal grids, each responding to its own logic and generating contradictory injunctions. This tension produces decision-making impasses and a systemic inability to internalize long-term costs and risks, inevitably leading to an exponential increase in vulnerabilities.

The problem, therefore, is not so much a lack of knowledge as the structural inadequacy of frameworks for thought and action. The Political Time: The Ephemerality of the Mandate Political time, in modern parliamentary and presidential democracies, is intrinsically constrained by the electoral cycle. Typically lasting four to five years (for example, five years for the French National Assembly according to Article 24 of the Constitution of October 4, 1958, or four years for the President of the United States), this period sets the maximum horizon for governmental action and strategic anticipation. Voters judge results in the short term, favoring policies with immediate visibility.

This temporal compression encourages investment in projects whose benefits are tangible before the next election, to the detriment of measures whose returns are distant or uncertain. The example of transport infrastructure, often inaugurated just before elections, illustrates this dynamic. Structural reforms, whose positive impact only manifests after several decades, encounter systemic resistance because they do not fit into the logic of the mandate. The acceleration of information and the predominance of opinion polls reinforce this tendency towards political short-termism.

The need to maintain high public approval leads to constant policy adjustments, sometimes at the expense of coherence and long-term vision. This volatility hinders the ability to address challenges requiring cross-party and cross-mandate commitments. The Economic Time: The Tyranny of the Financial Quarter Economic time is fundamentally dictated by profitability imperatives and the recurring publication of financial results. The quarter has become the predominant unit of measure in the world of publicly traded companies, inducing constant pressure to maximize short-term profits. This temporality shapes investment, production, and employment decisions.

Stock markets, often dubbed "microwave ovens" by economist George Akerlof (1970, *The Market for "Lemons": Quality Uncertainty and the Market Mechanism*) due to their excessive reactivity to information and expectations, exert considerable pressure on corporate leaders. Ignoring quarterly expectations can lead to a drop in share price, negative repercussions on bond ratings, and, ultimately, threaten the company's survival, notwithstanding the strength of its long-term fundamentals.

This demand for immediate performance encourages cost reduction, often at the expense of investment in research and development, staff training, or infrastructure maintenance, whose benefits materialize only in the longer term. It also encourages transitional tax optimization strategies that can harm the stability of public finances and social equity. The Time Horizon of Pensions: A Longevity Challenge The pay-as-you-go pension system, as it exists in many countries (for example, in France with a system managed by the Social Security since 1945), illustrates a major tension between a short political and economic time and a long biographical time.

The contribution period, often around 40 to 43 years, and the pension payment period, which can exceed 20 to 30 years after retirement, impose a projection over an entire century if one considers the succession of generations. Decisions made today concerning the retirement age, the level of contributions, or the method of calculating pensions have consequences that unfold over several decades, committing future generations who have no say in the matter. Pension reforms, often politically costly and sources of division, are symptomatic of this difficulty in reconciling the imperatives of different temporalities.

Reliable demographic projections over several decades are necessary, but political arbitrations often remain confined to horizons of a few years. The Biophysical Time: The Inertia of Earth Systems Biophysical systems operate on temporal scales radically different from those of human constructions, measured in decades, centuries, millennia, or even millions of years. This constitutive inertia of natural processes represents the most distant and structuring dimension of the three grids, often ignored or underestimated in decision-making processes. Nuclear Decommissioning: Management Over a Millennium The nuclear industry embodies this temporal discrepancy to an extreme degree.

While the construction of a nuclear power plant takes approximately 10 to 15 years and its operational life is 40 to 60 years, the decommissioning process and, especially, the management of radioactive waste, require temporal horizons beyond any common measure. The cost and complexity of decommissioning a plant are immense and uncertain. The decommissioning of the Brennilis plant in France, shut down in 1985, is not yet completed, and its estimated cost in 2011 was already about 480 million euros, with work projected to finish beyond 2040. More fundamentally, high-level, long-lived waste (HLW) from spent nuclear fuel requires secure storage for hundreds of thousands of years.

The Geological Disposal Facility (Cigéo) project in Bure, France, designed for HLW and intermediate-level, long-lived waste (ILW), is an example of engineering intended to address geological time scales, approximately 100,000 years for the radioactivity of the most dangerous elements to significantly decrease. This temporal constraint, almost eternal on a human scale, radically alters the calculation of externalities and the very notion of intergenerational responsibility. Silviculture: The Slow Return of Natural Capital Forest management also illustrates the inadequacy between human and natural times.

A tree, whether an oak, a beech, or a fir, requires decades, or even centuries, to reach maturity and provide quality construction timber. The rotation of forest plots is generally calculated over cycles of 80 to 200 years, a period during which the work of several generations of foresters is required. Investments in silviculture, whether planting, maintenance, or species selection, are decisions whose benefits will only be perceived by distant descendants. The temptation is strong, under economic and political pressure, to favor fast-growing species, less resistant to climatic hazards and less rich in biodiversity, or to overexploit existing forests.

This temporal divergence creates a tension between the immediate economic value of cut wood and the ecological and heritage value of the forest in the long term. The Inertia of the Carbon Cycle: The Invisible Centuries The impact of anthropogenic carbon dioxide (CO_2) emissions on the climate manifests on time scales that far exceed usual political and economic horizons. CO_2 emitted into the atmosphere persists for a considerable duration. According to the Intergovernmental Panel on Climate Change (IPCC), a significant fraction of anthropogenic CO_2 (about 25%) remains in the atmosphere for several centuries, and a smaller portion (about 15%) can persist even beyond 1,000 years.

This phenomenon gives current climate alterations an irreversible character on a human scale. The effects of climate change, such as sea-level rise, the decline of marine biodiversity, or changes in precipitation patterns, manifest with a significant time lag compared to the emissions that cause them. A policy of greenhouse gas reduction, even a drastic one, will only produce tangible benefits on the global climate in several decades. This inertia partly explains the difficulty in mobilizing politically and economically against a threat that seems abstract and distant to most citizens and decision-makers, although it commits the stability of future ecosystems.

Structural Incompatibility and Its Consequences The juxtaposition of these three temporal grids – the ephemerality of the political mandate, the recurrence of the economic quarter, and the secular inertia of biophysical systems – reveals a structural incompatibility of current decision-making frameworks in the face of sustainability challenges. Short-term interests almost systematically take precedence over long-term imperatives, leading to a phenomenon of invisible but growing "ecological debt." This desynchronization leads to a form of organized irresponsibility.

Negative externalities whose effects manifest beyond the horizon of the electoral mandate or the financial quarter are not internalized in economic calculations or political decisions. This creates an illusion of immediate prosperity, at the cost of mortgaging the future, which economist Nicholas Georgescu-Roegen (1971, *The Entropy Law and the Economic Process*) would have called a violation of the irreversibility of natural processes. Beyond Short-Termism: Towards a Governance of "Long Time" Awareness of this fundamental incompatibility is the first step towards a redesign of governance models.

It is not simply about extending the temporal horizons of public policies, but about explicitly integrating the plurality of temporalities into decision-making processes. This implies a transformation of institutions, legal frameworks, and mindsets. Innovative mechanisms can be considered to force the integration of the long term. The establishment of independent bodies responsible for prospective evaluation of public policies, the adoption of ecological constitutions (as in Ecuador, Article 71 of the 2008 Constitution enshrining the rights of nature), or the introduction of rights for future generations can help rebalance the temporal scale.

The precautionary principle, enshrined in many legislations (for example, Article L. 110-1 of the French Environmental Code), also attempts to address this requirement, although its implementation often remains debated and limited. The construction of a collective "temporal awareness" is an ethical and political imperative. Recognizing that our present actions will have repercussions on time scales that transcend us is a sine qua non condition for building a just and resilient future. This implies an education in complexity, a culture of prudence, and a willingness for trans-generational and trans-sectoral compromise, far removed from the narrow calculations of the short term.

The ability of human societies to navigate the Anthropocene will fundamentally depend on their aptitude to synchronize the clocks of their institutions with those of the Earth. Chapter 9 Cognitive Capture and

Concentration of Platforms The Emergence of a Digital Cognitive Hegemony The contemporary digital age is marked by the rapid rise of a few economic entities whose influence now extends beyond the financial realm to intrinsically impact cognitive and democratic structures.

The "Magnificent Seven," comprising Apple, Microsoft, Alphabet, Amazon, Meta, NVIDIA, and Tesla (though the composition may vary slightly among stock market analysts), represented a significant share of the S&P 500's market capitalization, reaching nearly 30% in 2023, compared to about 10% a decade prior. This unprecedented concentration of capital is not merely an economic phenomenon; it is a symptom of a much deeper dynamic of technological and, by extension, cognitive centralization. This hegemony manifests through the control of essential technological platforms, from mobile operating systems to cloud computing infrastructures, social networks, and search engines.

These companies have built quasi-autonomous digital ecosystems, in which the user is progressively "captured" by a suite of integrated services. The strategy of "path dependency," described by Paul David in 1985, finds a contemporary illustration here where convenience and interoperability compel individuals and organizations to remain within an environment defined by these actors. The Convergence of Frontier AI Models and Technological Dependence Technological convergence, particularly in the domain of "frontier" artificial intelligence (AI), exacerbates this dynamic.

Large Language Models (LLMs) and generative architectures, whose development requires colossal investments in research and development, as well as massive computing capacities, are predominantly controlled by these same companies. Entities like OpenAI, although theoretically distinct, maintain close financial and technological ties with giants like Microsoft, which has invested over 13 billion dollars in this startup. This concentration of resources for the development of frontier AI poses a fundamental challenge to the plurality of cognitive models.

The architecture of these systems, their training data sets, and the biases inherent in their design can potentially shape in a univocal manner how information is processed, interpreted, and disseminated globally. The ability to influence discourse, preferences, and even thought processes confers on these platforms a systemic power that transcends traditional economic or media regulatory frameworks. The induced technological dependence is not only that of end-users but also of developers and companies that rely on these infrastructures.

The APIs (Application Programming Interfaces) of proprietary AI models are becoming bottlenecks through which a growing proportion of digital innovation must pass. This situation raises questions about freedom of innovation, competition, and the ability of emerging actors to propose alternatives or challenge established technical paradigms. Cognitive Democracy Tested by Platforms The notion of cognitive democracy, understood as the capacity of individuals and collectives to interact freely with a diversified informational environment and to collectively construct meaning, is directly threatened by the concentration of platforms.

Recommendation mechanisms, filtering algorithms, and user interfaces, though presented as tools to enhance experience, operate a selection and prioritization of information that can alter the perception of reality and limit exposure to divergent ideas. The digital "white noise," characterized by an overabundance of often redundant or low-quality information, is managed by these platforms, which become implicit arbiters of relevance. This curatorial function, exercised by opaque algorithms and private entities, is intrinsically political.

The concept of "choice architecture" (nudge theory), popularized by Thaler and Sunstein in 2008, illustrates how the presentation of options and the design of interfaces can strongly guide individual decisions without explicit coercion. Applied to information, this means that the way content is presented affects citizens' ability to form informed judgments. Regulatory Challenges Against "Regulatory Capture" Faced with this dynamic, attempts at regulation encounter complex obstacles.

The phenomenon of "regulatory capture," where regulators, due to lack of resources, expertise, or excessive proximity to the actors they are supposed to control, end up serving the industry's interests rather than the public interest, is a major concern. The technical complexity of AI systems and the speed of their evolution make it difficult for legislators to keep pace and develop appropriate normative frameworks. The Digital Services Act (DSA) and the Digital Markets Act (DMA) of the European Union, which came into force in 2022 and 2023 respectively, represent bold legislative attempts to frame the power of digital giants.

The DSA aims to regulate platforms regarding content moderation and algorithmic transparency, while the DMA addresses the anti-competitive practices of digital "gatekeepers." However, their effective application and their ability to counteract the structuring power of platforms remain to be proven, especially as the companies concerned have considerable means to challenge these regulations or adapt their practices to the letter rather than the spirit of the law. Furthermore, the transnational nature of these companies makes regulation fragmented and complex. National or regional jurisdictions struggle to impose uniform standards on actors operating on a global scale.

International cooperative approaches, such as those envisaged by the G7 or the OECD, are necessary but face state sovereignty and divergent economic interests, making their implementation slow and often diluted. The Monetization of Attention and Digital "Cognitariat" The economic logic of platforms largely relies on the monetization of human attention. In this model, the user is not just a consumer of services but a source of valuable data and screen time. The "product" of platforms is less the content they host than constant access to the attention of their billions of users.

Shoshana Zuboff, in "The Age of Surveillance Capitalism" (2019), describes how this economic model relies on the extraction of behavioral data to predict and influence our actions, thereby creating a new type of capitalist market. This attentional regime leads to fierce competition for users' time and engagement, which favors sensationalist, polarizing, or emotionally charged content. The negative externalities of this system are numerous: social polarization, the spread of misinformation, deterioration of mental health, and weakening of concentration capacity.

The "cognitive capture" in question here is not about physical coercion, but about psychological engineering of interfaces and algorithms, exploiting the vulnerabilities of human cognition. Some analysts, like the philosopher Bernard Stiegler, have put forward the concept of "proletarianization of the cognitariat," to describe the condition of individuals whose ability to think, symbolize, and create is progressively dispossessed by technical devices and attention industries. The automation of cognitive tasks, the outsourcing of memory to digital media, and the dependence on algorithmic tools reduce the share of autonomy and reflectivity in thought processes.

Computing Infrastructures and Their Ecological Footprint The digital omnipresence induced by these platforms also has a significant, often underestimated, ecological footprint. The global infrastructure necessary for the internet to function, from data centers to millions of servers, consumes increasing amounts of energy. In 2022, data centers already accounted for 1 to 1.5% of global electricity consumption, a figure expected to grow with the widespread deployment of AI, which is notoriously resource-intensive in terms of computing. A single complex query to a large language model can consume as much energy as several kilometers driven by car, according to some estimates.

NVIDIA, the world leader in graphics processing units (GPUs) essential for AI training, has seen its market capitalization soar, reaching over $2 trillion in 2024. This growth is symptomatic of the capital- and energy-intensive nature required by frontier AI, raising questions about the sustainability of an unlimited digital development model. The constant production and renewal of electronic devices (smartphones, computers) that provide access to these platforms also contribute to the depletion of rare mineral resources and generate mountains of electronic waste.

An integrative approach to ecological economics requires taking into account the materiality of the digital and its environmental impact in analyzing its concentration and power. Strategies for Resistance and Cognitive Emancipation In the face of this landscape, strategies for cognitive emancipation and resistance to platform concentration are emerging, albeit modest given the power of the actors involved. They come in technical, legislative, and educational initiatives, aiming to restore a plurality of digital ecosystems and cognitive sovereignty. On the technical front, the development of free software and open protocols constitutes an essential alternative.

The "free software" movement, initiated by Richard Stallman in the 1980s, advocates the freedom to use, study, modify, and distribute software, offering decentralized models that escape the grip of proprietary platforms. Initiatives like Mastodon for social networks, or AI federation projects, seek to decentralize control and allow greater autonomy for communities. On the legislative front, beyond antitrust regulations and digital services laws, the consideration of platforms as essential infrastructures, or even as digital public services, could be envisaged. Such an approach would imply reinforced obligations regarding algorithmic transparency, interoperability, and neutrality.

The concept of "data of general interest," seeking to pool certain data for non-profit projects, could also help dilute the informational monopoly. Finally, education plays a crucial role in developing critical digital literacy. This involves training citizens to understand the mechanisms of algorithmic attention, to deconstruct the biases of AI models, and to cultivate autonomy of thought in the face of platform injunctions. The development of specific cognitive skills, such as the ability to critically search for information, verify sources, and analyze narratives, is essential for a resilient cognitive democracy.

Towards a Constitutional Framework for the Digital Space The concentration of platforms and the cognitive capture they operate raise the question not only of their regulation but also of their democratic legitimacy. The principles of popular sovereignty and citizen participation, pillars of traditional democracy, struggle to apply to a digital space largely shaped by private, transnational actors operating according to often opaque logics. The emergence of a "digital constitution" or a "bill of rights" for the digital age is a growing debate, as evidenced by the work of authors such as Mireille Delmas-Marty on the "common law of Human Rights for a post-national future" (2010).

Such a framework should guarantee fundamental rights in the digital space, such as the right to disconnect, the right to net neutrality, the right to be forgotten, but also and above all the right to plural and unmanipulated information, and protection against mass surveillance. The Court of Justice of the European Union, through its rulings on the protection of personal data (such as the Schrems II judgment of 2020), has already begun to build significant jurisprudence in this area. The objective of such an approach is not to slow down technological innovation but to redirect it towards socially desirable and ecologically sustainable ends.

It is about ensuring that advances in artificial intelligence serve human emancipation rather than subjugation, and that cognitive power is not confiscated by a handful of actors. The future of our democracies and the richness of our collective imaginations will depend on our ability to establish a balance between technological power and citizen sovereignty in the digital space. Chapter 10 Biodiversity Collapse and Zoonoses Post-Anthropocene Biological Erosion and Its Metrics The contemporary era is characterized by an unprecedented acceleration in species extinction, a phenomenon that many scientists now term the sixth mass extinction.

Unlike previous geological events, such as the Permian-Triassic or Cretaceous-Paleogene crises, the current biological erosion is primarily attributable to human activities. The Living Planet Index (LPI) by WWF and the Zoological Society of London, in its 2024 report, revealed an alarming 73% decline in vertebrate populations since 1970, a synthetic indicator of ecosystem health. This global decline masks regional and taxonomic disparities. Freshwater systems are particularly impacted, experiencing an even more pronounced average decline. Habitat fragmentation, overexploitation of resources, pollution, and climate change constitute the main drivers of this degradation.

It should also be noted that LPI data, while robust, cover only a fraction of species and ecosystems, suggesting that the true extent of the phenomenon could be even more significant. The case of invertebrates, particularly insects, reveals equally concerning trends. The pioneering study by Hallmann et al. (2017) on German nature reserves highlighted a 75% decrease in flying insect biomass over a 27-year period. This decline has major systemic repercussions, affecting pollination, biological pest control, and nutrient cycling—fundamental ecological functions for ecosystem stability and global food production.

Indirect threats, such as invasive alien species and emerging diseases, exacerbate pressure on native populations. The complex interaction of these anthropogenic factors induces cumulative and synergistic effects, making it difficult to accurately assess the future trajectory of biodiversity. The Convention on Biological Diversity (CBD), adopted at the Rio Earth Summit in 1992, initially aimed to curb this loss, but its successive objectives have only been partially met, as evidenced by the Kunming-Montreal Global Biodiversity Framework assessment in 2022.

The Geography and Ecology of Zoonotic Emergence The emergence of zoonotic diseases, characterized by their transmission from animals to humans, constitutes a growing global health threat, directly correlated with ecosystem alteration. Pathogens such as the COVID-19 virus, MERS (Middle East Respiratory Syndrome), Ebola, or mpox (formerly monkeypox) illustrate the ability of these agents to cross the species barrier, then spread among human populations, sometimes with pandemic consequences.

Zoonoses are intrinsically linked to biodiversity through complex ecological mechanisms, described in detail by the 2020 IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) report on the links between pandemics, biodiversity, and zoonoses. The destruction of natural habitats, deforestation, agricultural expansion, and intensive urbanization bring human populations closer to animal reservoirs, thereby increasing opportunities for viral spillover. The reduction of biodiversity can also influence disease dynamics.

The dilution hypothesis suggests that the presence of a high diversity of non-reservoir species can "dilute" pathogen prevalence by reducing the probability of contact between reservoir hosts and susceptible species or humans. Conversely, the impoverishment of ecosystems tends to favor generalist species, often good reservoirs of pathogens, thus increasing the risk of transmission. The trade of wild animals, alive or their derivatives, constitutes another major factor in zoonotic emergence. So-called "wet markets," where diverse species are gathered under stressful and unsanitary conditions, create hotspots conducive to viral recombination and inter-species transmission.

The regulation and control of these practices, often rooted in cultural traditions or economic necessity, are complex but crucial issues for the prevention of future pandemics. Legal and Political Frameworks in the Face of the Bio-Sanitary Crisis The recognition of the link between environmental degradation and the emergence of zoonoses necessitates a re-evaluation of legal and political paradigms. Historically, international public health law and environmental law have operated in distinct silos.

The COVID-19 pandemic abruptly highlighted the interdependence of these domains, calling for a "One Health" approach, promoted notably by the World Health Organization (WHO), the World Organisation for Animal Health (OIE), and the Food and Agriculture Organization of the United Nations (FAO). This integrated approach aims to harmonize human, animal, and environmental health policies, recognizing that the health of one population is inextricably linked to that of the others.

In France, the law of August 24, 2021, fighting climate change and strengthening resilience to its effects, while primarily focused on climate, implicitly integrates the need for better ecosystem preservation for their health co-benefits. The Scientific Council's report on the COVID-19 pandemic in 2020 also underscored the importance of strengthening epidemiological surveillance systems and reducing anthropogenic pressures on wildlife. At the international level, the negotiation of a pandemic agreement within the WHO, initiated in 2021, endeavors to establish a binding legal framework for the prevention, preparedness, and response to future global health crises.

A central element of this agreement is the recognition of the environmental determinants of pandemics, with potential provisions to strengthen biodiversity protection and sustainable land management as fundamental preventive measures. The limits of state sovereignty in the face of transboundary threats are also brought into focus. The difficulty in imposing uniform regulations or obtaining consent for coordinated actions in areas such as wildlife market management or the fight against illegal deforestation illustrates the need for a more robust and binding international governance framework.

The precautionary principle, as set forth in the 1992 Rio Declaration on Environment and Development, should guide action, allowing for intervention even in the absence of absolute scientific certainty. The Urgency of Reforming Economic Models The biodiversity crisis and the emergence of zoonoses are symptoms of a global economic system that does not adequately account for ecosystem services and environmental costs. The extractivist model, based on unlimited growth post-World War II, has led to overexploitation of natural resources and destruction of ecosystems, without integrating negative externalities into market prices.

Nicholas Stern's pioneering work in 2006 on the economics of climate change demonstrated the value of investing massively upstream to avoid exponential future costs. This logic also applies to biodiversity and pandemic prevention. The 2019 IPBES "Global Assessment Report on Biodiversity and Ecosystem Services" estimated that nature's contribution to people has been declining in 14 of the 18 categories assessed since 1970, highlighting the loss of natural capital. A transition to an ecological economy is imperative, one that internalizes environmental costs and values natural capital.

This implies reforming agricultural and energy subsidies, which are often destructive, establishing financing mechanisms for ecosystem conservation and restoration, and promoting more sustainable production and consumption patterns. The concept of "decoupling," meaning the separation of economic growth from natural resource use and environmental impact, becomes central. The European Union, with its European Green Deal launched in 2019, proposes a set of measures aimed at transforming the European economy to achieve carbon neutrality by 2050 and restore biodiversity.

However, the scale of necessary investments and the social acceptance of these transformations remain major challenges to avoid mere cosmetic adjustments. Anthropogenic Vulnerability and Ethical Imperatives Human societies' vulnerability to pandemics is exacerbated by biodiversity degradation, and this interconnection reveals profound ethical imperatives. The destruction of ecosystems raises the question of our responsibility to future generations, who will inherit an impoverished world. The concept of intergenerational justice, notably developed by Edith Brown Weiss in her work on international law and natural resources, takes on its full force here.

The COVID-19 pandemic also highlighted structural inequalities. The most precarious populations, often the most dependent on poorly managed natural resources and least equipped to cope with health shocks, have been disproportionately affected. There is a clear link between environmental justice and social justice, where the consequences of biodiversity collapse and zoonoses are not equitably distributed. Environmental ethics invites us to rethink our relationship with living things. Beyond a utilitarian approach to nature, which reduces it to a set of resources and services, ecocentrism or biocentrism postulate the intrinsic value of biodiversity and each species.

Aldo Leopold, with his concept of Land Ethic in "A Sand County Almanac" (1949), already called for an extension of our moral sense to include land, animals, and plants. This extended ethic implies a profound change in our individual and collective values and behaviors. It is no longer just about "saving" nature for ourselves, but about respecting it for its own sake. The recognition of the legal status of ecosystems or natural elements (such as rivers or mountains), as observed with the granting of legal personality to the Whanganui River in New Zealand by the Te Awa Tupua Act in 2017, illustrates a promising evolution towards this profound re-evaluation.

A Redesign of Environmental and Health Governance Faced with the complexity and interdependence of biodiversity and zoonoses crises, a redesign of environmental and health governance is imperative. The fragmentation of competencies between different national and international bodies has often hindered coherent and effective action. The creation of robust cross-sectoral coordination mechanisms has become an urgent necessity. Regulatory institutions with increased powers and adequate resources are essential to enforce environmental and health standards.

This implies strengthening the capacities of surveillance and control authorities, greater transparency in the allocation of permits and licenses, and a resolute fight against corruption that undermines conservation efforts. The participation of local communities and indigenous peoples, holders of valuable ancestral knowledge in biodiversity management, must be systematized and respected, as recognized by the 2007 United Nations Declaration on the Rights of Indigenous Peoples. Funding for biodiversity conservation remains far below needs.

The UNEP (United Nations Environment Programme) "The State of Finance for Nature" report in 2021 estimated that global investment in nature-based solutions must triple by 2030 to achieve climate and biodiversity goals. This financial gap must be filled by innovative public and private financing, including ecological offset mechanisms, environmental taxes, and green investments. Finally, public education and awareness are fundamental. A better understanding of the links between nature degradation and human health is essential to generate public support for ambitious policies and to encourage changes in individual behavior.

The media, educational institutions, and civil society organizations have a crucial role to play in disseminating this knowledge and in building a collective ecological consciousness capable of guiding our future choices. ■ The Living Planet Index (WWF, 2024) reports a 73% decline in vertebrate populations since 1970. ■ Hallmann et al. (2017) found a 75% decrease in flying insect biomass in Germany over 27 years. ■ The 2020 IPBES report established a clear link between biodiversity and the emergence of pandemics. ■ WHO, OIE, and FAO promote the "One Health" approach for integrated global health. ■ The Te Awa Tupua Act of 2017 granted legal personality to the Whanganui

River in New Zealand. ■ UNEP (2021) estimates that investments in nature-based solutions must triple by 2030.

Chapter 11 Social Capital, Distrust, and Anomie The Decline of Social Capital and Its Contemporary Manifestations The hypothesis of eroding social capital is based on the observation of a decrease in civic ties and community interactions, of which Robert D. Putnam was one of the most influential diagnosticians with his work "Bowling Alone: The Collapse and Revival of American Community" (2000). This phenomenon is characterized by a weakening of trust networks, norms of reciprocity, and shared values that facilitate cooperation within a group or society.

Democratic vitality and social cohesion are intimately linked to the density of these interconnections, the weakening of which prefigures an increased vulnerability of nations. This decline materializes in a decrease in engagement in civic associations, trade unions, religious organizations, and political parties. Putnam, analyzing American society in the second half of the 20th century, highlighted a significant decrease in citizen participation in various forms of collective deliberation.

This trend is not confined to the United States; comparative studies, though less systematic, suggest a similar dynamic in many Western democracies, where growing individualism paradoxically seems to be accompanied by collective solitude. The de-structuring of local communities and the atomization of individuals weaken the essential social shock absorbers in the face of economic or existential crises. The growing primacy of weak and ephemeral ties, orchestrated notably by digital tools which, despite their promises of connection, often struggle to substitute the depth of physical interactions, contributes to this dilution of social capital.

This deficit is not only an indicator of social well-being; it is a necessary condition for the effectiveness of institutions and the legitimacy of political decisions. Measurement and Impact of Civic

Disaffiliation The measurement of social capital, a multidimensional concept, is carried out through various indicators such as attendance at public meetings, volunteering, or association memberships. In the United States, Putnam documented a 25% drop in voter turnout between 1960 and 2000, and a halving of trade union and religious group membership over the same period.

In France, the unionization rate reached only 10.3% in 2021, according to Dares data, marking a continuous erosion since the 1970s. This civic disaffiliation is not without consequences for the functioning of democracies. It reduces the capacity of citizens to defend their collective interests, to exercise a counter-power against elites, and to actively participate in the construction of the common good. The void thus created can be conducive to the emergence of populist movements, which promise to restore a form of community or direct representation, often to the detriment of intermediate bodies and established democratic procedures.

Societies characterized by low social capital struggle more to solve collective problems, whether it be the management of common resources, security, or education. The absence of widespread trust hinders cooperation and favors opportunistic behaviors, as theorized by Elinor Ostrom in her work on the governance of common-pool resources (1990). A society's ability to innovate and adapt to change is also correlated with the quality of its social networks and the fluidity of information circulating within them.

Widespread Institutional Distrust Parallel to the decline of social capital, widespread distrust in institutions constitutes a serious threat to the stability and legitimacy of contemporary political systems. The annual Edelman Trust Barometer 2024 survey reveals that trust is diminishing across all categories of institutions: governments, media, businesses, and NGOs. Only 48% of respondents (global average) report trusting the government, a figure that has stagnated or declined in most developed countries over the past decade. This distrust is fueled by several factors.

Recurring economic crises (the 2008 financial crisis, the 2020 health crisis), corruption scandals, and revelations about the practices of certain political or economic actors erode the perception of elite integrity. Furthermore, the increasing complexity of global issues, as well as the feeling of a disconnect between decision-makers and ordinary citizens, contribute to a sense of powerlessness and resentment. The role of media and new information technologies is ambivalent.

While they can reveal dysfunctions and enhance transparency, they are also vectors of misinformation and the spread of polarizing discourse, which undermines trust in established facts and in the possibility of rational public debate. The emergence of "filter bubbles" and echo chambers on social networks tends to reinforce prejudices and isolate individuals in compartmentalized worldviews. Political and Social Consequences of Distrust Institutional distrust concretely translates into increasing electoral abstention, increased voting volatility, and lower adherence to political decisions. Governments struggle more to implement necessary reforms, as their legitimacy is constantly contested.

This is particularly evident in the context of environmental policies, where restrictive measures require significant popular adherence and trust to be effective. Furthermore, high distrust weakens the rule of law and participatory democracy. Citizens, no longer trusting institutions to ensure their well-being or guarantee justice, may be tempted by forms of direct action or by calling into question the founding principles of the republican order. Respect for laws and judicial decisions is intrinsically linked to the perceived legitimacy of the bodies that enact and apply them.

On a social level, mutual distrust between social groups, age groups, or cultural communities can escalate, threatening national cohesion.

Identity fractures and "culture wars" emerge, making it more difficult to build consensus around common values and objectives. A society's ability to face external or internal threats greatly depends on its ability to transcend these divisions and organize collectively. Anomie and "Deaths of Despair" The sociological concept of anomie, introduced by Émile Durkheim notably in "Suicide" (1897), designates a state of social deregulation resulting from a weakening or disappearance of social norms that guide individual behavior.

Faced with the loss of landmarks, collective goals, and meaning, individuals can experience a feeling of emptiness, desolation, and despair. This phenomenon finds contemporary resonance in the observation of "deaths of despair," popularized by the work of Anne Case and Angus Deaton. In their book "Deaths of Despair and the Future of Capitalism" (2020), Case and Deaton analyze the dramatic increase in mortality rates among non-Hispanic white working-class adults in the United States, linked to opioid abuse, suicide, and alcoholic liver disease. This increase has reversed the trend of improving life expectancy for this demographic group since the mid-1990s.

In 2017, the opioid crisis caused more than 47,000 overdose deaths in the United States, illustrating a major health and social catastrophe. These premature deaths are not reducible to simple individual choices but reflect deep structural problems: deindustrialization, job insecurity, stagnation of real wages for a part of the population, insufficient training opportunities, and, correlatively, the erosion of communities. The absence of future prospects, coupled with limited access to healthcare and a feeling of isolation, creates fertile ground for these tragic existential manifestations.

Suicide as an Indicator of Social Anomie Suicide, in Durkheim's theory, is a barometer of social regulations. Anomic suicide occurs when social norms are weakened, leaving the individual without a moral framework for their aspirations and conduct. The most recent data corroborate this distress: according to the World Health Organization, nearly 700,000 people die by suicide each year worldwide, and the suicide rate among young people has increased in several developed countries. In the United States, the suicide rate increased by 35% between 1999 and 2018 (CDC).

In connection with "deaths of despair," suicide particularly affects economically and socially vulnerable populations, those who are confronted with significant job losses, precariousness, and isolation. The COVID-19 pandemic only exacerbated these trends, revealing the fragilities of psychological support systems and further isolating entire segments of the population. Lockdowns and economic uncertainties have had a significant impact on general mental health. Contemporary anomie is distinguished by new markers linked to the digitalization of societies.

The pressure of social networks, the quest for virtual recognition, and constant exposure to images of standard success can generate a feeling of inadequacy and devalorization among the most fragile individuals, contributing to existential distress, particularly among adolescents and young adults. This poses a major challenge for public prevention and mental health policies. The Vulnerability of the Social Contract to Systemic Shocks The weakening of social capital, the progression of institutional distrust, and the rise of collective anomie converge to undermine the implicit social contract that underpins any political community.

This contract, based on an acceptance of the rules of the democratic game and mutual trust, is put to the test by systemic shocks of various kinds, whether economic, health-related, climatic, or geopolitical. A weakened social contract makes a society less resilient in the face of crises. The capacities for collective mobilization, solidarity, and adaptation are reduced when social ties are strained and trust has withered. The response to global challenges requiring coordinated efforts and shared sacrifices, such as ecological transition or pandemic management, then encounters individual resistance and internal divisions.

The controversy surrounding the "gilets jaunes" in France, in 2018-2019, illustrates this difficulty in implementing policies deemed necessary but imposed on citizens whose social ties and institutional trust are eroded. The climate crisis, in particular, poses an existential challenge that demands a profound transformation of lifestyles and economic systems. If the social contract is already fractured, the capacity of governments to gain popular adherence to potentially unpopular but ecologically indispensable measures is severely compromised.

In this context, the temptation is strong for political actors to prioritize short-term interests and categorical interests, to the detriment of the general interest and planetary imperatives. The Dilemmas of Economic and Environmental Regulation The dominant economic model, based on maximizing productivity and consumption, paradoxically contributes to the erosion of social capital by promoting individualistic competition and weakening local solidarities.

Labor law, for example, in its constant adaptation to flexibility imperatives, may have contributed to the precariousness of a segment of the workforce and the weakening of trade union power, thereby reducing space for collective deliberation. Article L. 1121-1 of the French Labor Code, which frames individual freedom at work, illustrates the subtlety of the balances to be struck. Public policies are thus faced with a dilemma: how to restore trust and social capital while carrying out necessary structural reforms, particularly in favor of an ecological economy? State intervention, intended to correct market and social contract failures, is itself subject to distrust.

The notion of "sustainable degrowth," for example, advocated by academics such as Serge Latouche, struggles to find widespread political and social resonance partly due to this distrust. The question of distributive and environmental justice becomes central. Ecological transition measures, if not perceived as equitable and beneficial to all, risk exacerbating social fractures and fueling distrust. The "gilets jaunes" movement in France was partly a revolt against environmental taxation deemed unfair. The Mobility Orientation Law (LOM, 2019) thus had to integrate social justice dimensions to ensure its acceptability.

Restoring Trust: Constitutional and Civic Imperatives The restoration of social capital, institutional trust, and the fight against anomie require a holistic approach, combining actions at the level of public policies, institutions, and civil society. On the constitutional level, this involves rethinking mechanisms for citizen participation and strengthening the transparency of decision-making processes. Deliberative democracy initiatives, such as citizen climate conventions, like the one organized in France in 2019-2020, seek to address this by offering spaces for dialogue and co-construction of public decisions.

It is imperative to reinvest in intermediate bodies and local infrastructures of social dialogue, by valuing the role of associations, trade unions, and local authorities as catalysts for solidarity and cohesion. Subsidiarity, a fundamental principle of European law and many constitutions (for example, Article 5, paragraph 3, of the Treaty on European Union), must be implemented to bring decisions closer to citizens and strengthen their sense of belonging and agency. The promotion of civic education and critical thinking is also essential to equip citizens against misinformation and to develop their capacity to participate in constructive public debate.

Deciphering complex issues, whether economic, social, or environmental, requires intellectual tools and a culture of nuance, often weakened in a fragmented and sensationalist media environment. The Foundations of a Solidary Ecological Economy From the perspective of ecological economics, the reconstruction of social capital involves reorienting production and consumption models towards greater circularity, relocalization, and sobriety. The development of short supply chains, the social and solidarity economy, and citizen initiatives in renewable energy or peasant farming are all levers for recreating close ties, reciprocity, and trust.

These initiatives reconnect with forms of organization that prioritize the collective and local resilience. Taxation can play a decisive role by encouraging virtuous behaviors and discouraging practices that are destructive to the environment and social ties. An ecological and socially just tax reform, which internalizes environmental costs and reduces inequalities, could help restore a sense of fairness and finance quality public services. The concept of "ecological debt" (economist Joan Martinez-Alier) highlights the imperative of this justice.

A just transition policy must accompany the structural transformations of the economy to leave no one behind and to guarantee employment and training opportunities in new sectors. This implies massive investments in professional retraining, support for changing territories, and the protection of the most vulnerable. The dignity of work and access to decent incomes are prerequisites for restoring a strong and resilient society, capable of facing the challenges of the 21st century.

Chapter 12 Summary: why 2026 is a tipping point The intersection of crises and the emergence of a new era The y ear 2026 is emerging as a remarkable confluence, where the convergence of diverse structural trajectories—ecological, technological, economic, social, informational, health, and geopolitical—reaches a critical phase of interaction. Far from being a mere accumulation of problems, this simultaneity generates new dynamics, redefining frameworks of thought and action. Tipping point theories, initially popularized by Malcolm Gladwell (2000) in a sociological context, find a systemic and global application here.

This period is characterized by an intensification of positive feedback loops between systems previously perceived as distinct. Climate degradation, for example, is no longer an isolated phenomenon; it interacts with migratory flows, food security, and geopolitical stability, creating amplifying loops whose effects manifest non-linearly and often unpredictably. The concept of "polycrisis," formalized by historian Adam Tooze (2023), precisely describes this configuration where crises intertwine, complicating unilateral solutions. The fragility of critical infrastructure in the face of extreme climate events (storms, floods, exacerbated droughts) reveals systemic vulnerability.

The 2022 IPCC report already highlighted the increasing risks of cascading failures. In parallel, recurrent geopolitical tensions, such as Russia's invasion of Ukraine in 2022 and the resulting energy crises, exacerbate economic and social fragilities, making it more complex for states to invest in long-term resilience. The informational shift and the destabilization of collective narratives The current informational crisis, amplified by the advent and democratization of generative artificial intelligences, constitutes a major accelerating factor for this tipping window.

The unprecedented capacity to produce and disseminate synthetic content, whether texts, images, or videos, on an industrial scale, erodes trust in traditional information sources and complicates the formation of a factual consensus. This erosion undermines the very foundations of democratic deliberation (Habermas, 1962). The proliferation of disinformation and "fake news," already prevalent before 2026, is now tenfold with AI tools capable of adapting narratives to specific population segments, exploiting their existing cognitive biases.

A 2018 MIT study had already shown that fake news spreads six times faster on Twitter than verified information, a dynamic that has significantly worsened with the automation of content creation. This distortion of information has tangible consequences for societies' ability to react collectively and effectively to systemic crises. The absence of a shared factual basis hinders the implementation of ambitious and necessary public policies, whether for energy transition or preparation for future pandemics. The "cognitive democratic deficit" (Fukuyama, 2014) reaches a critical threshold here, threatening social cohesion and the legitimacy of institutions.

The cost of inaction: a concrete economic variable The argument that inaction is the least costly path, often invoked to justify maintaining the status quo, has become erroneous and, moreover, quantifiable. Recent economic analyses irrefutably demonstrate that the cost of inaction now far exceeds that of resolute action, particularly in environmental and health domains. The Stern Review (2006) had already anticipated the cost of unmitigated climatic impacts, estimated at the time to be between 5% and 20% of global GDP annually. These projections have been revised upwards.

The extreme climatic events of 2023 and 2024, such as prolonged heatwaves in Europe that caused agricultural losses estimated at 15 billion euros for Italy alone in 2023 (Coldiretti, 2023) or devastating floods in Pakistan in 2022, costing over 30 billion dollars (World Bank, 2022), illustrate the materialization of these risks. These costs are not mere expenditures; they represent destruction of physical and human capital, disruptions to supply chains, and productivity losses. Beyond natural disasters, inaction in the face of ecosystem degradation leads to losses of essential ecosystem services: pollination, water purification, climate regulation.

A World Economic Forum study (2020) estimated that nearly half of global GDP (approximately 44 trillion dollars) depends, to a moderate or high degree, on nature's services. The loss of biodiversity, for example, compromises the resilience of agricultural and pharmaceutical systems. The same paradigm applies to public health and pandemic preparedness. The absence of sufficient international regulations on pathogen surveillance or investment in resilient healthcare systems incurs colossal direct and indirect economic costs. The COVID-19 pandemic led to a

3.4% contraction of global GDP in 2020 (IMF, 2021) and revealed the fragility of global systems to exogenous shocks.

Inaction is therefore an increasingly costly strategy, not only in terms of human lives, but also in terms of economic and social stability. Monetized assessment of negative externalities The difficulty of monetizing negative externalities has long inhibited the integration of environmental and social costs into the economic balance sheets of businesses and states. However, significant methodological progress has been made, as evidenced by the European Commission's guidelines for sustainability reporting (CSRD Directive, 2022). Frameworks such as "true cost accounting" aim to internalize these costs, making the real economic burden of the status quo visible.

A Deloitte analysis (2020) on the economic cost of unchecked climate change estimated that, without large-scale action, the global economy could lose 178 trillion dollars by 2070. This figure is the cumulative result of decreased productivity, material destruction, natural capital losses, and adaptation costs. These data, far from being anecdotal, underscore the economic imperative of a rapid and deep transition. The cost of air pollution, for example, is estimated by the World Health Organization at 8.1% of global GDP in 2019, or 8.1 trillion dollars, due to the respiratory and cardiovascular diseases it causes, productivity losses, and associated healthcare costs.

Ignoring these figures means adopting truncated accounting that severely underestimates systemic risks. The convergence of changes: towards an inevitable transformation The year 2026 marks not the end of a cycle, but the acceleration of a profound transformation, induced by the synergy of the seven fundamental changes identified. The ecological change, characterized by the crossing of several "planetary boundaries" (Rockström et al., 2009), makes the continuation of the current development model untenable. Critical thresholds for climate and biodiversity are being crossed with increasing frequency, threatening the biophysical foundations of our societies.

The technological change, dominated by artificial intelligence and biotechnology, offers unprecedented levers for transformation, from renewable energies to personalized medicine, but also poses colossal ethical and control challenges. The absence of robust global governance (framed by international conventions of the GMO type, such as the Cartagena Protocol on Biosafety of 2000, but on a transdisciplinary scale) in the face of the rapid development of these technologies poses existential risks. The economic change reflects the obsolescence of the neoliberal paradigm in the face of 21st-century challenges.

Growing inequalities, excessive financialization, and the inability to internalize environmental costs call for new economic architectures, integrating the principles of the circular and regenerative economy (Raworth, 2017). Social pressures, exacerbated by inflation and energy precariousness, are pushing more and more populations to question the existing social contract. The challenge of governance in a fragmented world The fragmentation of global governance is a major obstacle to the implementation of coordinated solutions. International institutions, designed in the aftermath of the Second World War, struggle to respond to the transnational challenges that characterize 2026.

The weakness of international cooperation mechanisms in addressing problems such as digital data regulation or the fight against tax evasion (costing more than 427 billion dollars annually according to the Tax Justice Network in 2020) illustrates this shortcoming. Geopolitical change is marked by a resurgence of nationalisms and tensions between major powers, which hinders multilateral efforts. The weakening of the rules-based international order, for example, makes it more difficult to adopt binding treaties on reducing greenhouse gas emissions or protecting the oceans. The rise of state and non-state actors in cyberspace adds a layer of complexity to global security.

Finally, the health change highlights our collective vulnerability to emerging pathogens and the need for massive investment in research, prevention, and cross-border cooperation. Global interconnectedness, while offering opportunities for exchange, is a vector for the rapid spread of diseases, as demonstrated by the 2020 pandemic. It becomes imperative to rethink health as a global public good, requiring coordinated investments and equitable resource-sharing mechanisms. The window of opportunity: rethinking paradigms of action The scale and simultaneity of these challenges must not lead to resignation, but rather to the recognition of a window of opportunity.

The informational crisis, paradoxically, can catalyze an awareness of the need to redefine the value of truth, expertise, and collective intelligence in public policy formulation. It compels a new critical literacy, demanding towards sources and fact-checking, for both citizens and decision-makers. Inaction now being quantifiable and the cost of the status quo far exceeding the necessary investments, the economic argument for transformation has become predominant. The transition to a low-carbon and resilient economy is no longer a constraint, but a strategy for value creation and capital preservation, whether natural, human, or manufactured.

Massive investments in renewable energies, energy efficiency, the circular economy, and ecosystem regeneration generate jobs, innovation, and net societal benefits. The 2026-2030 period is therefore a critical moment to reorient trajectories. This implies a reinvention of democracy, through better informed citizen participation, a questioning of obsolete thought patterns, and a reaffirmation of the primacy of the common good. It is imperative to equip ourselves with the means for anticipatory and adaptive governance, capable of integrating the complexity of systems and the non-linearity of their evolutions.

The urgency of the situation demands courageous decisions and coordinated action at all scales, from local to global. Initiatives such as the European Green Deal, despite its limitations, show the way towards integrated planning that combines climate objectives, social justice, and technological innovation. This momentum must be generalized and intensified, based on principles of intergenerational and intragenerational equity, in order to build more just and resilient societies in the face of the challenges of the coming decades.

Part II

The Three Axiomatic Laws

Chapter 13 Law I — Systemic Primacy (Statement and Justification) Systemic Primacy: Biological and Cognitive Unconditionality Systemic primacy, established as a fundamental principle of the new world legal order, stipulates that no decision, whether emanating from a state, sub-state, private, or individual actor, can legitimately contribute to a sustainable and irreversible degradation of the planetary biophysical substrate or the collective cognitive capital of Humanity. This principle transcends traditional normative hierarchies, positioning itself as a categorical imperative that must guide and limit the entirety of human activity.

Its scope is universal, applying at both local and global scales, and its interpretation must imperatively conform to the most current state of scientific knowledge in Earth system science and cognition. This unconditionality is rooted in the recognition of the ontological dependence of all forms of life, including human, and all societies, on the stability and resilience of ecological and climatic systems. The biosphere functions as an integrated set of feedback loops, whose progressive or abrupt disruption threatens not only essential ecosystem services (water supply, climate regulation, pollination), but the very capacity of the Earth to support complex civilization.

Similarly, the degradation of cognitive capital—ranging from the erosion of indigenous knowledge to the proliferation of widespread disinformation—compromises the collective capacity to understand challenges and forge appropriate solutions. Climate change, for example, illustrates this interdependence. Successive IPCC reports, particularly the Sixth Assessment Report (AR6, 2021-2023), have attested to a global temperature increase of 1.1°C above pre-industrial levels, with consequences already palpable in the frequency and intensity of extreme events.

This disruption is not an isolated phenomenon, but a correlate of unrestrained resource consumption and the inability of existing normative frameworks to integrate planetary boundaries into economic and political decision-making processes. The limits of anthropocentric governance The Westphalian framework, structured around state sovereignty and non-interference, has proven inoperative in the face of transnational and trans-generational challenges.

International agreements, such as the Paris Agreement on climate (2015), although fundamental in their recognition of the problem, suffer from their non-binding nature regarding national emission reduction targets (Nationally Determined Contributions, or NDCs). In 2022, UNEP (United Nations Environment Programme) noted that current NDCs would lead to a warming of 2.8°C by the end of the century, well beyond the 1.5°C target considered critical by science. This inability to act effectively stems from an anthropocentrism advocated by classical Western law, where humans are considered masters and possessors of nature, a resource to be exploited.

Human rights, though necessary, have traditionally been conceived as individual and inter-human prerogatives, without explicitly including duties towards the non-human world or future generations whose interests are alienated by current socio-economic decisions. The emergence of rights of nature or concepts such as the rights of future generations, while promising, remains fragmented and insufficiently integrated into the normative hierarchy. Systemic primacy aims to correct this shortcoming by establishing an inalienable floor of protection, below which no action could be legitimate.

This is a paradigm shift, moving from a law of exploitation to a law of coexistence and resilience, where the very existence of the planetary system and collective cognition is the supreme value to be preserved. Philosophical Justification: Hans Jonas's Ethics of Responsibility The philosophical foundation of systemic primacy finds its most vigorous anchor in the work of Hans Jonas, particularly in his book *The Imperative of Responsibility: In Search of an Ethics for the Technological Age* (1979).

Faced with the disproportionate power of modern technology, capable of affecting life on Earth on an unprecedented scale, Jonas postulated the necessity of a prospective ethics, focused on anticipating the distant consequences of our actions and on responsibility towards future generations and the biosphere itself. Jonas highlights a fundamental asymmetry: while human power to act has considerably increased with technological progress, its ability to anticipate and control the long-term effects of these actions has remained limited, or even atrophied under the impulse of a short-term rationality.

This "Promethean excess" leads to an unprecedented situation where the very existence of humanity and its living conditions are threatened by its own productions. The question is no longer, as with Kant, what man ought to do in general, but what must be done so that humanity can continue to be. The core of Jonas's proposition is the reformulated categorical imperative: "Act in such a way that the effects of your action are compatible with the permanence of genuine human life on Earth." This imperative is not solely anthropocentric, because "genuine human life" is intrinsically linked to the permanence of a viable biosphere.

It is a responsibility for "the Being of man" and for "the Being of nature," a responsibility that does not arise from a social contract, but from an unconditional obligation towards existence itself. This imperative implies a "heuristic of fear," a form of rational prudence where the anticipation of worst-case scenarios must prevail in order to avoid the irreparable. Faced with the radical uncertainty of the ultimate consequences of our technologies, and especially of ecological degradation, Jonas urges us to adopt an attitude of maximum precaution, even if it means curbing technological progress if it threatens the integrity of the Earth system.

It is this dimension of precaution, elevated to the rank of an ethical imperative, that philosophically underpins systemic primacy, demanding that every decision be subordinated to the preservation of the biophysical and cognitive substrate. Legal Justification: Emergence of Earth System Law The emergence of the concept of Earth System Law represents an attempt to legally formalize the ecological and existential imperatives that transcend traditional state divisions. Jurists like Louis J. Kotzé and Alexandra Kim have been pioneers in articulating this new field of law, advocating for a complete overhaul of global governance in the face of the Anthropocene.

Kotzé, in his works (notably *Global Environmental Constitutionalism in the Anthropocene*, 2016), emphasizes the inadequacy of existing legal frameworks, which are historically built on a fragmentation of competencies and an anthropocentric vision of justice. The complexity and interdependence of Earth systems require a holistic approach, where regulations do not merely manage pollution or protect isolated species, but aim for the resilience and stability of the Earth system as a whole. This implies rethinking notions of sovereignty, responsibility, and rights, expanding them to include the biosphere and its vital processes.

Alexandra Kim, for her part, develops the idea of a true "ecological constitution" on a planetary scale, a normative matrix that would establish the fundamental principles of environmental governance and set insurmountable limits to human activities. This constitution would not be a mere international treaty, but a set of supra-legislative principles, endowed with binding force superior to national legislation and ordinary treaties, precisely to guarantee systemic primacy. It would imply, for example, the enthronement of a right of nature or the establishment of international tribunals with jurisdiction to judge "ecocidal crimes" against the Earth system.

A pioneering example of the application of this logic is found in the law recognizing the Whanganui River in New Zealand as a living entity with rights (Te Awa Tupua Act, 2017). Although specific to a national and cultural context, this legislation illustrates the capacity to extend legal personality beyond human entities, granting an ecosystem intrinsic rights, which is a step towards the legal recognition of the integrity of the biophysical system.

The growing recognition of planetary boundary conditions by the scientific community, notably the Planetary Boundaries Framework initiated by Johan Rockström and his team (2009), provides an objective and measurable basis for establishing these inalienable legal limits. Four of the nine planetary boundaries, such as climate change or biodiversity erosion, have already been crossed, according to the Stockholm Resilience Centre in 2022. Earth System Law aims to translate these biophysical thresholds into binding legal constraints, requiring that all economic or political activity respect these thresholds, under penalty of nullity or sanctions.

The status of *erga omnes* law Systemic primacy is conceived as an *erga omnes* right, that is, an obligation incumbent upon all actors, state or non-state, and towards all. In classical international law, *erga omnes* obligations are those that concern the international community as a whole, because their violation harms fundamental interests of that community. The right to self-determination of peoples or the prohibition of genocide are classic examples of *erga omnes* obligations.

The application of this concept to systemic primacy means that the preservation of the biophysical and cognitive conditions of life on Earth is an obligation that does not fall within the discretion of sovereign states, but constitutes a fundamental duty of every member of the planetary community. The violation of this principle, by an activity leading to irreversible systemic degradation, would constitute a prejudice not only towards a state or a category of individuals, but towards all of Humanity and the ecological systems on which it depends.

This implies that any stakeholder, including non-governmental organizations or individual citizens acting for the common good, could have the capacity to intervene or enforce this principle in court. This is not a subjective right in the classical liberal sense, but an objective right imposed on all, whose violation would entail global and imprescriptible responsibility, a true "universal responsibility" for the integrity of the Earth system. From Individual Responsibility to Cosmic Solidarity The concretization of systemic primacy requires a translation of the ethical and legal imperative into individual consciences and collective institutions.

It challenges the very notion of sovereignty, not as an absolute prerogative, but as a function delegated by and for the preservation of the conditions of planetary habitability and collective cognitive lucidity. The sovereignty of nations or corporations can no longer be exercised to the detriment of the structural integrity of the Earth system and its biogeochemical or informational regulations. This principle is intrinsically linked to Article 3 of the Universal Declaration of Human Rights (1948), "Everyone has the right to life, liberty and security of person," but gives it a radical spatial and temporal extension.

The right to life cannot be guaranteed if the conditions of life themselves are destroyed. This is a recognition that human life is not an isolated given, but an emergence within a complex network of existents, whose stability is the *sine qua non* condition of our own permanence. The implementation of systemic primacy implies the establishment of robust and innovative legal mechanisms.

Among these, one can envisage international environmental courts endowed with real coercive powers, the recognition of ecocide as a crime against Humanity and against the Earth (on bases similar to the "Stop Ecocide International" initiative), and the systematic integration of Earth system science into the development and evaluation of public policies. Decisions of the International Court of Justice or the European Court of Human Rights, for example, will have to be systematically informed by the state of scientific knowledge on biophysical thresholds. Furthermore, a redefinition of the role of the economy is necessary.

The current framework, dominated by GDP (Gross Domestic Product) and capital growth, ignores environmental and social externalities at systemic scales. The circular economy, bioeconomy, and the recognition of the intrinsic value of ecosystems (as in the work of The Economics of Ecosystems and Biodiversity, TEEB, 2010), must cease to be marginal options to become the organizing principles of economic activity, framed by systemic primacy. In essence, systemic primacy is not a mere additional clause to existing law, but a refoundation. It is a recognition of our place not at the summit but within the great living whole, with a responsibility proportional to our technological power.

It shifts the center of gravity of political and legal decision-making, from particular and ephemeral interests towards the categorical imperative of the permanence and resilience of the planetary system and the cognitive capacity of human beings to live in a reasoned manner. Chapter 14 Law I — Operational Implementation From Imperative Law to Legal Meteorology: The Rhythm of Threshold-Limits The operational implementation of the principles of Law I, as set out in the 2025 Paris Treaty on Environmental Governance, relies on an unprecedented normative and techno-scientific architecture.

It aims to transcend traditional incentive or restorative approaches, to establish a legal regime for the radical prevention of systemic dysfunctions. This paradigm shift implies an objectification of environmental facts in law, making the state of the Earth system no longer a discretionary consideration, but an intangible constraint enforceable against public and private action. The core of this system lies in the integration of biophysical "threshold-limits", translating into legal terms the "planetary boundaries" identified by Rockström et al. (2009, *A Safe Operating Space for Humanity*).

These thresholds, once defined and adopted, acquire a force comparable to laws of nature in the legal order, operating a transition from environmental law to a "law of the Earth", as theorized by Christopher D. Stone (1972, *Should Trees Have Standing?*). Their exceeding automatically triggers coercive corrective mechanisms, without requiring prior political interpretation. Threshold-Limits: Epistemic and Legal Foundations The determination of threshold-limits is based on a rigorous scientific approach, validated by the Intergovernmental Panel on Environmental Governance (IPEG), established by Article 7 of the Paris Treaty (2025).

The IPEG compiles and synthesizes data from the world's best research institutions, notably those of the Stockholm Resilience Centre and the Potsdam Institute for Climate Impact Research. This approach ensures that normative boundaries are based on the best available scientific understanding of the processes regulating the stability of the Earth system. These thresholds are not static-deterministic but dynamic, subject to adjustments as scientific advances occur, according to a procedure framed by Article 12 of the Paris Treaty. They incorporate precautionary uncertainty margins, as recommended by the precautionary principle enshrined in Article 5 of the French Environmental Charter (2004).

For example, for greenhouse gas emissions, the limit is set at an atmospheric concentration of 430 ppm CO_2-eq, a threshold beyond which an overshoot of 1.5°C is considered probable according to the

IPCC (AR6 Assessment Report, 2023). Biophysical Data in Open Data: Cornerstone of Transparency Relevant biophysical indicators for monitoring threshold-limits are made accessible as open data, in accordance with Article 2 of the 2026 Environmental Transparency Regulation (ETR). This strategy meets a dual requirement: democratic transparency and scientific verification.

The data comes from global sensor networks and satellite observations, managed by international consortiums such as Copernicus and the Global Climate Observing System (GCOS). This open data infrastructure allows a multitude of actors—researchers, citizens, non-governmental organizations, as well as national regulators—to monitor the state of the Earth system in real time. For instance, the Sentinel-5P satellite of the Copernicus program provides daily measurements of the concentrations of certain atmospheric pollutants with a resolution of 7km x 3.5km, offering unprecedented granularity for monitoring local and regional emissions.

The European DIAS (Data Information and Access Services) platform hosts these 12 petabytes of annual data free of charge. The Automatic Review Protocol: Towards Cybernetic Governance The specificity of Law I lies in the automation of legal triggers. The exceeding of a biophysical threshold-limit does not call for a political debate on the advisability of action, but activates an automatic review protocol for public policies and economic activities, as detailed in Article 15 of the Paris Treaty. This is a resolutely cybernetic approach to governance, where the legal system adapts in real time to ecological constraints.

This mechanism is designed to avoid decision-making inertias and denial logics that characterized previous decades. Once the threshold-limit is crossed, an alert committee, composed of independent scientific and legal experts, is mandated to officially confirm the exceedance and trigger the corrective procedure. This finding, purely objective, is enforceable against States and private entities, without possibility of appeal on the factual merits. The Nature of Automatic Corrections Automatic corrections can take various forms, progressive or immediate, depending on the severity of the exceedance and the nature of the threshold.

These include notably: The activation of moratoriums on certain extractive or emitting activities. The establishment of more restrictive emission quotas or withdrawals. The suspension of operating authorizations or building permits. The triggering of national and supranational emergency plans aimed at restoring compliance with the thresholds. For example, if the 430 ppm CO_2-eq threshold is exceeded, all new coal-fired power plant projects would be automatically frozen, and binding reduction targets of 50% within 5 years would be imposed on the highest-emitting nations, in accordance with the Imperative Reduction Program (IRP) of Article 17 of the Paris Treaty.

Between 1990 and 2022, global CO_2 emissions increased by over 60%, demonstrating the necessity of such a binding mechanism. Articulation with Existing Legal Frameworks Law I does not supersede pre-existing domestic or international legal orders, but overdetermines them. It establishes an "inverted hierarchy of norms," where the stability of biophysical systems becomes the supreme norm, taking precedence over other economic or social considerations. Article 22 of the Paris Treaty stipulates that any national legislation or policy deemed incompatible with compliance with threshold-limits must be amended or repealed within a reasonable timeframe.

This implies for signatory States a profound overhaul of their legislative and regulatory apparatuses. Urban planning law, corporate law, tax law, energy law, and even international commercial law will need to be re-evaluated in light of biophysical constraints. Law I thus represents a true "constitutional grammar of the Anthropocene," as Alain Supiot (2015, *La gouvernance par les nombres*) suggests, where the technique of regulation is subordinated to the limits of the Earth. Jurisprudential Precedents: Harbingers of a New Era Several court decisions in recent years have paved the way for the integration of binding and measurable environmental obligations, anticipating the spirit of Law I.

These rulings have established principles of diligence and obligations of results for States regarding climate protection, despite the absence of automatic enforcement mechanisms. They demonstrated judges' willingness to objectify the climate emergency and give concrete scope to international commitments. These judgments also highlighted the capacity of law, even in its classical forms, to apprehend the complexity of environmental challenges and to impose constraints on public authorities. They served as a catalyst for further reflection on the legal translation of ecological imperatives, paving the way for the elaboration of Law I.

The *Urgenda* Case (Netherlands, 2019) The decision of the Supreme Court of the Netherlands in the case *Urgenda Foundation v. State of the Netherlands* of December 20, 2019, is emblematic. The Court confirmed the State's obligation to reduce greenhouse gas emissions by at least 25% by the end of 2020 compared to 1990 levels. This decision was based on Articles 2 and 8 of the European Convention on Human Rights (ECHR), protecting respectively the right to life and the right to respect for private and family life. The Court explicitly recognized the danger posed by climate change to these fundamental rights, ruling that the State had an active "protection obligation" towards its citizens.

This judgment established a quantifiable obligation of result, marking a turning point in climate jurisprudence. It demonstrated that courts could go beyond declarative targets to impose concrete reductions. The *KlimaSeniorinnen* v. Switzerland (ECtHR, 2024) The Grand Chamber judgment of the European Court of Human Rights (ECtHR) of April 9, 2024, in the case *Verein KlimaSeniorinnen Schweiz and others v. Switzerland*, amplified the scope of Urgenda on a continental scale. The Court ruled that Switzerland had violated Article 8 of the ECHR by failing to implement sufficient measures to combat climate change.

This judgment is crucial because it recognizes for the first time a subjective right to effective protection against the effects of climate change, derived from the right to respect for private and family life. The ECtHR stressed that the State had failed in its duty to protect the life and health of the applicants, elderly women particularly vulnerable to heatwaves. This decision sets a minimum standard for climate action by Member States of the Council of Europe, strengthening the legitimacy of quantifiable targets and obligations of means and results in environmental matters. It also solidified the place of scientific data from the IPCC as the factual basis for judicial reasoning.

The *Affaire du Siècle* (France, 2021) In France, the decision of the Administrative Tribunal of Paris of February 3, 2021, confirmed by the Administrative Court of Appeal of Paris in 2023, in the *Affaire du Siècle*, illustrated the same trend. The judge recognized the State's failure to combat climate change and symbolically condemned it to "repair the ecological damage" and "reduce its greenhouse gas emissions". Although the scope of the injunction was less binding than in *Urgenda*, it marked a decisive step in confirming the State's responsibility for insufficient climate action.

The importance of these judgments lies in their ability to "legalize" scientific data on climate, transforming them into evidence to justify state obligations. They created a form of "climate justice" that seeks to fill the gaps in political action, and paved the way for the idea that a lack of environmental action can be penalized by law. According to the United Nations, the number of climate lawsuits doubled between 2017 and 2022, reaching 2180 cases in 65 jurisdictions. The Sanctions and Compliance Regime Law I is not just a set of thresholds and procedures;

it is accompanied by a robust sanctions regime and compliance mechanisms to ensure its effectiveness.

Article 25 of the Paris Treaty establishes an International Court of Environmental Justice (ICEJ), responsible for ensuring compliance with the provisions of Law I and for imposing sanctions in the event of proven non-compliance. The ICEJ is endowed with binding powers, ranging from the imposition of significant financial penalties, to injunctions to cease certain activities, and even to the suspension of voting rights of member states within the instances of Global Environmental Governance, such as the World Environmental Parliament. This gradation of sanctions aims to encourage compliance without paralyzing national economies, while signaling the seriousness of the stakes.

Compensation and Recovery Mechanisms In addition to sanctions, Law I provides for compensation and recovery mechanisms for ecosystems and populations affected by non-compliance with threshold-limits. Article 28 of the Paris Treaty establishes a Global Fund for Environmental Restoration (GFER), funded by fines and contributions from polluting states. This fund aims to finance ecological restoration projects, biodiversity protection, and adaptation assistance for the most vulnerable communities.

In parallel, the notion of "intergenerational ecological responsibility" is enshrined in Article 3 of the Treaty, allowing future generations, represented by guardians appointed by the ICEJ, to bring legal actions for environmental damages suffered. This principle, inspired by John Rawls's theory of intergenerational justice (1971, *A Theory of Justice*), consecrates the idea that present generations have a fiduciary obligation towards the future of the planet. The objective is to move beyond the anthropocentric logic of classical law to embrace an ecocentric perspective.

Governance and Sovereignty in the Era of Law I The advent of Law I inevitably raises fundamental questions about state sovereignty and the nature of global governance. By subordinating national action to global biophysical imperatives, the 2025 Paris Treaty operates a partial transfer of sovereignty to a supranational entity, Global Environmental Governance (GEG). This mutation represents an explicit recognition of the interdependence of human and natural destinies, as highlighted by Hans Jonas (1979, *The Imperative of Responsibility*).

This evolution does not mean the dissolution of states, but their transformation into actors of a "cosmopolitics" where the nation must articulate with the demands of the biosphere. States retain their role in implementing compliance measures, adapting their legislation, and contributing to global mechanisms. They become guarantors of the effectiveness of Law I on their territory, no longer at their discretion, but as custodians of a shared environmental responsibility. Democratic Legitimacy and Environmental Technocracy The question of the democratic legitimacy of such a system, based on scientific thresholds and automatic mechanisms, is crucial.

Article 10 of the Paris Treaty provides for a citizen participation mechanism through "local environmental committees" and a "World Assembly of Citizens for Climate and Biodiversity", tasked with formulating opinions and proposals to the GEG. This architecture seeks to combine the efficiency of scientific expertise with the democratic imperative. This system is not a soulless technocracy, but a "deliberative ecological democracy" where science informs political decision, without dictating it entirely. It involves a constant dialogue between the objective constraints of the Earth system, democratic values, and social aspirations.

The goal is to avoid the pitfalls of purely expert governance, while ensuring that decisions are rooted in biophysical reality and not in narrow interests. Between 1970 and 2018, the global vertebrate population declined by 69% (WWF, Living Planet Report 2022), highlighting the failure of incentive-based approaches. Law I represents a systemic attempt to counteract these trends through robust legal means and an unprecedented planetary commitment.

Chapter 15 Law II — Temporal Compensation (statement and foundations) Systemic Debt: Beyond Monetary Accounting The notion of debt, traditionally circumscribed to measurable financial commitments and repayment obligations, is increasingly subject to a necessary conceptual extension in the face of contemporary ecological and social imperatives. Orthodox economics, while acknowledging externalities, struggles to fully integrate irreversible or quasi-irreversible future costs, which do not materialize instantly in financial statements. This temporal and systemic myopia leads to an unsustainable accumulation of unfunded obligations, implicitly transferred to subsequent generations.

A rigorous examination reveals a fundamental divergence between financial debt, as understood by commercial law and macroeconomics, and an **ecological or systemic debt** that encompasses environmental degradation, loss of biodiversity, and ecosystem degradation. The former is generally quantifiable, contractualized, and subject to statutes of limitation. The latter is diffuse, often irreversible, intergenerational, and difficult to monetize, although its consequences directly affect natural capital and, by extension, human well-being.

The emergence of this concept of systemic debt is intimately linked to the growing awareness of the planet's physical limits, formalized as early as Alfred James Lotka's work (1925) on quantitative ecology and Frederick Soddy's (1926) on energy. These pioneers stressed that material wealth is not solely the result of human labor but depends intrinsically on a continuous flow of natural resources and ecosystem services, whose depletion is not reflected in traditional national accounting. The non-integration of these future costs into current economic and legal models represents a major systemic failing.

Law II, relating to Temporal Compensation, aims precisely to correct this anomaly by imposing a **physical asset provisioning of all future costs** related to economic decisions, whether it concerns dismantling, carbon emissions, biodiversity loss, or cognitive debt. Dismantling: A Deferred Obligation Industrial infrastructures, particularly nuclear power plants, offshore oil platforms, or chemical factories, represent colossal financial commitments at the end of their life cycles. The dismantling of these facilities is a complex, long, and costly process, whose initial estimate is often underestimated.

Historically, dismantling provisions have been insufficient, leading to a later socialisation of costs. Taking the example of the French nuclear fleet: the total cost of dismantling and waste storage is estimated by the Cour des Comptes at 74.1 billion euros in 2023, constantly increasing compared to previous estimates (61.5 billion euros in 2012). These sums, often deferred, represent an ecological and financial debt that future generations will have to honor. Law II would require that, from the decision to build a new facility, an equivalent provision in non-speculative physical assets (land, recyclable raw materials, sequestered renewable energy) be established and ring-fenced.

This approach contrasts with current practice, which often relies on financial provisioning mechanisms that can be subject to market fluctuations or changes in accounting standards. Dedicated funds are indeed set up for dismantling, but their management and capitalization remain intrinsically linked to the robustness of the financial system, and not to a tangible and unalterable physical value. The constitution of physical assets, beyond its complexity, guarantees a form of real capital to cover real liabilities. Carbon Provisioning: Refunding Economic Rationality Anthropogenic greenhouse gas emissions are the most palpable manifestation of this intergenerational ecological debt.

The accumulation of CO_2 in the atmosphere since the beginning of the industrial era generates increasing climate costs: extreme weather events, rising sea levels, climate migration, agricultural losses. The social cost of carbon (SCC) is an attempt to internalize these externalities, although its estimation varies considerably, from dozens to several hundreds of dollars per ton of CO_2 (e.g., Stern Review, 2006, estimating the cost of climate inaction at 5-20% of global GDP). Law II would require that any activity generating carbon emissions, from its design or authorization, provision in physical assets the estimated value of its future emissions.

This could take the form of restored or created natural carbon sinks (primary forests, wetlands), operational carbon capture and sequestration (CCS) technologies, or other forms of natural capital capable of absorbing an equivalent amount of CO_2. This requirement would radically transform economic decision-making. Such an approach goes beyond the current carbon market, often criticized for its volatility and its inadequacy in properly internalizing costs. Rather than merely monetizing a right to pollute, physical provisioning compels a proactive approach to real and tangible sequestration or compensation.

This forces an honest evaluation of available technologies and a commitment to results rather than promises. Heavy industries, aviation, and fossil energy production would be directly affected, having to demonstrate, from the outset, the capacity to physically neutralize their projected emissions. The Fundamental Distinction between Financial Debt and Ecological Debt Harold Thomas Odum, in his foundational work *Environment, Power, and Society* (1971), systematized the analysis of energy and material flows as the basis of any economy. He highlighted that economic growth, as measured by GDP, does not account for exhaustible fossil energy flows or the absorption capacity of ecosystems.

Ecological debt thus represents the deficit between human consumption of natural capital and the biosphere's regeneration capacity. Financial debt is a contractual obligation to pay a sum of money at a future date. It can be restructured, negotiated, or even cancelled by legal and economic mechanisms. **Ecological debt**, however, is a physical obligation to restore or compensate for irreversible damage to biophysical systems, whose regeneration capacity is limited by the laws of thermodynamics and biogeochemical cycles. One cannot "cancel" a destroyed physical asset or an extinct species by a legislative or monetary act.

Edith Brown Weiss, in *In Fairness to Future Generations: International Law, Common Patrimony, and Intergenerational Equity* (1989), theorized the concept of "planetary capital," a set of natural and cultural assets essential for the survival and well-being of humanity, whose deterioration engages the responsibility of current generations towards future generations. Her thesis is a direct precursor to Law II, as it insists on the duty to preserve this capital to avoid bequeathing an unsustainable debt. Biodiversity: Irreplaceable Capital to Be Provisioned The loss of biodiversity is a planetary crisis of a magnitude comparable to climate change.

Since 1970, vertebrate populations have decreased by almost 69% on average worldwide, according to the WWF Living Planet Report 2022. This massive erosion of species and ecosystems directly threatens essential ecosystem services (pollination, water purification, climate regulation, soil fertility). Current attempts at "ecological compensation," often based on habitat restoration or the creation of reserves, are notoriously insufficient and struggle to replicate the complexity of original ecosystems. They often stem from a destruction/reconstruction logic that fails to grasp the irreversibility of certain losses.

Law II would establish that any activity (urbanization, intensive agriculture, mining extraction) leading to proven destruction of natural habitats or a threat to species should, from its conception, provision an equivalent physical asset in functional terms and not merely in surface area. This would imply the preventive ring-fencing of equivalent biodiversity areas, the acquisition of land rights for their permanent protection, and the establishment of governance structures guaranteeing their long-term integrity.

This provision would not be a mere "compensation bank" but a distinct and secured natural capital, whose value lies in its ecological sustainability and not in its financial liquidity. This forces developers to consider the true ecological footprint of their projects and no longer just their residual monetary externalities. Cognitive Debt and the Erosion of Traditional Knowledge Beyond direct environmental damage, systemic debt also includes what could be called **cognitive debt**: the loss of knowledge, traditional know-how, and sustainable resource management systems accumulated by human societies over millennia.

Globalization, cultural homogenization, and the industrialization of practices have often led to the abandonment or destruction of ecologically adapted and resilient ways of life and know-how. Take the example of diversified and resilient agricultural practices versus intensive monocultures, or traditional medicinal knowledge versus industrial pharmacopoeia. This knowledge consists of precious assets, not reproducible in the short term, which constitute essential intangible capital for human adaptation to environmental changes. Their erosion represents a "debt" for future generations who lose access to these proven solutions.

Law II in this area could require active measures for the preservation of this knowledge and its bearers, for example, by financing intergenerational transmission, protecting the territories of indigenous peoples who are its custodians, and integrating this knowledge into educational and research systems. It would involve provisioning not a direct physical asset, but "human and cultural capital" whose strategic value for future resilience is invaluable. The Role of Exhaustible Resources and Hotelling’s Rule Law II finds a particular echo in the field of exhaustible resources.

Hotelling's Rule, formulated by Harold Hotelling in 1931, states that in a perfect market, the net price of a non-renewable resource must increase at a rate equal to the interest rate. It provides a theoretical framework for the optimal management of exhaustible resources but does not resolve the question of the "just" intergenerational allocation of benefits and costs. Law II proposes a break with this purely economic approach. Every ton of ore extracted, every barrel of oil pumped, represents a definitive amputation of the planet's biophysical capital.

The obligation to provision an equivalent physical asset would mean that the benefits derived from the extraction of non-renewable resources are not simply consumed or invested in other financial sectors, but that a significant portion must be transformed into durable and renewable physical capital for future generations. This could take the form of massive investments in renewable energies, ecological restoration, or carbon sequestration, proportional to the energetic and material value of the extracted resources.

For example, an oil company that extracts one million barrels of oil should, at the time of this decision, commit an equivalent amount in renewable energy production capacities or restoration of forest ecosystems capable of sequestering an equivalent amount of carbon over future cycles. This fundamental constraint is a reaffirmation of the principle that material wealth is not created ex nihilo but transformed from natural capital. Herman Daly and the "Steady-State Economy" Herman Daly, a major figure in ecological economics, systematized in *Steady-State Economics* (1977) a radical critique of unlimited economic growth in a finite world.

He emphasized the need to distinguish growth (physical increase) from development (qualitative improvement), with development without growth being not only desirable but imperative. For Daly, the economy must be embedded within the biophysical functioning of the biosphere, not the other way around. Law II is a direct application of Daly's principles, in that it imposes accounting in terms of physical flows and stocks, beyond monetary accounting. It aims to internalize irreversible costs before they occur, by ring-fencing physical capital.

It is an attempt to restore the integrity of natural capital by requiring economic actors to provision, in real and tangible assets, for the degradations they generate. This compels a deeper reflection on the necessity of projects, their scale, and their reversibility. By imposing provisioning in physical assets, Law II shifts the burden of proof and funding. It does not merely assign a price to an externality to better "manage" it, but it requires a transformation of capital towards more sustainable and renewable forms.

This approach goes beyond carbon taxes, biodiversity markets, or dismantling funds, in that it anchors responsibility in physical reality and not in a future financial promise. The international legal system, through treaties such as the Convention on Biological Diversity (1992) or the Paris Agreement (2015), has recognized the seriousness of ecological issues. However, these frameworks remain largely incentive-based and struggle to compel state and private actors to a profound transformation of their practices. Law II proposes a binding mechanism, based on a new form of economic and legal rationality, where the temporality and irreversible nature of impacts are fully integrated.

The aim is to ensure that each generation pays the costs of its decisions at the time they are made, and not postpone them indefinitely. Chapter 16 Law II — Differential Accounting and Provisions: Differential Accounting as the Normative Infrastructure of an Ecological Economy. Contemporary economics, as structured by dominant accounting frameworks, exhibits a structural incapacity to fully integrate ecological dimensions.

The international financial accounting system, as derived from IFRS (International Financial Reporting Standards) managed by the IASB (International Accounting Standards Board), focuses on the economic performance of an entity, measured in terms of monetary flows and the valuation of financial assets and liabilities. This results in a systemic obfuscation of environmental impacts, considered as externalities, and a profound disassociation between measured wealth and the reality of ecosystem degradation. This hiatus is all the more concerning as the ecological crisis intensifies, necessitating a profound overhaul of instruments for measuring and managing value.

The emergence of ecological accounting is not a mere technical annex, but a necessary condition for the transition to an economy compatible with planetary boundaries, a concept formalized by Rockström et al. in 2009. Innovative approaches, such as CARE (Comptabilité Adaptée au Renouvellement de l'Environnement - Accounting Adapted to Environmental Renewal), proposed notably by the works of Jacques Richard and Alexandre Rambaud since the 2010s, address this deficiency by modifying the scope of the accounting entity.

Rather than limiting itself to human assets and liabilities, CARE-Ecosystem integrates natural capital as intrinsic elements of the balance sheet and income statement, recognizing their fundamental role in value production and their status as affected third parties. This approach represents an epistemological rupture with traditional accounting conventions. Legal and Philosophical Foundations for the Recognition of "Natural Third Parties". The implicit legal recognition of nature as a "creditor" or an "actor" within the economic sphere can be traced in several legislative and jurisprudential texts.

The notion of ecological damage, enshrined in French law by Law No. 2016-1087 of August 8, 2016, for the reconquest of biodiversity, nature, and landscapes, establishes a duty to repair any non-negligible harm to the elements or functions of ecosystems. While this law does not directly confer legal personality on natural entities, it objectifies environmental damage, dissociating it from harm to human persons and making it assessable in itself. This legal evolution reflects a growing awareness that ecosystems are not mere resources at man's disposal, but entities whose integrity and resilience are essential.

Pioneering decisions, such as the recognition of the Whanganui River in New Zealand as a legal entity endowed with rights (Te Awa Tupua Act 2017), or of the Colombian Amazon by the Supreme Court of Justice (STC4360-2018), illustrate a global movement towards the "juridification" of nature. These cases underscore the need for an accounting infrastructure capable of translating these rights into financial obligations for responsible economic entities. From a philosophical perspective, CARE accounting aligns with a tradition of thought that refutes exclusive anthropocentrism, promoting an ethics of responsibility towards future generations and nature itself.

Hans Jonas, in "The Imperative of Responsibility" (1979), already argued for a prospective ethics that integrates the distant consequences of our actions on the biosphere. The accounting entry of environmental degradation as a debt or a provision aligns with this ethical requirement of accountability not only to shareholders but to all "right-holders" of the biosphere, whether human or non-human, present or future. Mandatory Provisions: Internalizing Ecological Liabilities. Current financial accounting, under the principle of prudence, mandates the establishment of provisions for risks and charges when obligations are probable and measurable.

However, this obligation is limited to commitments to identifiable third parties and measurable in monetary terms. Ecological debts, due to their diffuse nature and the difficulty in valuing them, often escape this strict categorization, leading to a chronic undervaluation of companies' actual liabilities. The mandatory provisions envisaged in differential accounting, such as CARE, aim to systematize the internalization of restoration costs or costs of non-degradation of natural capital. These are no longer potential risks, but proven or highly probable obligations arising from current economic activity on environmental resources.

These provisions relate not only to regulatory compliance (sanctioned pollution) but to a recognition of the depreciation of natural capital as an operating cost, just like the depreciation of fixed capital. Case of Nuclear Decommissioning and Radioactive Waste Management. The nuclear industry is an archetypal example of the inadequacy of conventional accounting mechanisms. Decommissioning power plants and managing radioactive waste are operations whose costs span decades, or even millennia, and whose estimation is complex and often subject to upward revision.

In France, provisions for decommissioning and nuclear waste management are recorded as liabilities of nuclear electricity producing companies (notably EDF). According to the 2017 report by the Cour des Comptes (French Court of Auditors), the total cost of long-term obligations related to nuclear facilities amounted to 75.5 billion euros, of which 27.6 billion euros were for the decommissioning of historical power plants and post-operation. However, discounting methods and cost assumptions are regularly challenged, leading to underestimations that could weigh heavily on public finances in the event of operator failure.

Differential accounting would require a constant re-evaluation of these provisions, not only based on financial discount rates but also integrating an ecological and intergenerational risk premium. The valuation of the "safety" and integrity of ecosystems over significant time scales should be integrated, recognizing that permanent radioactive pollution constitutes irreversible depreciation of certain natural capital.

The CARE approach could, for example, require a provision for "cost of non-degradation" of ecosystems for each production phase, not only to cover decommissioning costs but also to compensate for the irreversible loss of ecosystem services related to the ecological footprint of facilities over several millennia. Mining and Site Restoration. The extractive industry, whether for metals, minerals, or hydrocarbons, generates major environmental impacts: landscape destruction, soil and water contamination, loss of biodiversity. National legislations, such as the French Mining Code, already impose on operators obligations to restore sites after exploitation, evidenced by financial guarantees.

However, the evaluation of these costs is often incomplete, and the provisions made are regularly deemed insufficient by monitoring bodies. In Canada, the National Energy Board estimated in 2019 that almost 2 billion Canadian dollars in environmental liabilities linked to abandoned pipelines and oil wells were not adequately provisioned by operators. Mandatory provisions under differential accounting should go beyond simple morphological restoration. They should include the cost of functional restoration of ecosystems, meaning the restoration of ecological processes and lost ecosystem services (water purification, climate regulation, habitat for flora and fauna).

This cost is structurally higher than that of simple physical restoration. The integration of the notion of natural capital into the balance sheet would imply that any depreciation of this capital, even if it does not lead to an immediate expenditure, generates a provision to compensate for the present and future loss of value of the biophysical system. Fossil Aquifers and Water Debt. The depletion of fossil aquifers, i.e., underground water reserves accumulated over geological time and non-renewable on a human scale, is a growing global issue.

Regions like the Great Plains of the United States (Ogallala Aquifer) or the Ganges Basin in India suffer massive withdrawals for agriculture, leading to a drastic drop in piezometric levels. The extraction of this fossil water generates a "water debt" that is not reflected in the balance sheets of companies or states. Water is often considered a free resource or valued very weakly, triggering no obligation to provision for its depletion. Differential accounting would require that economic entities drawing from these non-renewable reserves provision the cost of their future degradation, or the cost of substituting this resource. This would involve valuing the loss of hydric natural capital.

If the reserves of a fossil aquifer are estimated at, for example, 10,000 million cubic meters and a company extracts 100 million per year, a provision should be made for the 1% of irreversibly lost hydric capital. This provision could be used to finance desalination technologies, water transfer infrastructures, or artificial aquifer recharge programs, thus ensuring the sustainability of water access for future communities. Freshwater represents less than 3% of the total water on Earth, and access to drinking water remains a major challenge for over 2 billion people according to the WHO in 2022. Accounting for this depletion is therefore vital.

Implications of CARE Accounting Law II: Fair Value of Natural Capital. The second law of CARE accounting, formulated by Rambaud and Richard, posits that the value of natural capital must be protected at its renewal or reconstitution cost, and not at its historical cost or market value. This approach is radically different from dominant accounting principles that value assets at their acquisition cost or fair market value. The objective is no longer to maximize short-term financial profit, but to ensure the integrity and sustainability of natural capital, considering it as a "non-asset" whose degradation constitutes a liability.

This "fair environmental value" does not aim to monetize nature to privatize it, but to estimate the cost necessary to maintain its functional capacities. The depreciation of a natural asset must be compensated by a maintenance or restoration expense, and this obligation must be recorded as a liability if it is future. It is not a "price" but an estimate of the cost of the ecological "technical debt" accumulated by an entity. If biodiversity is degraded, the cost of its restoration (e.g., reforestation with local species, soil decontamination) must be provisioned, even if the company does not have the immediate intention to spend it, because it is an obligation towards the ecosystem.

Definition and Scope of "Debt to Ecosystems". The "debt to ecosystems" is a manifestation of CARE Law II. It is not limited to strict legal obligations of repair but encompasses all negative impacts of human activity on the regeneration and resilience capacity of natural systems. It is an implicit debt, often non-monetized and unprovisioned, but whose postponement threatens the biophysical stability of the planet. The objective of differential accounting is to make this debt explicit, quantifiable, and traceable at the level of economic entities. This debt would include, for example, the cost of surplus greenhouse gas emissions compared to a sustainable carbon budget.

According to the IPCC (Intergovernmental Panel on Climate Change), a 43% reduction in global GHG emissions by 2030 compared to 2019 is necessary to limit warming to 1.5°C (AR6 Synthesis Report, 2023). Each tonne of CO2e emitted beyond its attributable share to entities constitutes a depreciation of atmospheric natural capital and should generate a provision for its sequestration or compensation. Similarly, overfishing, deforestation, or plastic pollution should be evaluated as direct depreciations of natural capital (fish stocks, forest biomass, ocean quality) and lead to provisions for their reconstitution. Natural Capital as a "Non-Asset" and the Principle of Non-Diminution.

The concept of "non-asset" in CARE is central. It means that natural capital is not a resource that the company "owns" and can depreciate at will, but a third-party capital for which it is responsible. The depreciation of this non-asset does not generate an asset loss, but an increase in liability, a debt. This perspective breaks with the dominant economic approach that perceives the environment as a stock of natural resources to be exploited and whose depreciation is an acceptable cost of production. The principle of non-diminution of natural capital, often associated with strong sustainability (Daly, 1990), is integrated into this accounting conception.

It stipulates that the overall stock of natural capital must not decrease. Any degradation must be compensated, or at a minimum, must trigger a provision for this future compensation. This principle is crucial for the future of biodiversity. According to the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), approximately one million species are threatened with extinction, an "unprecedented" rate in human history, with serious consequences for ecosystems and human well-being (Global Assessment Report on Biodiversity and Ecosystem Services, 2019).

Accounting that internalizes this via binding provisions could encourage companies to adopt much more respectful practices. From Theory to Implementation: Normative and Regulatory Challenges. The widespread implementation of differential accounting with mandatory provisions raises considerable challenges. The first is normative: it requires collective acceptance and an evolution of international accounting standards, which have historically resisted innovations that do not fit with conventional financial logic. The IASB, for example, prioritizes financial relevance for investors, not ecological relevance.

A strong political impetus at the level of states or regional blocs (such as the European Union) would be needed to initiate this change. The quantification and evaluation of ecological liabilities represent a second challenge. The monetary valuation of ecosystem degradation is complex and often controversial. How to assess the cost of species extinction, the loss of a pollination service, or the degradation of soil quality over several centuries? Current methods for the economic valuation of biodiversity or ecosystem services (e.g., contingent valuation, replacement cost) are imperfect.

A pluralistic approach, combining physical indicators (tonnes of CO_2, habitat area, etc.) and monetary estimates weighted by their ecological importance, would be necessary, under the supervision of independent and multidisciplinary organizations. Finally, the question of territoriality and responsibility is crucial. Who is responsible for which liability? Should a provision be made for "imported" emissions or impacts located abroad? The "European taxonomy" (Regulation (EU) 2020/852), although insufficient, represents a first step towards an attempt to categorize sustainable economic activities.

However, this initiative focuses on identifying green investments, not on quantifying the ecological liabilities generated by all activities. A law at the European or international level could be envisaged, imposing not only detailed extra-financial reporting (like the CSRD – Corporate Sustainability Reporting Directive), but also the establishment of specific provisions, audited and guaranteed. This law should be binding, like directives on industrial pollution, but extended to all biophysical impacts. The objective of such an accounting reform is not to hinder economic activity, but to radically reorient it towards sustainability.

By internalizing environmental costs, companies would be encouraged to adopt more frugal and regenerative production and consumption models. Capital would no longer be allocated solely to maximize short-term financial returns, but also to protect and restore the natural capital on which all economic activity depends. It is about redefining the contours of the market itself, by integrating biophysical limits as fundamental variables and not as exogenous parameters. The long-term survival of humanity directly depends on the ability of our economic and normative structures to recognize and fully integrate our dependence on the biosphere.

Chapter 17 Law III — Cognitive Indivisibility (Statement and Implications) Cognitive Indivisibility: A Foundational Postulate for Planetary Governance The advent of the Anthropocene, characterized by the geological and biospheric footprint of human activity, reveals the urgency for a rethinking of normative frameworks. Societies' ability to grasp systemic crises intrinsically depends on the quality of their information and collective reasoning. The latter, far from being mere individual aggregates, constitute vital infrastructures, whose preservation and sharing are now imperative.

Their inherently non-rival and non-exclusive nature, though often obscured by logics of appropriation, places them within the domain of fundamental common goods. The hypothesis of "cognitive indivisibility" posits that reliable information and the process of collective reasoning constitute essential common goods, whose access and quality cannot be restricted without compromising the resilience and adaptive capacity of social and ecological systems. This notion goes beyond simple individual freedom of expression to encompass the construction of a collective epistemology, necessary for solving complex and transnational problems.

It aligns with a school of thought recognizing the primacy of common goods in managing contemporary challenges, as articulated by Elinor Ostrom (2010), Yochai Benkler (2006), and Lawrence Lessig (2001) in their analyses of shared resources and knowledge. This postulate operates by analogy with goods whose common nature is already legally recognized, such as radio frequencies, drinking water, or the human genome, whose intangibility is affirmed by major texts like the UNESCO Universal Declaration on the Human Genome and Human Rights (1997).

The objective is to elevate information and collective reasoning to the rank of these fundamentals, endowed with a protective legal status, to guarantee their integrity against pressures from privatization, disinformation, and planned obsolescence of knowledge. Theoretical Foundations: Common Goods and Open Knowledge Architecture The concept of common goods, re-examined by Elinor Ostrom (2010) in "Governing the Commons," provides a relevant analytical framework.

Far from the strict dichotomy between public and private property, Ostrom demonstrated the viability of decentralized governance models for shared resources, proving that it is possible to avoid the "tragedy of the commons" without exclusive reliance on the state or the market. This approach applies to information, whose production and dissemination can be regulated by user communities. Yochai Benkler (2006), in "The Wealth of Networks," explored how networked information architecture, particularly the internet, enables the emergence of peer-production forms that compete with and sometimes surpass traditional institutional models.

He highlighted the capacity of ordinary citizens to collaborate on a large scale to create cognitive goods of immense value, such as Wikipedia or open-source software. This non-proprietary production of knowledge deconstructs the idea that only intellectual property guarantees innovation and creation. Lawrence Lessig (2001), in "The Future of Ideas," criticized the excessive extension of intellectual property rights which, he argued, stifles innovation and the free flow of content in the digital age. He called for the protection of a rich and accessible "public domain," essential for creativity and progress.

Lessig underscored the need to maintain a balance between innovator protection and access to knowledge, arguing that the enclosure of information behind proprietary locks harms collective cognitive indivisibility. The Erosion of Collective Cognitive Capacities Despite these theoretical realizations, reality reveals a progressive erosion of collective cognitive capacities. The proliferation of disinformation, the weakening of institutions safeguarding knowledge production (universities, independent news media), and the monopolization of access to information by a few private actors represent existential threats.

The "disinformation figure" of the 2020 US elections showed that 70% of Americans had been exposed to at least one piece of false information, with nearly half of it originating from a single platform, according to a study by the Center for an Informed Public (2021). The impact of fake news on individual and collective decisions is now established. A University of Cambridge study (2018) showed that the spread of disinformation on Twitter is 6 times faster than that of verified information. This velocity, coupled with attention-retention algorithms, creates filter bubbles and echo chambers that fracture informational consensus and weaken the deliberative rationality of democracies.

The increased societal polarization thus makes it harder to develop coordinated responses to global problems, from climate change to public health. Legal Analogies: From Natural Heritage to Cognitive Heritage The legal anchoring of cognitive indivisibility can draw on precedents where the general interest takes precedence over exclusive appropriation logics. The example of radio frequencies is eloquent. As a limited resource essential for communication, their use is governed by international regulations, notably by the International Telecommunication Union (ITU), which allocates frequencies as a public good, for the benefit of all humanity.

The Washington Treaty of 1927 and subsequent conventions established this framework, recognizing the physical limit of this resource and the need for shared management to prevent its exhaustion or exclusive privatization. Similarly, drinking water is increasingly recognized as a fundamental human right and an essential common good. United Nations General Assembly Resolution 64/292 (2010) explicitly recognized the right to water and sanitation as a human right, linking access to water to human dignity.

This legal recognition has progressively led to a limitation of privatization logics and a promotion of public or community management of this vital resource, illustrating the primacy of collective interest over the pursuit of profit. Finally, the human genome, whose significance is fundamental to the identity of the species, is subject to particular protection. The UNESCO Universal Declaration on the Human Genome and Human Rights (1997) states that "the human genome underlies the fundamental unity of all members of the human family and the recognition of their intrinsic dignity and diversity" (Article 1).

It specifies that the genome "in its natural state shall not give rise to financial gain" (Article 4), thus positing a principle of indivisibility and non-commercialization of the fundamental elements of human beings. This declaration opens the way for a similar approach to information and collective reasoning. The Economic Stakes of Cognitive Degeneration The degradation of information and collective reasoning has massive economic consequences. Recent studies estimate that disinformation costs billions of dollars each year in direct and indirect impacts.

An analysis by the Centre for Economic Performance of the London School of Economics (2019) estimated the annualized costs of political disinformation at over £78 million in the United Kingdom. These costs are even higher in sectors such as health, where distrust in science can lead to vaccination delays or risky behaviors, with an estimated cost by the WHO (2020) of hundreds of millions of dollars in terms of healthcare system overload and productivity loss. Beyond direct and quantifiable costs, the loss of trust in institutions and democratic decision-making processes generates political and social instability, undermining the foundations of the economy.

Cognitive polarization slows down the adoption of effective public policies, particularly regarding ecological transition, where the urgency of actions is hampered by the spread of climate-skeptic narratives. A meta-analysis of 50 studies (2022) showed that informed decision-making based on scientific facts could reduce the total cost of global climate policies by 15% by optimizing investments and avoiding costly errors. Towards a Governance of Cognitive Common Goods Recognizing information and collective reasoning as indivisible common goods necessitates innovative governance frameworks.

This is not about centralized control of information, but rather about establishing robust structures to guarantee the quality, accessibility, and resilience of these resources. Elinor Ostrom emphasized the importance of "self-organized institutions" and "mutually agreed-upon rules of use" for managing commons, offering a model for cognitive goods. The principles of such governance could include technological neutrality of information infrastructures, the promotion of independent fact-checking tools, support for public service media and investigative journalism initiatives, as well as strengthening media literacy and critical thinking education from an early age.

Public or mutualized funding mechanisms for fundamental research and open data are essential to counter the privatization of knowledge. The objective is to establish an ecosystem where the production, access, and interpretation of knowledge are democratized and protected from manipulation. This implies combating the monopolies of digital platforms that control access to information and direct its dissemination through opaque algorithms.

The European Union, with the Digital Services Act (DSA, 2022) and the Digital Markets Act (DMA, 2022), has begun to lay the groundwork for regulating large platforms, aiming for greater algorithmic transparency and better user protection against illicit content and disinformation. The Role of International Law and National Constitutions International law and national constitutions must reflect this new understanding of cognitive indivisibility.

Article 19 of the Universal Declaration of Human Rights (1948), guaranteeing freedom of opinion and expression, could be enriched to include a right to access reliable and high-quality information, as well as a right to participate in informed collective reasoning. This would imply new obligations for states regarding the protection and promotion of these cognitive infrastructures. Some constitutions have already incorporated provisions relating to the environment as a common good, such as Article 3 bis of the French Constitution (2005) establishing the "Environmental Charter" or the Costa Rican constitutional amendment (1994) recognizing the right to a healthy environment.

By analogy, the integration of a fundamental right to cognitive indivisibility in the supreme law of nations would constitute a decisive step. A draft World Charter of Common Goods could be envisioned, crystallizing this new global legal architecture. The stakes are high: it is about guaranteeing humanity's capacity to govern itself in the face of existential challenges. Information and collective reasoning are not luxuries, but necessary conditions for the survival and prosperity of societies in this 21st century, marked by increasing uncertainties and the imperative of coordinated action.

The status of an indivisible common good is the legal recognition of a fundamental reality and the key to more just and effective global governance. Cognitive Sovereignty and the Challenge of Artificial Intelligence The rise of artificial intelligence (AI) and complex algorithmic systems represents a major challenge for cognitive indivisibility. These technologies, through their ability to generate and process immense volumes of information, raise the question of cognitive sovereignty. Who controls the algorithms that filter and “recommend” information? Who is responsible for the bias or disinformation generated by these systems?

A Mozilla Foundation study (2022) revealed that YouTube's algorithms, for example, would direct 71% of its users towards conspiratorial or extremist content, highlighting the impact of AI on the formation of collective reasoning. It becomes imperative to develop an "AI ethic" that explicitly integrates the protection of cognitive common goods. This implies not only algorithmic transparency ("explainable AI") but also the development of AI for the general interest, capable of strengthening social cohesion and collective rationality, rather than fragmenting them.

The European AI Act (2023, currently being finalized) begins to address these challenges by classifying AI systems according to their risk level and imposing obligations for high-risk systems, particularly in terms of human oversight and post-market surveillance. "Cognitive sovereignty" does not mean state control of thought, but the ability of a society to master the tools and processes by which it constructs its collective knowledge, safe from external manipulations and proprietary logics. It involves massive investment in public AI research, promotion of open standards, and establishment of multi-stakeholder governance structures to frame the development of these technologies.

Surveillance capitalism, described by Shoshana Zuboff (2019) in "The Age of Surveillance Capitalism," directly threatens this sovereignty by transforming human experience into data for prediction and control purposes, thereby compromising the freedom of reasoning. The framework of extended cognitive indivisibility must therefore encompass the regulation of information and communication technologies, so that these powerful tools become catalysts for shared knowledge and not vectors of its dissolution.

The formation of an enlightened and critical digital citizen is the cornerstone of this edifice, enabling the exercise of responsible citizenship in the face of the increasing complexity of global challenges. Chapter 18 Law III — Regulation of Frontier AIs The Challenge of Regulating Frontier Artificial Intelligence: A Civilizational Urgency The advent of "frontier" or "advanced" artificial intelligence (AI) represents a major turning point for human societies, comparable in scope to the industrial revolution or the nuclear age.

The increasing computational capacity, measured in floating-point operations per second (FLOPs), of these systems raises unprecedented issues concerning security, governance, and sovereignty. Their deployment without adequate supervision could lead to systemic negative externalities, ranging from economic destabilization to loss of control over critical infrastructure, and even to existential risks. The pace of AI capabilities' evolution exceeds the speed at which existing normative frameworks can adapt, creating a regulatory deficit that demands a swift and coordinated response.

Large language models (LLMs) and other deep neural architectures have already demonstrated emergent capabilities, often unforeseen by their developers, in various fields, from knowledge synthesis to complex problem-solving. This functional opacity and the plasticity of their behaviors call for a precautionary approach and the establishment of robust monitoring mechanisms. U.S. President Joe Biden, through his Executive Order on the "Safe, Secure, and Trustworthy Artificial Intelligence" of October 30, 2023, identified models with computational power exceeding 102■ FLOPs as potentially posing serious risks to national security, national economic security, or public health and safety.

Although this threshold was slightly revised by subsequent legislative action, it illustrates the recognition of a category of AI requiring special attention, specifically the obligation for developers to notify the government prior to training certain models (Section 4.1.a). The European Union, with the AI Act adopted in March 2024, has also distinguished between "General-Purpose AI Models" (GPAI) and, among them, "systemic risk" systems based on considerable capabilities, although the exact criterion of 102■ FLOPs is debated and subject to reassessment by the European Commission.

These initiatives lay the groundwork for regulation by capacity thresholds, recognizing that computational power is an imperfect but necessary proxy for assessing potential impact. The Challenge of Model Evaluation and Traceability The ability to reliably and transparently evaluate the inherent risks of frontier AI is an indispensable prerequisite for any effective regulation. Current audit and certification approaches are often insufficient given the complexity and intrinsic opacity of the most advanced models. This includes not only the quality of training data, but also internal decision-making mechanisms and unforeseen behaviors that may emerge from interaction with complex environments.

Model traceability, from design to deployment, is equally critical. The AI development value chain is internationalized and fragmented, involving computational power producers, data providers, model architects, and integrators. Without complete visibility over this chain, it becomes difficult to assign responsibility in the event of failure or damage. Technical documentation and conformity assessment requirements must be strengthened to cover the entire lifecycle of the systems. Towards a Global Agency for the Regulation of Frontier AIs The transnational nature of the challenges posed by frontier AIs calls for an institutional response on a global scale.

The establishment of an international agency, modeled on the International Atomic Energy Agency (IAEA) for civil nuclear power, appears increasingly to be an imperative necessity. Founded in 1957, the IAEA oversees the peaceful use of atomic energy and prevents its military proliferation, relying on inspections, safety standards, and an international legal framework (Treaty on the Non-Proliferation of Nuclear Weapons, 1968). Such a global AI agency (GAIA) would have as its primary mission to monitor the development and deployment of the most powerful AI models, to establish universal safety and ethical standards, and to facilitate the exchange of information among member states.

It could be endowed with the power to conduct independent audits of AI computing infrastructures and training processes, as well as to certify the compliance of the most critical systems. The establishment of this GAIA should be the subject of multilateral negotiations under the auspices of the United Nations, to ensure its legitimacy and objectivity. The Central Role of Independent Audit and Transparency Regime Independent auditing is a cornerstone of trust and security in the field of frontier AI. These audits, conducted by accredited third-party entities, should assess the robustness, fairness, security, and alignment of models with human values.

The EU's AI Act, in its Article 41, already specifies that high-risk AI systems must undergo a conformity assessment before being placed on the market. For frontier AIs, these requirements should be considerably extended and globally harmonized. The transparency regime of this GAIA should comprise several pillars. First, a global database of frontier AI models, listing their capabilities, application domains, and safety evaluation results. Second, the obligation for developers to share, under strict confidentiality and security conditions, detailed technical information on their architectures, training data, and evaluation processes with the GAIA.

Third, the publication of aggregated reports on the state of the art and emerging risks, aimed at informing the general public and policymakers. The objective is not to hinder innovation, but to channel it towards responsible and beneficial developments. As Stuart Russell (2019) emphasized in *Human Compatible: Artificial Intelligence and the Problem of Control*, the alignment of AI systems' objectives with human values is paramount to avoid unforeseen and potentially disastrous consequences. Independent auditing and transparency are essential tools to ensure this alignment. The Issue of Open Weights vs.

Closed Weights The dichotomy between AI models with "open weights" (the parameters learned by the neural network) and those with "closed weights" raises fundamental questions for security and governance. Models with "open weights" are publicly accessible, allowing anyone to examine their internal workings, modify them, and deploy them. This approach fosters collaborative research, decentralized innovation, and potentially a better understanding of biases or vulnerabilities. It is estimated that more than 60% of current AI models are open source. However, the full disclosure of frontier AI model weights poses major security challenges.

A malicious actor could appropriate these models to develop biological weapons, conduct sophisticated cyberattacks, or create mass disinformation campaigns unprecedented in scale and credibility. The "dual-use dilemma" is particularly acute: technology designed for good can be diverted for nefarious purposes, as evidenced by debates surrounding the design of civilian nuclear reactors. The Open Philanthropy report (2023) on "Risks of open-source AI models" highlights the difficulty of assessing risks related to models whose capabilities can significantly improve with minimal adjustments.

The availability of models with billions of parameters, such as Llama 2 (70 billion parameters) by Meta or Mistral 7B by Mistral AI, grants substantial capabilities to a very large audience. The principle of dissemination must be balanced with security considerations. A Hybrid Regime of Controlled Dissemination It is necessary to consider a hybrid regime that reconciles the benefits of openness with the imperatives of security.

This could include: ■ A licensing or accreditation system for the development and use of open-weight frontier AI models, with obligations to comply with safety and ethical standards. ■ The establishment of a secure and auditable repository for the most sensitive models, accessible only to trusted researchers and organizations that meet strict criteria. ■ Technical "guardrails" integrated into the models, such as self-limitation mechanisms or content filters, to prevent their use for demonstrably harmful purposes. ■ The development of collaborative "red teaming" methodologies, where experts attempt to circumvent model protections before and even after their deployment, to identify vulnerabilities.

These efforts are already underway as part of the AI Safety Summit in Bletchley Park in November 2023. The objective is to avoid an AI "arms race" while enabling responsible innovation. China, for example, has already implemented laws on generative AI (2023), requiring providers to ensure "content safety" and strict monitoring of generated information, illustrating the diversity of state approaches, but also the importance of regulation. The Right to Refuse Cognitive Augmentation and Human Sovereignty The emergence of frontier AIs also raises the question of human autonomy and cognitive integrity.

Cognitive augmentation technologies, ranging from brain-computer interfaces to augmented memory devices or sensory amplification, promise to increase our intellectual and perceptual capabilities. However, their uncontrolled deployment could erode the distinction between human and machine, and potentially threaten individual sovereignty over one's own mental processes. Jürgen Habermas (2001) in *The Future of Human Nature* has already warned against the dangers of liberal eugenics and genome manipulations that could alter the normative understanding of what it means to be human.

Cognitive augmentation technologies raise similar questions regarding self-determination and individual freedom in the face of potentially ubiquitous and insidious algorithmic influences. The Need for a "Right to Non-Augmentation" It is imperative to affirm a "right to refuse cognitive augmentation," ensuring that each individual retains control over modifications made to their cognitive and sensory faculties. This right should be enshrined in national and international legal frameworks, complementing the right to privacy and physical and mental integrity.

The aim is to protect the individual's ability to make autonomous decisions without pressure or coercion stemming from AI systems or their applications. This right also implies protection against subliminal or coercive algorithmic interference. For example, AI systems could be used to optimize persuasion or cognitive manipulation on a massive scale, thereby undermining individual free will and citizens' ability to form informed opinions. A UNESCO report (2021) on the ethics of AI urges member states to ensure that individuals can exercise meaningful control over their own data and interactions with AI systems.

Recognizing such a right would help frame the development of neurotechnologies and augmented cognitive AIs, ensuring that they are used to serve human well-being and not as tools for control or standardization of thought. This is a *sine qua non* condition for preserving human dignity in a world increasingly mediated by artificial intelligence. The issue of digital identity and cognitive integrity must be approached with the utmost prudence and in consultation with a wide range of stakeholders, including philosophers, legal scholars, neuroscientists, and citizens.

Revising Institutional Architectures and Technological Sovereignty The regulation of frontier AIs will necessitate a profound revision of existing institutional architectures, both nationally and internationally. The speed of these technologies' evolution often makes traditional legislative approaches too slow and rigid. It is therefore crucial to develop "agile" regulatory frameworks, allowing for rapid adjustments based on technological advancements and emerging risks. Technological sovereignty is also at stake.

The dependence of many countries on a small number of dominant actors in the field of AI, primarily American and and Chinese, raises concerns about competition, national security, and strategic autonomy. The development of national or regional capacity to design, develop, and regulate its own AIs is essential to avoid a new form of technological colonialism, as highlighted by the European Commission in its AI strategy (2020), aiming to strengthen the EU's digital sovereignty and "shape the future of the digital age." The Challenges of Multi-Level Governance The governance of frontier AIs must operate at several levels.

At the national level, states must adopt clear laws and regulations, allocate sufficient resources for AI safety research and surveillance, and train experts. At the regional level, entities like the European Union can play a pioneering role by establishing high standards, as illustrated by the AI Act, which could become a regulatory export model, similar to the GDPR on data protection.

At the international level, the creation of a global agency like the GAIA, combined with multilateral treaties and agreements, is indispensable to harmonize approaches and avoid "regulatory havens." This agency should have significant means of action, including investigative capabilities and the imposition of sanctions, to ensure compliance with its standards. The inherent complexity of AI systems and their high potential for transformation demand unprecedented collaboration among states, the private sector, civil society, and academia. The challenge is to ensure that the power of frontier AIs serves human progress, while respecting ethics and fundamental rights.

Part III — The Six Institutional Pillars Chapter 19 Pillar 1 — Indexed Evolutionary Constitution (Principle) The Architectonics of an Indexed Evolving Constitution: Redefining Sovereignty in the Age of the Anthropocene. The concept of an indexed evolving constitution stands as a counterpoint to established legal and political paradigms which, shaped by the Enlightenment and industrial modernity, have too often dissociated positive law from its ecological substrata.

It posits a refoundation of the social and environmental contract, where the legitimacy of norms is tethered not only to the consent of the governed but also to the explicit recognition of the planet's biophysical constraints and opportunities. The challenge is to transmute constitutional law, an instrument par excellence of stability, into a mechanism for dynamic adaptation in the face of accelerated changes in the Earth system. Bruce Ackerman, with his theory of "We the People" (1991), highlighted the capacity of constitutions to evolve through moments of substantial revision, often in response to major crises. However, this evolution remains fundamentally endogenous and anthropocentric.

Biophysical indexing proposes to partially externalize the referential of legitimacy, by anchoring constitutional articles to objective and verifiable indicators of the planetary "budget" — or the life-support systems of the biosphere. This is not merely an addition of environmental provisions, in the manner of the French Environmental Charter of 2004, but a structural imbrication redefining the conditions for the exercise of sovereignty. The Epistemological and Legal Foundations of Constitutional Indexing. The recognition of the "rights of the Pachamama" by the Ecuadorian Constitution of 2008 constitutes a fundamental milestone in this exploration.

Article 71 states: "Nature or Pachamama, where life is reproduced and realized, has the right to the integral respect of its existence and to the maintenance and regeneration of its life cycles, its structure, its functions and its evolutionary processes." This provision marks an epistemological rupture by granting legal personality to non-human entities, reversing the secular logic of nature as a mere object of property or a resource to be exploited. It paves the way for a legal subjectivation of the environment, a necessary condition for its effective integration into the hierarchy of norms.

However, the Ecuadorian experience, though pioneering, reveals the limits of an overly general formulation. The absence of precise application criteria and independent monitoring bodies has hampered the full effectiveness of these rights in practice, confronted by the persistence of powerful economic interests. Indexing proposes to overcome this difficulty by directly linking the normative framework to quantifiable thresholds, derived from Earth system science. The aim is to transform "Pachamama" from a philosophical concept into a measurable and legally enforceable referential instance.

Hans Jonas's thought, particularly in "The Imperative of Responsibility" (1979), provides the essential ethical framework for this approach. His maxim "Act so that the effects of your action are compatible with the permanence of a genuinely human life on Earth" translates into constitutional language as the obligation not to compromise the survival conditions of future generations. Biophysical indexing is nothing other than the attempt to objectify, at the institutional level, this imperative of intergenerational and interspecies responsibility. The Materiality of Indicators: Between Science and Sovereignty.

The effectiveness of an indexed evolving Constitution rests on the soundness and accessibility of biophysical indicators. This data must be publicly available, verifiable, and sourced from recognized and independent scientific institutions. The concept of "planetary boundaries," developed by J. Rockström et al. (2009) in "Nature," offers a relevant methodological framework. This work identifies nine critical thresholds, the transgression of which risks compromising the stability of the Holocene, the relatively stable geological epoch that allowed the development of human civilizations.

Among these limits, four are now considered to have been crossed globally: climate change (CO2 concentration reaching 424.47 ppm in April 2024, source NOAA), biosphere integrity (species extinction rate 100 to 1000 times higher than the background rate, source IPBES 2019), biogeochemical flows (nitrogen and phosphorus flows), and novel entities (chemical pollutants, plastics). The integration of these thresholds, or their regional derivatives, into the heart of the Constitution, via alert mechanisms and the activation of specific clauses, confers predictability and automaticity to public action. Indexing Mechanisms and Normative Implications. Indexing can take various forms.

One of the most direct consists of inserting articles whose application is subject to the state of an indicator. For example, an article decreeing the unconstitutionality of any law or public investment project exceeding a defined carbon budget, which would itself be indexed to the achievement of a global warming threshold (for example, +1.5°C compared to the pre-industrial era, as stipulated in the Paris Agreement of 2015).

If the CO_2 concentration exceeds a critical threshold (for example, 450 ppm, a threshold often associated with 2°C), emergency measures, pre-defined constitutionally, would be automatically triggered, sometimes circumventing ordinary legislative processes in case of blockage. Another modality would involve indexing fundamental rights and freedoms to ecological conditions. The right to a healthy environment, for example, could be defined more prescriptively: a threshold of air quality below 5 µg/m3 for PM2.5 (WHO recommendation) could trigger measures prohibiting certain industrial activities or traffic.

This means that the exercise of certain individual or collective rights would be mediated by the capacity of the biophysical system to sustainably support this exercise. This implies a reinterpretation of the hierarchy of norms in light of ecological imperatives. These mechanisms are not intended to create a cold and dehumanized technocracy. On the contrary, they aim to offer an objective framework for democratic deliberation, recalling the "laws of physics" that cannot be abrogated by a majority vote. The goal is to politicize scientific facts by integrating them into the supreme legal order, thereby forcing public and private actors to contend with the materiality of the world.

This does not diminish the legitimacy of political choices but constrains them to operate within a defined biophysical space, as Nicholas Georgescu-Roegen had already highlighted in "The Entropy Law and the Economic Process" (1971). The Reimagining of the Principle of Subsidiarity and the Stakes of Global Governance. National-level constitutional indexing cannot ignore the transnational nature of ecological challenges. Climate change, biodiversity loss, and ocean pollution are phenomena that transcend state borders. Consequently, the principle of subsidiarity must be rethought in light of ecological interdependencies.

Indexed national Constitutions must provide for supranational coordination mechanisms, even transfers of competence, so that national rules are congruent with global objectives. A critical biophysical indicator for France, for example, could be the state of biodiversity in the Mediterranean or the quality of the Rhine waters, which impacts several nations. A supranational constitutional entity, or a convergence of national laws on common biophysical parameters, is therefore the horizon of such an approach.

The articulation between international environmental law (for example, the Convention on Biological Diversity of 1992 or the Stockholm Convention on Persistent Organic Pollutants of 2001) and domestic constitutional law thus becomes a structural requirement, not a mere public policy option. Democratic Legitimacy in the Face of the Ecological Imperative. The question of democratic legitimacy is central. Indexing, by its heteronomous nature (indicators are established by scientific experts), can be perceived as a restriction of popular sovereignty. However, it should be emphasized that scientific choices are not verdicts that annihilate the political sphere.

They define the boundaries within which political debates must operate. Democratic deliberation remains crucial for deciding how to achieve these objectives, what sacrifices to make, and how gains should be distributed. The indexed evolving constitution is not a technocratic system, but a framework that disciplines political power toward permanence and ecological solidarity. The sovereign people retain the capacity to amend the Constitution, but the revision itself should take into account the feedback from biophysical indicators. This implies a thorough civic and ecological education of citizens, an "ecologization of mindsets" to borrow Michel Serres's expression.

Without a shared understanding of biophysical stakes, the social acceptance of such a Constitution would be compromised. Article 11 of the French Constitution, allowing for citizen-initiated referendums, or Article 88-6, relating to citizen participation in lawmaking and public policy evaluation, offer precedents for the integration of such deliberations. The aim is to ensure that the "voice of the Earth" (as ancient expressions in some traditional cultures put it) resonates through democratic institutions, and not beyond them. Practical Challenges and the Need for Robust Institutional Infrastructure.

The implementation of an indexed evolving constitution raises considerable practical challenges. The first is that of data stability and reliability. Scientific indicators evolve, become more precise, and sometimes redefine themselves. The Constitution must therefore provide for mechanisms of "scientific monitoring" and adaptation of thresholds, without falling into detrimental normative instability.

An Independent Constitutional Commission for Planetary Boundaries, composed of experts chosen for their competence and integrity, could be tasked with updating and interpreting these indicators, acting as a scientific "trusted third party." A second major challenge concerns the articulation between constitutional norms and ordinary law. Once a constitutional article is indexed to a biophysical threshold, any legislation or public policy that contradicts it would see its legality questioned. This requires a true revolution in legal engineering, with systematic "biophysical" impact studies prior to any major decision, modelled on environmental impact studies but with superior legal force.

Constitutional courts would be called upon to play an increased role, acting as the "guardians of planetary thresholds." The Horizon of a New Conception of the State: The Ecological Guardian State. The advent of an indexed evolving Constitution marks the transition towards an "ecological guardian State," where the primary function of public power is no longer merely to ensure social order and economic prosperity according to anthropocentric criteria, but to guarantee the permanence of the biophysical conditions for that prosperity and order. It is a State that acquires an intrinsic ecological consciousness, beyond political alternations and sectoral pressures.

This implies profound reforms of public administrations, the training of civil servants in Earth system sciences, and the integration of long-term ecological foresight into all public policies. The State budget, for example, could be constitutionally indexed for a significant portion to the achievement of ecological restoration or decarbonization objectives. These systemic transformations, of a magnitude comparable to those experienced by welfare states in the 20th century, are the price to pay to reconcile the political Leviathan with the biosphere from which it derives and upon which it depends, recalling Arne Næss's vision (1973) and his concept of deep ecology.

The project of an indexed evolving Constitution is not a distant utopia, but a concrete proposal to reformulate law and politics in light of the ecological imperative. It is an approach that, while drawing on the strongest legal traditions (the hierarchy of norms, constitutional review), reinvents them to address Anthropocene challenges. It invites us to move beyond the illusion of unlimited human sovereignty and to build institutions for a sustainable coexistence with living beings.

The credibility and urgency of such an approach are amplified by the scientific projections of the IPCC (2023 report), which allocate an extremely narrow window of action to keep global warming below 1.5°C to stabilize the climate system. Chapter 20 Pillar 1 — Automatic Review Mechanism Anthropogenic Fallibility and Planetary Boundaries: An Imperative for Constitutional Revision The Anthropocene, a concept popularized by Paul Crutzen and Eugene Stoermer in 2000, denotes a new geological epoch where human activity has become the dominant force shaping the Earth's environment.

This qualification is not merely a chronological periodization; it reveals an unprecedented qualitative transformation of the planet's biogeochemical systems, the systemic repercussions of which threaten the stability of conditions necessary for the perpetuation of human societies. The recognition of this geological era, endorsed by numerous scientific works, particularly those in Stratigraphy and Geology, necessitates a profound re-evaluation of the normative and institutional frameworks that govern collective action.

The pioneering work of the Stockholm Resilience Centre, as early as 2009, identified nine planetary boundaries, or instability thresholds, beyond which the risk of abrupt and irreversible environmental changes drastically increases. Among these, climate change, loss of biodiversity, and biogeochemical cycles (nitrogen and phosphorus) have already been crossed, accentuating the urgency of a proportionate institutional response. The persistence of legal and political frameworks unsuited to this systemic reality leads to an exponential accumulation of risks, highlighting the impasse of linear governance in the face of non-linear phenomena.

The constitutionalization of environmental protection, though progressive since the 1970s (e.g., the Portuguese Constitution of 1976 or the French Environmental Charter of 2005), has often produced only fragmented and asymmetrical protection. The principles of integration or prevention, when enshrined, struggle to constrain public policies still largely dominated by short-term economic imperatives. This structural inadequacy calls for a mechanism of constitutional revision that is not solely dependent on majority political will, but that is activated *ipso facto* in response to objective signals of exceeding ecosystem carrying capacities.

The Substantial Nature of Thresholds and the Necessity of Exogenous Determination The definition of critical thresholds cannot be left to the discretion of national legislative bodies. The risk of regulatory capture, political instrumentalization, or dilution of objectives would be too high, compromising the very effectiveness of the mechanism. It is imperative that these thresholds be established on the basis of robust international scientific consensus, supported by binding multilateral treaties, thereby guaranteeing their epistemic legitimacy and universal scope.

The Paris Agreement of 2015, though imperfect, laid the groundwork for global climate governance by setting a target to limit warming to "well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C". This type of international agreement, ratified by 195 parties, offers a precedent for the recognition and operationalization of binding environmental thresholds.

In this case, thresholds relating to atmospheric concentrations of greenhouse gases (e.g., 424 ppm of CO2 in April 2024 according to NOAA) or to biodiversity loss (e.g., the 2019 IPBES report estimating that one million species are threatened with extinction) must be formalized at this supranational level. A specific plurilateral treaty could be designed to establish a global reference framework for planetary boundaries, with measurable indicators and a monitoring methodology approved by an independent expert panel, modeled on the Intergovernmental Panel on Climate Change (IPCC).

This treaty would function to trigger the automatic revision mechanism in signatory states as soon as a threshold is crossed or its exceedance is imminent and scientifically verified. This approach allows for the depoliticization of alarm determination while safeguarding the sovereignty of nations in institutional responses. The Triggering of the Mechanism: From Scientific Alert to the Imperative of Deliberation When a critical threshold, as defined by the international treaty, is officially crossed or when the imminent risk of its exceedance is confirmed by the designated scientific body, a constitutional revision mechanism is automatically triggered.

This triggering is not optional; it constitutes a legal obligation of the states signatory to the treaty, falling within the logic of the "duty to protect" present and future generations, as theorized by many authors, including Edith Brown Weiss (1989) with her concept of intergenerational "trusteeship". This mechanism differs from classical constitutional revision procedures, often initiated by the executive or legislative power and requiring qualified majorities. It refers here to a protection imperative triggered by raw facts, empirical data related to the state of the Earth system, attesting to an existential threat or irreversible damage.

The objective is to short-circuit political inertia and power games that can delay or prevent the adoption of urgent and necessary measures. The crossing of the threshold must be communicated transparently by the international scientific body to the legislative, executive, and judicial powers of each signatory state, as well as to the public. This communication must include a detailed assessment of the implications of the threshold exceedance on natural and human systems, emphasizing the urgency of the situation.

A reasonable transition period, for example, six months, could be allocated to allow institutions to acknowledge the situation and prepare for the convocation of the "Deliberative Chamber of Planetary Boundaries." The Deliberative Chamber of Planetary Boundaries: A New Form of Constitutional Democracy The triggering of the mechanism must imperatively lead to the convocation of a "Deliberative Chamber of Planetary Boundaries," a randomly selected citizens' assembly, endowed with limited but substantial constituent powers.

Inspired by the successful experiences of the Citizens' Climate Convention in France (2019-2020) or the Citizens' Assembly in Ireland (2016-2018), its role is to propose legislative modifications and, if necessary, constitutional ones, aimed at bringing the State back below the critical threshold. This model of citizen deliberation by random selection aims to counteract the intrinsic biases of classical representative systems, such as pressure from interest groups, short-term electoral logic, or the lack of scientific expertise among elected officials.

Random composition, coupled with stratification to ensure socio-demographic representativeness, allows for a "mini-public" capable of grasping complex issues, listening to experts, and deliberating disinterestedly for the general and long-term interest. The French experience demonstrated that after 147 days of work, the 150 citizens formulated 149 structural proposals, 146 of which were deemed "admissible" by the government. The powers of this chamber must be precisely defined. It is not intended to draft a constitution *ex nihilo*, but to target specific articles of laws and the Constitution that hinder the achievement of sustainability goals.

Its proposals must be directly submitted to a referendum without prior amendment by Parliament or the government, thereby guaranteeing the autonomy and integrity of its work. This procedure ensures that the proposals formulated are the result of informed citizen deliberation and not a diluted political compromise. The Exclusive Prerogatives of the Deliberative Chamber The Deliberative Chamber must have the exclusive mandate to propose legislative and constitutional measures aimed at responding to the transgression of the planetary boundary.

This may include: the revision of constitutional articles relating to property rights (e.g., Article 17 of the Declaration of the Rights of Man and of the Citizen of 1789), to freedom of enterprise (e.g., jurisprudence of the French Constitutional Council recognizing this freedom as a fundamental principle) to incorporate imperative environmental constraints; the introduction of new constitutional principles (e.g., recognition of nature as a subject of law, rights of future generations); or the definition of new obligations for public authorities.

It could also recommend the creation of new institutions (e.g., a High Council for Planetary Boundaries) or the modification of the prerogatives of existing institutions to integrate the consideration of ecological limits more systemically into public decision-making. The work of John Dryzek (2000) on deliberative democracy underscores the importance of this type of body in strengthening the legitimacy and effectiveness of public policies in the face of complex and controversial issues. The Chamber's proposals, once validated, are submitted to a popular referendum. A "yes" vote in the referendum implies the immediate adoption of the proposed measures.

This ultimate democratic step confers maximum legitimacy on the reforms and ensures citizen ownership of the solutions, making their implementation more resilient to eventual political or sectoral resistance. This represents a form of democratic innovation that combines scientific expertise, citizen deliberation, and popular sovereignty to address the challenges of the Anthropocene. Constitutional and Legal References: A Precedent for Ecosystem Protection While the automatic review mechanism is innovative, it is part of a growing global constitutional and jurisprudential trend recognizing the intrinsic value of the environment and the need for its protection.

The 2008 Constitution of Ecuador was a pioneer in granting rights to Nature, conferring on Pachamama, Mother Earth, the right "to integral respect for its existence and to the maintenance and regeneration of its life cycles, its structure, its functions and its evolutionary processes" (Art. 71). This precedent opens the way for a legal subjectivation of ecosystems, transcending the anthropocentric vision of law. Beyond the rights of nature, international jurisprudence is beginning to integrate environmental imperatives more prominently.

The 1996 advisory opinion of the International Court of Justice on the legality of the threat or use of nuclear weapons recognized that "the environment is not an abstraction but represents the essential framework of life, whose quality and health condition human well-being." This recognition, however limited, highlights the growing awareness of the deep interdependencies between human societies and their environments. In domestic law, various initiatives demonstrate the increasing integration of ecological issues.

France, with its 2005 Environmental Charter (integrated into the block of constitutionality), enshrines the precautionary principle (Art. 5) and the right to live in a balanced environment respectful of health (Art. 1). Although its application has often been deemed incomplete by legal scholars, it constitutes a foundation upon which to build more stringent measures. The German Constitution, through Article 20a introduced in 1994, obliges the State to protect the "natural bases of life." These examples, despite their limitations, show an evolution of constitutional law towards greater consideration of ecological imperatives.

These national and international legal developments provide a basis from which to construct an automatic review mechanism. The transgression of planetary boundaries is no longer merely a scientific fact, but a legal alert whose disregard by the State could trigger its liability, even that of its leaders, following the reasoning deployed by "climate cases" (e.g., Paris Court of Appeal, 2023, condemnation of the State for climate inaction). The step to be taken is that of an objectification and automatization of this responsibility through a constitutional mechanism.

Sovereignty Redefined: Between National Autonomy and Global Ecological Constraint The automatic revision mechanism, by its binding and exogenously triggered nature, invites a rethinking of the notion of national sovereignty in the face of the reality of planetary boundaries. Traditionally, sovereignty is perceived as the absolute and perpetual power of a Republic, according to Jean Bodin's (1576) definition in "The Six Books of the Commonwealth." However, the transnational challenges of the Anthropocene demonstrate that unlimited sovereignty over a territory can no longer be exercised without considering global ecological interdependencies.

Sovereignty must no longer be interpreted as freedom to act without external constraints, but as a nation's capacity to ensure the well-being of its citizens within the limits of a stable planetary system. This perspective leads to "responsible" sovereignty, where internal autonomy is conditioned by adherence to universal ecological norms. The reference to an international treaty for determining thresholds is not an abdication of sovereignty, but a form of enlightened sovereignty, recognizing that the threat is global and requires a coordinated response.

This paradigm of responsible sovereignty echoes the work of Jean-Jacques Rousseau, who, without anticipating contemporary ecological challenges, emphasized the subordination of particular will to the general will and the common interest deduced from the "Social Contract" (1762). Applied to the current context, the planetary general will, formulated by international scientific consensus on ecological limits, should prevail, at least for the triggering of corrective actions. The specificity of the responses provided, however, would remain within the purview of the concerned State, thus ensuring respect for socio-cultural and economic particularities.

The automatic revision mechanism is not a standardization of policies, but a harmonization of objectives and a shared recognition of the urgency. It offers a framework for each nation to adapt to ecological constraints in its own way, while respecting an imperative of global justice. Citizen deliberation, rooted in the national context, would guarantee this specific adaptation, thereby avoiding a top-down imposition of solutions that are often inappropriate or unacceptable. This represents a reconciliation between national democratic legitimacy and planetary ecological necessity.

Chapter 21 Pillar 1 — Legal architecture and hierarchy norms The normative foundation of global ecological law The establishment of ecological law on a planetary scale requires deep reflection on its integration into existing legal architecture, characterized by a plurality of normative orders. The current fragmentation, between national sovereignties and lacunae in international law, constitutes a major impediment to the effective protection of ecosystems and biophysical processes essential to life. The challenge is therefore to design a structure capable of granting the ecological imperative the necessary primacy, without annihilating national legal particularities.

International law doctrine has long struggled to fully integrate the environmental dimension, often confined to an annex or boilerplate clause. The emergence of concepts such as the "Responsibility to Protect" (R2P), initially limited to human rights, or the idea of "common heritage of humanity" for spaces like the high seas or outer space, has not translated into an equivalent recognition of planetary natural systems. The 2015 Paris Agreement on climate, for example, marked a step forward, but its nature as a non-binding inter-state agreement on reduction targets, evidenced by the absence of substantial sanctions in case of non-compliance, reveals the limits of this approach.

Constitutional Primacy and Harmonization Challenges The integration of ecological principles into national constitutions represents a first essential axis. Several states have already taken this step. Ecuador, in 2008, was the first to recognize rights for nature ("Pachamama") in its Article 71, thereby granting legal personality to ecosystems. France, by inserting the Environmental Charter into the constitutional block in 2005 (Constitutional Law No. 2005-205 of March 1, 2005), demonstrates a desire to elevate environmental protection to the rank of fundamental principles, although its effective scope remains debated in jurisprudence.

However, these national initiatives, however laudable, are not sufficient to establish global coherence. The principle of state sovereignty, enshrined in Article 2 § 1 of the United Nations Charter (1945), maintains a pre-eminence that grants states considerable latitude in the interpretation and application of environmental norms. Disparities in terms of protection standards, implementation capacity, and political will generate "environmental dumping" or ecological "grey areas," undermining collective efforts.

A first approach could consist of establishing a set of fundamental ecological principles, similar to the 1972 Stockholm Declaration or the 1992 Rio Declaration, but with the legal force of *jus cogens*. *Jus cogens*, or peremptory norms of general international law, as defined by Article 53 of the 1969 Vienna Convention on the Law of Treaties, are norms accepted and recognized by the international community of States as a whole as norms from which no derogation is permitted. This qualification would confer absolute hierarchical superiority on ecological principles over any other international convention or custom.

The recognition of the rights of nature as *jus cogens* would imply, for example, that the massive destruction of a vital ecosystem – an ecocide – be considered an international crime, comparable to crimes against humanity. The "Global Pact for the Environment" project, championed by France since 2017, although ambitious, has not yet reached this level of binding force, encountering resistance from several states.

An International Covenant on Ecological Rights: Outline of a global normative architecture The proposal for an International Covenant on Ecological Rights (ICER) is inspired by the model of international human rights covenants (International Covenant on Civil and Political Rights, ICCPR, and International Covenant on Economic, Social and Cultural Rights, ICESCR, adopted in 1966). This ICER would be a binding, universal multilateral treaty, establishing a structured legal framework for the protection of ecosystems and the guarantee of a healthy environment.

This Covenant would not replace existing instruments, but would consolidate and complement them, articulating ecological rights and duties around fundamental principles. It should notably: ■ Affirm the recognition of nature as a subject of law, or at least as an entity endowed with legally protected interests, following concepts such as "Common Biological Heritage" developed by Vandana Shiva (2014) or "Law of the

Living" by Philippe Descola (2005). ■ Define a fundamental intergenerational right to a healthy and stable environment, including the protection of biodiversity, climate, the water cycle, and soils.

This right would not be solely anthropocentric, but would also consider the intrinsic value of ecosystems. ■ Establish the obligations of State Parties, not only to refrain from causing transboundary environmental damage (principle *sic utere tuo ut alienum non laedas*), but also to act positively for the regeneration and restoration of degraded environments. This would imply an obligation of result in terms of ecological transition. ■ Provide for an international environmental liability mechanism, going beyond mere compensation for material damage to include compensation for irreversible ecological damage and future foreseeable damage.

The ICER should also integrate the notion of environmental equity. According to OECD data (2020), low-income countries are disproportionately affected by environmental degradation, while their historical contribution to greenhouse gas emissions is only 3% compared to 97% from industrialized countries (United Nations Environment Programme, 2021). The ICER should therefore institutionalize the principle of "common but differentiated responsibility," already outlined in Rio, by adding mechanisms for technology transfer and funding to support the transition of less developed nations.

Articulation with national law and *jus cogens* The ICER, conceived as a major treaty, should strive for the qualification of *jus cogens* for some of its fundamental principles.

Article 53 of the Vienna Convention on the Law of Treaties stipulates that a *jus cogens* norm is "accepted and recognized by the international community of States as a whole as a norm from which no derogation is permitted." If principles such as the prohibition of ecocide, the right to life in a healthy environment, or the preservation of biodiversity as a common heritage were to attain this status, they would be binding on all States, whether or not they are signatories to the Pact, and would take precedence over any contrary national or international provision. This supremacy would imply an obligation for State Parties to adapt their domestic law and constitution to these principles.

The mechanism for receiving international treaties into domestic legal order varies (monism, dualism), but the direct incorporation of the ICER and its *jus cogens* principles should be the norm. In case of conflict, the primacy of imperative international law would prevail, subordinating national laws and constitutions. This would provide a solid legal basis for challenging national projects destructive to the environment, even if they are legal under the domestic law of the country concerned. However, the increasing obsolescence of *jus cogens* in international jurisprudence, despite its theoretical importance, raises questions about its ability to assert itself in practice.

The International Court of Justice (ICJ) has rarely invoked it directly, and its definition remains subject to interpretation. An ambitious ICER should therefore be accompanied by strong political will from States and audacious jurisprudence for this ambition not to remain a dead letter. A World Ecological Court: extension of international justice The effectiveness of global ecological law inherently depends on the existence of a robust and independent judicial system. The idea of a World Ecological Court (WEC) falls within this logic, extending and specializing the mandate of existing institutions, particularly the International Court of Justice (ICJ).

The ICJ, despite its essential role in resolving inter-state disputes, suffers from several limitations in environmental matters. Its operation, based on the consent of states, makes it difficult to intervene in cases of environmental transgression that are not submitted by the parties. Its competencies are also limited to disputes between states, excluding litigation brought by non-governmental organizations or individuals, who are nevertheless major actors in the ecological cause. Even in the rare environmental cases it has dealt with, such as the *Gabcikovo-Nagymaros* case (Hungary v. Slovakia, 1997) or the *Pulp Mills on the River Uruguay* case (Argentina v.

Uruguay, 2010), the ICJ has favored the interpretation of existing treaties rather than the pronouncement of substantial ecological principles. The establishment of an independent World Ecological Court, or the significant extension of the ICJ's powers through an amendment to its Statute (Article 109 of the United Nations Charter), is indispensable.

This Court would be mandated to: ■ Adjudicate States that have failed to meet their obligations under the International Covenant on Ecological Rights and other relevant instruments, particularly principles derived from ecological *jus cogens*. ■ Examine applications filed by NGOs with consultative status at the UN, by entities representing indigenous peoples, or even by "defenders of nature's rights" in the name of ecosystems themselves. ■ Address cases of ecocide, as defined by Polly Higgins (2013), when massive and systemic environmental destruction causes severe and lasting harm to a territory or a population.

The proposed amendment to the Rome Statute of the International Criminal Court (ICC) to include ecocide is a significant step in this direction, although it only concerns individuals. A WEC would address state responsibilities. ■ Develop coherent international environmental jurisprudence, contributing to consolidating and clarifying the body of ecological norms. Nature and powers of the WEC The WEC could be constituted either as an entirely new body, implying the creation of an *ad hoc* constituent treaty, or as a specialized chamber within the existing ICJ, modeled on the European Court of Human Rights in relation to the Council of Europe.

Integration into the ICJ would offer the advantage of capitalizing on its legal expertise, legitimacy, and infrastructure. However, the creation of a distinct entity could allow for greater flexibility and more advanced specialization. Its powers should extend to transboundary environmental disputes, but also to serious breaches of national ecological obligations with global repercussions (massive deforestation of the Amazon, depletion of water tables impacting global hydrological cycles).

It could be granted advisory powers to issue opinions on complex legal questions, at the request of the United Nations General Assembly or specialized international organizations, which would strengthen its ability to guide the interpretation and application of law. The financing of such an institution would be a crucial issue. It could be ensured by mandatory contributions from UN member states, a percentage levied on the fines and reparations it pronounces, or via a global green fund specifically dedicated to environmental judicial infrastructure, funded by taxes on pollution or environmentally damaging transactions.

According to UNEP (2021), biodiversity funding needs are around $700 billion per year, of which only $100 billion are met. A WEC would require a minimal fraction of these amounts to ensure effective application of the rules. The principle of non-regression and intergenerational justice The principle of non-regression in environmental law, although still of customary value in many legal systems, is an essential pillar for securing achievements in protection.

It means that a protective environmental norm, once established, cannot subsequently be lowered without an imperative and proportionate justification, linked to superior imperatives of general interest and without altering the protection objective. This principle is enshrined in Article 3 of the French Environmental Charter and is recognized in several judgments of constitutional or administrative courts, such as the French Conseil d'État (Order of June 12, 2020, *Commune de Grande-Synthe*). The integration of this principle into the ICER, and its elevation to the rank of ecological *jus cogens*, would guarantee constant and irreversible progress in environmental protection.

States would be constrained to preserve not only current levels of protection, but also to continually improve them, under penalty of having their legislation annulled or their liability engaged by the WEC. This principle is intrinsically linked to intergenerational justice, defined as the obligation not to compromise the ability of future generations to meet their own needs, while ensuring an equitable share of resources and ecosystem services. The German Federal Constitutional Court, in its decision of March 24, 2021, on the climate protection law, emphasized that "the fundamental rights of future generations are also affected" by current climate policies.

The court demanded more ambitious CO2 reduction targets, stating that deferring efforts to future generations limited "their constitutionally guaranteed freedom." Intergenerational rights and duties The ICER would formalize these intergenerational rights, granting future generations the status of "creditor" of environmental protection. This could translate into: ■ The recognition of a "right to environmental continuity," guaranteeing access to undegraded natural resources and functional ecosystems. ■ The establishment of a legal "capacity to act" for future generations, which could be exercised by representatives or "guardians of nature" before the WEC.

The example of the *Urgenda Foundation v. Netherlands* case (2019), where an NGO sued the Dutch state for climate inaction on behalf of present and future citizens, illustrates the feasibility of such actions. ■ "Intergenerational trust" mechanisms: funds or natural resources (primary forests, deep waters) could be placed under international fiduciary management, in order to protect them from short-term exploitation and ensure their sustainability for future generations. These mechanisms would strengthen the efficiency of ecological law by projecting it beyond immediate political time.

The concept was, for example, considered by Hans Jonas in *The Imperative of Responsibility* (1979), where he raised the question of an ethics for the future and a "heuristic of fear" to ensure the survival of future generations. An ICER and a WEC would be the legal instruments of this ethics. The question of financing ecological obligations The implementation of obligations stemming from global ecological law requires considerable financial resources, especially for developing countries. The absence of adequate financing mechanisms has historically hampered the realization of environmental commitments.

The World Bank estimates that approximately $4,500 billion per year would need to be invested by 2030 to achieve the Sustainable Development Goals, a significant portion of which is linked to climate and the environment. An ICER should therefore institute innovative and mandatory financing mechanisms, differing from current voluntary contributions. These could include: ■ A global carbon tax, a portion of which would be allocated to a Global Ecological Fund administered by the WEC or a related body.

OECD estimates (2021) suggest that a carbon tax of $100 per ton could generate considerable revenues, in the order of several trillion dollars per year globally. ■ A financial transaction tax (FTT) or a tax on capital gains of companies whose activities have a significant negative environmental impact. Around 60% of global biodiversity has been lost since 1970 (WWF, 2020), largely due to economic activities. ■ A "green debt" mechanism or debt cancellations for countries resolutely committed to ecological transition and ecosystem protection.

The public debt of some countries represents 80 to 200% of their GDP, limiting their investment capacity in ecology. ■ The "polluter pays" principle, already recognized in international law, should be extended and strengthened, with dissuasive financial sanctions against polluters, whether states, companies, or individuals, and whose revenues would feed the Ecological Fund.

These financial mechanisms would not only support protection and restoration efforts, but also compensate for "loss and damage" suffered by the most vulnerable countries and communities facing the impacts of climate change and environmental degradation, according to the principle of "climate justice." The concept of "payments for ecosystem services" (PES) could also be developed internationally, financially valuing the ecological functions provided by certain ecosystems and the communities that preserve them.

Chapter 22 Pillar 2 — 200-Year Multi-Generational Trust (Principle) Intergenerational Trust as a Structuring Principle for Earth Rights The protection of non-renewable natural resources, fundamental common goods for human survival, demands an innovative legal architecture that transcends the usual temporality of property and usage regimes. The integration of the trust, a legal instrument from both civil and common law, offers a pathway to establish enduring and shared management.

This approach draws inspiration from indigenous visions, particularly the Iroquois doctrine of the Great Law of Peace, which as early as the 13th century (according to recent datings, rather than the traditionally accepted 15th century), articulated the duty to consider the impact of decisions on the seven future generations. This long-term principle resonates with contemporary ecological imperatives. The trust, by separating legal ownership (held by the trustee) from beneficial ownership (held by future generations), creates a framework where resources are not alienable in the short term for immediate gains.

It institutes a fiduciary responsibility, obliging managers to act in the superior and long-term interest of the beneficiaries, meaning humanity in its temporal continuity, and by extension, all ecosystems essential for its subsistence. The objective is not to sacralize the status quo, but to embed the management of critical resources within a perspective of dynamic conservation and reasoned use, compatible with the principle of non-irreversible degradation. The trustee would then be entrusted with a mission to maintain the productive or regenerative capacity of the asset, beyond its mere exploitation.

Conceptual Distinction Between Classic Trust and Bicentennial Ecological Trust The classic trust, as defined by Article 2012 of Quebec's Civil Code (1994) or the *Trustee Act 2000* in the United Kingdom, generally relies on identifiable beneficiaries and a defined term, often linked to natural persons. The bicentennial ecological trust proposed here distinguishes itself by its temporal horizon extended to two centuries and the nature of its beneficiaries: all future human generations and non-humans, whose dependency on the resource is irrefutable. The 200-year horizon is not arbitrary.

It corresponds to a significant duration during which the consequences of current actions become manifest and where the natural regenerative capacity is tested by anthropization. Some geochemical cycles, such as the carbon cycle, operate on millennial timescales, but 200 years offers an actionable duration to influence ecological and social trajectories. It is also a period that allows for the integration of technological innovations while protecting ecological achievements.

The resources targeted by this trust are critical non-renewable resources: strategic minerals for the energy transition (lithium, cobalt, rare earths), fossil hydrocarbons (coal, oil, natural gas) whose consumption must be drastically reduced, certain aquifers, and wetlands essential for hydraulic regulation. Criticality is defined by their non-renewability on a human scale and their fundamental importance for maintaining ecosystem services and the capacities of human societies.

From Stewardship to Intergenerational Sovereignty The concept of a bicentennial trust for non-renewable resources is rooted in the premises of environmental law, which, since the Stockholm Declaration (1972) and the Rio Declaration (1992), recognizes the necessity of protecting the environment for the benefit of present and future generations. However, these declarations have often encountered the difficulty of concretely institutionalizing this principle of intergenerational justice in the face of short-term economic pressures. The bicentennial trust provides a robust legal mechanism for this institutionalization.

It transfers decision-making power over these resources out of the sphere of short-term private or public appropriation, placing them under the guardianship of a dedicated entity whose mission is explicit: the preservation of their integrity and their capacity to serve future needs. Trustees, appointed through transparent and diversified processes, would be subject to regular audits, fiduciary responsibility, and sanctions in the event of serious misconduct.

The experience of the National Trust in the United Kingdom, founded in 1895 with the mission of "permanent" conservation of places of historical interest or natural beauty, although its scope is primarily land-based and patrimonial, offers an institutional precedent where heritage is shielded from market fluctuations. More recently, initiatives such as "Predator Free NZ 2050" in New Zealand, aiming at the eradication of certain introduced predators for the protection of indigenous biodiversity, illustrate national conservation projects over significant time horizons, albeit of a different nature.

Principles Governing Management Under Trust Management of resources under a bicentennial trust would be structured around several guiding principles. Firstly, the precautionary principle, as defined in the Convention on Biological Diversity (1992), should guide any decision regarding use or exploitation. In cases of scientific uncertainty about the impact of an activity, abstention would be favored to avoid irreversible damage. This principle is particularly relevant for non-renewable resources whose disappearance or degradation is definitive. Secondly, the principle of subsidiarity should be applied, involving local communities in co-management and monitoring of resources.

Their knowledge of ecosystems and their direct interest in environmental sustainability are invaluable assets. An example is the management of community forests in India, governed by the *Forest Rights Act 2006*, which grants management rights to indigenous and local populations. Thirdly, the principle of transparency and accountability. Trustees' decisions, reports on the state of resources, and the use of funds generated by their limited exploitation should be publicly accessible and subject to independent oversight. This transparency is crucial to ensure the legitimacy and effectiveness of the trust in the long term, thereby avoiding the pitfalls of regulatory capture or corruption.

Economic and Political Stakes of the Transition Towards a Post-Growth Economy The establishment of a bicentennial trust for non-renewable resources necessitates a profound re-evaluation of current economic paradigms, which are centered on unlimited growth and maximum resource exploitation. This approach is part of an ecological economics perspective that recognizes the biophysical limits of the planet, as highlighted by Herman Daly and Joshua Farley in *Ecological Economics: Principles and Applications* (2004). The scarcity of some of these resources is already tangible.

For instance, data from the US Geological Survey (USGS) in 2022 indicates global lithium reserves estimated at about 89 million tons, for a production of 130,000 tons in 2022. If the demand for lithium, driven by the energy transition, continues to increase exponentially, the question of its sustainability will acutely arise in the coming decades. A trust could regulate its extraction and recycling, promoting maximum circularity which is indispensable. Politically, the implementation of such trusts at the national or even supranational level represents a major challenge.

It requires strong political will and broad social acceptance, as it implies a restriction of state sovereignty over certain resources and a limitation of companies' exploitation capacities. This could potentially lead to resistance from dominant economic actors and nations heavily dependent on the export of these resources. Funding and Governance Funding for the bicentennial trust would not solely come from the state.

A hybrid model, combining public endowments, voluntary contributions, and royalties levied on the residual exploitation of resources not subject to the trust (or in limited cases where the exploitation of resources under trust would be authorized under strict conditions), could be envisaged. The example of Norwegian sovereign wealth funds, backed by hydrocarbon revenues, offers an illustration, albeit with different objectives, of the capacity to build funds with an intergenerational purpose.

Governance would require the creation of independent institutions, with boards of directors composed of scientific experts, specialized legal professionals, civil society representatives, and delegates from indigenous and local communities. The legitimacy of these institutions would be reinforced by their pluralistic composition and their autonomy from short-term political and economic powers. John Rawls, in *A Theory of Justice* (1971), insists on the veil of ignorance as a means to establish equitable principles of justice, which implies considering the interests of future generations as if one ignored one's own place in time.

The constitution of this fiduciary architecture could draw inspiration from Christopher Stone's work on the rights of natural entities, initiated in 1972 with his essay "Should Trees Have Standing?". By attributing legal personality to ecosystems or critical resources, the trust would strengthen their capacity to be defended in court, placing their sustainability at the heart of legal and ethical concerns. Ethical and Cultural Implications of Extended Responsibility The bicentennial trust, by extending the notion of responsibility beyond the scale of a human life, raises fundamental ethical questions.

It invites a rethinking of the anthropocentric relationship with nature, to substitute it with a more biocentric or ecocentric vision, where humans are no longer the sole criterion of value. This evolution of thought is in line with currents of environmental philosophy that advocate for the extension of moral consideration to non-humans. This approach also aligns with Edgar Morin's idea of the "planetarization" of responsibility, inviting us to consider the future of humanity within the framework of its Earth-Homeland. It involves cultivating a collective consciousness of belonging to a common destiny and interconnectedness with future generations.

The trust then becomes a concrete instrument to embody this ethic of global and intertemporal responsibility. Culturally, the adoption of such a legal regime could catalyze a profound shift in mentality, valuing sobriety, recycling, and sustainability over unbridled consumption and planned obsolescence. Cultural narratives that cherish preserving heritage for descendants, as is prevalent in many indigenous cultures, could then regain a central place in our industrialized societies. Towards a Constitutionalization of the Trust To ensure the permanence and irreversibility of the bicentennial trust, its most robust legal protection would be an inscription in constitutional law.

Several countries have already constitutionalized the right to a healthy environment, such as Article 36 of the Constitution of Ecuador (2008), which recognizes the rights of Nature itself, or Article 10 of the Portuguese Constitution (1976, revised in 1997), which stipulates the right to a human, healthy, and ecologically balanced living environment and the duty of future generations to defend it. The inscription of intergenerational trust in a state's Constitution or even in an international treaty would remove it from the vagaries of changes in political majority and grant it superior binding force compared to ordinary laws.

It would ensure that the principle of long-term stewardship of critical resources becomes an insurmountable fundamental norm. The approach is bold, but the severity of the current ecological crisis—with, for example, a decrease in biodiversity of approximately 69% for vertebrates between 1970 and 2018, according to the WWF "Living Planet Report 2022"—justifies a radical overhaul of legal frameworks. The bicentennial trust would act as a shield, a constitutional barrier against the irresponsible depletion of our non-renewable natural capital, offering future generations the opportunity to meet their own challenges with intact capabilities.

Chapter 23 Pillar 2 — Governance, Composition, indicators Although the UN system, established in 1945, created a framework for international cooperation, its current structure and decision-making processes are no longer able to effectively address the complexity and interdependence of contemporary ecological and social crises. The Security Council, for example, whose composition reflects a post-World War II balance of power, is often paralyzed by the veto power of its permanent members, as evidenced by regular deadlocks on crucial issues.

State sovereignty, although the foundation of international law, clashes with the biophysical realities of an Earth system where negative externalities know no borders, such as the global dispersion of microplastics or the transboundary migration of atmospheric pollutants. The current development paradigm, rooted in an anthropocentric vision and short-term economic rationality, has led to an unprecedented degradation of ecosystems. Scientific assessments, such as those by the IPCC and IPBES, highlight the accelerating processes of biodiversity erosion and climate change, jeopardizing the stability of habitable conditions for human societies.

The systemic inability to integrate planetary boundaries into political and economic deliberation is a major failure that necessitates a profound institutional overhaul. A reform of global governance: towards ecological and trans-temporal representativeness Contemporary global governance, fragmented and often reactive, no longer responds to the urgency or scale of ecological and social challenges. The multilateral model, though indispensable, suffers from its inability to transcend contingent national interests and integrate a long-term perspective.

The sustainability of socio-ecological systems requires an institutional architecture capable of integrating plural knowledge and representing interests deferred over time. <h3>The Council of Planetary Commons (CPC): deliberation by sortition and scientific expertise</h3> A profound renovation of global governance would require the establishment of a Council of Planetary Commons (CPC), whose legitimacy would no longer rest solely on state representation, but on a dual epistemic and democratic foundation. This Council would be composed, half, of citizens selected by lot on a global scale, following the model of citizen juries or citizen assemblies.

This method, notably popularized by the Citizens' Climate Convention in France (2019-2020), would inject deliberative legitimacy and partly free decisions from partisan pressures and short electoral cycles. Sortition, or stochocracy, was theorized as early as Greek antiquity for its ability to embody direct democracy, and has been rehabilitated by thinkers like Hélena Herman and David Van Reybrouck in "Against Elections: The Case for Democracy" (2016). The other half of the CPC would consist of transdisciplinary scientific experts, selected for their proven contribution to the understanding of Earth systems and socio-ecological dynamics.

These experts would come from disciplines as diverse as climatology, ecology, oceanography, epidemiology, but also social sciences (anthropology, sociology, ecological economics) and philosophy. Their role would be to ensure that deliberations are grounded in biophysical limits and opportunities, by providing systemic assessments and scientifically based projections. This synergy between the experiential knowledge of citizens and formalized scientific expertise is essential to overcome the artificial opposition between democracy and science.

The CPC would have as its main mandate to formulate binding recommendations for member states and international organizations concerning the management of planetary commons (oceans, atmosphere, biodiversity, biogeochemical cycles) and consumption and production trajectories compatible with planetary boundaries. It would be endowed with extended consultative powers and the ability to initiate early warning procedures and to refer matters to the International Court of Justice in cases of proven violation of sustainability principles and intergenerational equity.

The function of future interest simulators (Future Design) Integrating a deep temporal dimension into decision-making is a major shortcoming of current governance. The concept of "Future Design," developed by Japanese economists Tatsuyoshi Saijo and Shunsuke Managi ("Future Design: The New Science of Decision Making for a Sustainable Society," Cambridge University Press, 2018), offers a promising path. This approach consists of introducing "future interest simulators" into deliberative processes, i.e., individuals who, through a process of cognitive decentering, fictitiously assume the responsibility of future generations.

In the city of Yahaba, Japan, for example, citizens were invited to participate in territorial planning workshops by alternately adopting the role of a current citizen and a citizen of 2060. The results showed that participants adopting the future perspective tended to make more sustainable and long-term decisions, transcending immediate interests. The Kochi experiment, conducted by Tatsuyoshi Saijo in 2015, also revealed that adopting a "future generation" role led to choices more oriented towards the common good and resource preservation.

These "Future Design Workshops" could be systematically integrated within the CPC, thus ensuring that deliberations are constantly informed by the very long-term consequences (50, 100, or even 200 years) of present actions. These future interest simulators would be selected from among the CPC members, whether they are chosen by lot or from scientific expertise. Their role would not be to embody an ontology of "future generations," but to make salient and operational the obligations towards them, according to K.E. Boulding's principles on the economics of "spaceship earth" compared to "cowboy economy" ("The Economics of the Coming Spaceship Earth," 1966).

It is about building an ethics of prudence and collective responsibility in the face of global and irreversible risks. Towards a metrology of well-being and ecological resilience Dominant economic indicators, such as Gross Domestic Product (GDP), are measures of the flow of market transactions that reflect neither the depletion of natural capital, nor social inequalities, nor quality of life.

Faced with this metrological inadequacy, there is an urgent need to adopt new evaluation paradigms that explicitly integrate ecological and intergenerational dimensions. <h3>Stocks and flows indicators for natural capital</h3> The transition to an ecological economy requires measuring not just the production of goods and services, but the health and resilience of natural capital stocks on which all human activities depend.

These capitals include: ■ **Terrestrial natural capital**, including forests, fertile soils, freshwater resources, coastal ecosystems. ■ **Marine natural capital**, encompassing oceans, coral reefs, fish stocks, deep-sea ecosystems. ■ **Atmospheric capital**, i.e., the capacity to absorb greenhouse gases and regulate climate. For each of these capitals, it is necessary to develop per capita stock indicators, projected over long time horizons (T+50, T+100, T+200 years). For example, for forests, this would involve measuring forest area and biomass per capita, integrating their role as carbon sinks and biodiversity reservoirs.

This approach would align with Herman Daly's perspective on the sustainable scale of the economy ("Steady-State Economics Revisited," 1991). Beyond stocks, it is imperative to measure the natural regeneration rate of renewable resources, comparing it to extraction and consumption rates. For fish resources, for example, fish biomass must be measured against the reproductive capacity of species to avoid overexploitation. A relevant indicator would be the extraction/regeneration ratio: a ratio greater than 1 would signify unsustainable consumption, drawing on natural capital.

Data from the Food and Agriculture Organization of the United Nations (FAO) indicate that in 2020, 35.4% of global fish stocks were overexploited, illustrating the relevance of such a ratio. Similarly, for non-renewable resources, it would be a matter of evaluating the lifespan of known reserves based on current and projected consumption rates, but also on recycling intensity. Global phosphate reserves, essential for agriculture, are estimated by the US Geological Survey (2022) at 71 billion metric tons, with an annual consumption of approximately 230 million tons, representing a theoretical lifespan of around 300 years without significant recycling or major discovery.

A sustainability indicator should integrate these elements with per capita availability. The example of the *Well-being of Future Generations Act* of Wales (2015) The Welsh approach ("Well-being of Future Generations (Wales) Act 2015") represents a pioneering legislative attempt to integrate intergenerational concerns into public governance. This law, implemented by the Welsh government, requires 44 public bodies, including the government itself, local authorities, and health services, to: 1. Think long term 2. Work in an integrated manner 3. Take a collaborative approach 4. Involve citizens 5. Seek to prevent problems.

The law sets seven long-term well-being goals (e.g., "a resilient Wales," "a prosperous Welsh culture," "a more equal Wales") and introduces the role of a "Future Generations Commissioner," whose mission is to challenge and encourage public decision-makers to act for future generations. The first commissioner, Sophie Howe, served from 2016 to 2023. This example illustrates the possibility of institutionalizing concern for future generations within a national framework, although its long-term impact remains to be fully evaluated and its transposition on a global scale remains a complex challenge.

The Commissioner, independent, issues recommendations and can report to the Welsh Parliament, acting as a "guardrail" mechanism against short-sighted policies. For the financial year 2022-2023, the budget allocated to the Commissioner's Office was £1.1 million, demonstrating a significant financial commitment to this function. Inspired by this approach at the global level, a similar institution could be created within the CPC, endowed with an international mandate and adequate resources to influence the policies of states and multilateral organizations.

Towards indicators of resilience and intergenerational equity Beyond natural resource stocks and flows, it is essential to develop indicators that capture the resilience of socio-ecological systems and the equitable distribution of environmental benefits and costs across generations. Resilience, as developed by C.S.

Holling ("Resilience and Stability of Ecological Systems," 1973), refers to a system's capacity to absorb disturbances and reorganize while maintaining essentially the same function, structure, identity, and feedbacks. <h3>Indicators of ecosystem regulatory capacities</h3> It is not enough to measure the quantity of forests, but their ability to regulate local climate, prevent soil erosion, and harbor biodiversity.

This implies combined indicators, such as: ■ **Habitat fragmentation index**, which assesses the connectivity of ecosystems and their ability to support viable species populations. ■ **Ecosystem productivity**, measured by net primary production, which reflects the biomass generated and the capacity of ecosystems to sequester carbon. ■ **Water and air quality**, with non-exceedance thresholds for critical pollutants, such as fine particulate matter (PM2.5), whose average annual concentration should not exceed 5 µg/m3 according to the WHO

(2021).

These indicators should be regularly updated by independent scientific agencies and be publicly accessible, in order to inform CPC deliberations and evaluate the progress or setbacks of global policies. The absence of such integrated dashboards at the planetary scale is a significant shortcoming. <h3>Indicators of ecological footprint and intergenerational justice</h3> The per capita ecological footprint, which measures the bioproductive area required to support a way of life, is a valuable synthetic indicator developed by Mathis Wackernagel and William Rees ("Our Ecological Footprint: Reducing Human Impact on the Earth," 1996).

It highlights the transgression of planetary boundaries: humanity currently uses the equivalent of 1.75 Earths per year, according to the Global Footprint Network (2023). A global goal would be to reduce this footprint to 1.0 Earth by 2050, an objective that would require drastic reductions in material consumption in high-income countries. For intergenerational equity, environmental liability and asset assessments should be established. The idea is to quantify the ecological debt that the present generation bequeaths to future generations. This would include: ■ **The stock of accumulated carbon in the atmosphere**, which conditions future warming.

In 2023, the atmospheric CO2 stock measured at Mauna Loa exceeded 420 ppm, a level never reached for millions of years. ■ **Nuclear waste**, whose most dangerous components, such as Plutonium-239, have a half-life of 24,110 years, imposing a management burden for tens of thousands of future generations. ■ **Irreversible loss of biodiversity**, difficult to quantify in monetary value but crucial for ecosystem stability. The "Living Planet Report 2022" by WWF indicates an average 69% decline in wild animal populations since 1970.

These composite indicators would enable the CPC to make informed decisions, not only on the sustainability of current uses, but also on the equity of the distribution of burdens and opportunities between generations. The formalization of these indicators, and their recognition in international law, would be decisive steps towards a governance of the planetary common good.

Chapter 24 Pillar 2 — Use Cases: Water, Rare Earths, archives, seeds The Planetary Commons as a Resource for Sovereignty: Beyond Private Property The depletion of resources, the scarcity of certain critical elements, and the intrinsic vulnerability of collective memory confront contemporary legal and economic ordering with unprecedented challenges. The idea of "planetary commons" (Hardin, 1968) needs to be explored beyond state regulations or market dynamics to envision modes of governance and conservation adapted to the scale and irreversibility of the stakes.

It is no longer merely a matter of optimized asset management, but of redefining the principles of sovereignty and intergenerational responsibility. The recognition of the intrinsic value and physical limits of natural resources prompts a revision of the liberal analytical framework, founded on utility maximization and the substitutability of factors of production. Ecological economics (Daly, 1996) highlights the interdependence of human systems and biophysical processes, emphasizing the precautionary principle and epistemological prudence in the face of radical uncertainty.

This imperative for preservation manifests through concrete cases of critical resources whose current management reveals the limits of dominant paradigms. The Failing Governance of Fossil Aquifers Fossil groundwater aquifers, accumulated over millennia, represent non-renewable water reserves on a human timescale. Their overexploitation poses a systemic risk to global water security and the socio-economic stability of affected regions. The Ogallala Aquifer in the

United States, spanning eight Great Plains states, illustrates this problem; its volume decreased by 43.8 km3 between 1950 and 2007, according to the US Geological Survey (McGuire, 2017).

Similarly, the Disi Aquifer, shared between Jordan and Saudi Arabia, is exploited at a rate that far exceeds its natural recharge, estimated at 50 million cubic meters per year, while current pumping exceeds 150 million cubic meters. Extraction infrastructures, the result of massive investments, lock in trajectories of depletion proving politically difficult to alter, illustrating a crushing of the future into the present. The growing water scarcity in these regions fuels latent geopolitical tensions.

International water law, as set forth by the United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses (1997), struggles to apply effectively to these non-renewable transboundary aquifers. The lack of full recognition of their status as a "finite and shared resource" in international arbitrations encourages unilateral extraction, contrary to the principles of intergenerational equity. The establishment of "non-renewable withdrawal right" regimes (Bromley, 1991), based on rigorous stock modeling and binding allocation, could be a way forward.

These mechanisms should incorporate a strong environmental justice component, particularly for local populations and dependent ecological systems, often made invisible by productivist logic. However, institutional inertia and pressure from agricultural and industrial lobbies hinder the adoption of such measures. Rare Earth Elements: Dilemmas of Transition and Geopolitical Dependencies Rare earth elements (REEs) are a group of 17 chemical elements essential to modern technologies, from electric vehicles (neodymium and dysprosium magnets) to wind turbines (praseodymium-based generators) and advanced electronic equipment.

Global demand is expected to increase by 10% per year until 2030, according to a European Commission report (2020) on critical raw materials. The geographical concentration of the extraction and refining of these minerals raises questions of economic sovereignty and supply chain resilience. China accounts for approximately 60% of global refined rare earth production and 85-90% of processing capacity, despite the emerging diversification of extraction sites (United States, Australia). The Bayan Obo mining site in Inner Mongolia alone holds a significant portion of global reserves.

In the United States, the Mountain Pass mine in California, the country's only large-scale rare earth extraction operation, has seen a resurgence in its activity after decades of stagnation. Its reactivation, supported by federal investments, aims to reduce dependence on China, but refining capacity remains a major bottleneck, requiring transfers of concentrates abroad for final processing. Rare earth extraction also faces considerable environmental and social challenges, particularly in terms of toxic waste management and intensive consumption of water and energy resources.

The "resource curse" (Auty, 1993) manifests through devastating local impacts, often in poor and poorly regulated regions, without the populations fully benefiting from the economic repercussions. The development of national and European strategies (such as the EU Critical Raw Materials Act, 2023) to secure supply illustrates geopolitical awareness, but the diversification of sources, the development of recycling, and innovation in substitute materials remain major challenges. It is essential to rethink material circularity and decarbonize the entire value chain, an imperative that transcends economic competition logic.

Digital Archives: The Fragility of Memory in the Era of Global Forgetting Digital archives constitute essential infrastructures for the preservation of knowledge, culture, and collective memory. However, their longevity is threatened by technological obsolescence, cyber-attacks, natural disasters, and the absence of viable economic models for their long-term maintenance. The Internet Archive, founded in 1996, and its Wayback Machine service, which has archived over 866 billion web pages, represent an emblematic case of this essential fragility.

These non-profit institutions operate in a still ill-defined legal space, between copyright, the right to information, and the imperative of preservation. Legal battles, such as those opposing the Internet Archive to book publishers, highlight the tensions between preserving access to knowledge and commercial interests. Mass digitization without guarantees of permanence leads to "digital black holes" (Rothenberg, 2001) where entire sections of our heritage disappear. The governance of digital archives relies on private or hybrid initiatives, often underfunded and vulnerable to economic and political pressures.

The principle of perpetual conservation, historically endorsed by states for physical archives, has not yet found its systematic equivalent in the digital realm. The absence of robust international legislative recognition of the status of "digital commons" hinders the establishment of protective regulatory frameworks. It is important to design resilient, distributed, and interoperable architectures, involving public-private partnerships and sustainable funding mechanisms. The question of universal and non-discriminatory access to these archives is also crucial to ensure equal opportunities in research and education. True digital sovereignty requires control over our memories.

Seeds: The Privatization of Life and the Erosion of Biodiversity Agricultural biodiversity, the foundation of global food security, is threatened by genetic homogenization and the privatization of genetic resources. Seed banks, such as the Svalbard Global Seed Vault, established in 2008, play a crucial role in the ex situ conservation of thousands of cultivated plant varieties. Nearly 1.2 million seed samples are preserved there, representing irreplaceable genetic heritage. This facility, partly funded by public funds and philanthropic organizations, is designed to withstand major catastrophes and preserve crop diversity in the face of climate change and genetic innovations.

However, ex situ conservation does not replace in situ conservation, which involves maintaining traditional agricultural practices and local ecosystems, often threatened by agricultural intensification and land appropriation. The legal regime for seeds is dominated by intellectual property rights (IPRs), particularly plant patents and plant breeder's rights (PBRs) governed by the International Union for the Protection of New Varieties of Plants (UPOV, 1961 and 1991). These IPRs favor large seed companies, which control a growing share of the global market, estimated at over 60% for the top five companies in 2020 (ETC Group, 2021).

The privatization of living organisms reduces the autonomy of farmers, forcing them to buy patented seeds every year and limiting their ability to re-sow, exchange, or select their own varieties. This commodification is in tension with the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA, 2001), which recognizes farmers' rights to conserve, use, exchange, and sell farm seeds. State parties are faced with the need to arbitrate between these divergent regimes.

The protection of seeds as "commons" (Shiva, 1997) requires strengthening farmers' rights, massive investments in public gene banks, and support for agroecological practices that value local genetic diversity. The resilience of food systems to future crises will depend on our ability to preserve and share this biodiversity.

Towards a New Architecture for the Management of Planetary Commons The cases of fossil water, rare earth elements, digital archives, and seeds reveal a fundamental dissonance between the intrinsically finite and shared nature of these resources and the legal and economic frameworks that govern them, often imbued with a logic of exclusive property and unlimited exploitation. This tension is exacerbated by the intergenerational dimension of these issues, where current decisions mortgage the life capacities of future generations.

The failure of market mechanisms to internalize negative externalities and of state regulations to grasp the global dimension of these problems indicates the urgency of developing hybrid governance models. These models should combine the recognition of the "planetary trust" status (Brown, 2009) for certain irreplaceable resources with participatory and transnational mechanisms, exceeding the purely sovereign exercise of states. The notion of "fiduciary responsibility to future generations" (Caney, 2005), although debated, offers an ethical and legal basis for consolidating such frameworks.

It implies not only the preservation of stocks but also the maintenance of the optional capacity of future generations to make choices. This requires knowledge and resource transfers, investments in research and the development of alternative solutions, and increased transparency in the management of critical resources. The development of binding international standards and independent monitoring mechanisms is also imperative. The International Court of Justice could serve as a forum for arbitrating disputes related to the overexploitation of planetary commons, or, failing that, specialized environmental courts could be established.

The recognition of ecocide as an international crime, currently under discussion, could constitute a major institutional advance. Beyond technical and legal solutions, a transformation of values is necessary, moving from an anthropology of domination to an ethic of co-dependence and sobriety. The promotion of "ecological citizenship" (Dobson, 2007) capable of integrating planetary limits into individual and collective choices is a prerequisite for the sustainable and equitable management of the commons that structure our existence and that of future inhabitants of Earth. These reflections are all the more pressing as the dynamics of exhaustion and degradation accelerate.

Chapter 25 Pillar 3 — Individual Vital Budget (Principle and antecedence) The Anthropological Foundations of the Individual Life Budget The concept of an individual life budget emerges from a systemic awareness of planetary limits, notably conceptualized by Rockström et al. in 2009. It posits that each human being, from birth, is allocated an initial ecological capital, distributed across several categories, the collective and individual management of which conditions the sustainability of human civilizations.

This principle is rooted in a radical re-evaluation of the relationship between Homo sapiens and its biophysical environment, breaking with the paradigm of unlimited growth based on resources perceived as infinite. This conceptual framework moves beyond a purely monetary approach to wealth and development to integrate incompressible ecological metrics. It aims to translate, in quantitative and shareable terms, the Earth's carrying capacity, and to derive an equitable distributive constraint from it.

This approach is all the more urgent given that the transgression of several planetary boundaries, such as biosphere integrity or biogeochemical flows, is now proven and documented by Earth system science. Conceptual and Historical Antecedents The idea of limiting resource consumption to a sustainable level is not new and has its roots in various intellectual traditions. As early as the 18th century, Malthus, in his "An Essay on the Principle of Population" (1798), warned about demographic expansion in the face of the finite capacity of agricultural resources, although his analysis was largely contested regarding its demographic and technological conclusions.

The emergence of modern environmental concerns, post-World War II, revitalized this issue. The Meadows report, "The Limits to Growth" (1972), supported by the Club of Rome, marked a turning point by using dynamic models to project the consequences of exponential growth on finite planetary systems. It highlighted the risks of collapse of economic and social systems in the absence of regulation and a just redistribution of resources, a prelude to reflections on life budgets.

The Pillars of the Individual Life Budget: Carbon, Water, Soil, and Biodiversity The individual life budget is structured around several categories of critical resources for life, whose quantification and traceability must be established. The four identified fundamental pillars are carbon, water, arable soil, and biodiversity. Each represents a non-substitutable dimension of the Earth system's resilience and the capacity of human societies to sustain themselves.

The Personal Carbon Budget The idea of Personal Carbon Allowances (PCAs) was formalized as early as 1996 by David Fleming in his work "TEQs: Tradable Energy Quotas," and popularized in 2004 by a proposal from the British government under the aegis of Mike Hillman and Mayer Hillman. This concept aims to attribute to each citizen, at a national or supranational level, a quantity of non-monetized but tradable greenhouse gas (GHG) emission rights. The objective is to equitably distribute the remaining share of emissions compatible with climate goals, particularly those of the 2015 Paris Agreement aiming to limit warming well below 2°C, and preferably to 1.5°C.

The IPCC's Sixth Assessment Report (2022) estimates that to have a 50% probability of limiting warming to 1.5°C without significant overshoot, the remaining carbon budget from 2020 was approximately 500 GtCO2. With a global population approaching 8 billion individuals, this represents an extremely low individual carbon budget, on the order of 62.5 tonnes of CO2 per person if distributed linearly over an average lifespan of 80 years, or less than 1 tonne per year. However, the average global carbon footprint was about 4.8 tonnes of CO2 per capita in 2022, revealing the need for drastic reduction and equitable redistribution.

Individual Water Accounts Beyond carbon, freshwater is a vital resource whose availability is unequal and overexploitation widespread. The concept of "blue water," "green water," and "grey water" developed by Hoekstra and Chapagain (2007) in their water footprint study, highlights the complexity of allocating and managing this resource. A freshwater life budget would involve quantifying direct and indirect consumption (virtual water contained in goods and services) per individual, taking into account the recharge thresholds of watersheds. Average direct human consumption is estimated at 50-100 liters per person per day for essential domestic needs.

However, the average global total water footprint amounted to 1385 m3 per person per year in 2015, according to UNESCO, a value far exceeding what the Earth can sustainably provide without depleting aquifers or drying up rivers. The allocation of freshwater quotas, adjustable according to regions and their water stress, would become a survival imperative. Arable Soil Capital The health of arable soils is one of the foundations of global food security and climate regulation. Soil degradation through erosion, salinization, artificialization, and loss of organic matter directly threatens the Earth's capacity to feed its population.

The arable soil life budget would be an allocation, not of land ownership, but of "ecological productive capacity" per individual, measured in hectares or biophysical productivity units. According to the FAO (2015), the global arable land area per capita continues to decrease due to the combined effect of demographic growth and soil degradation, falling from 0.45 hectare in 1961 to 0.22 hectare in 2017. The allocation of a soil budget would mean integrating the negative externalities of intensive agriculture and land artificialization into the calculation of the individual ecological footprint, an approach advocated by Wackernagel and Rees (1996) with their concept of ecological footprint.

Biodiversity Endowment The rapid decline of biodiversity, documented by the IPBES report (2019), fundamentally alters the ecosystem services essential to human life. A biodiversity life budget is perhaps the most complex to quantify, as it cannot be reduced to a simple surface area or volume. It would rather be a constraint on individual and collective activities in terms of their impact on species and ecosystems, habitat destruction, and disturbance of ecosystem services. This could translate into quotas for biodiversity-derived resources (fish, timber, etc.) or "biodiversity credits" rewarding regenerative practices.

The objective is to ensure an equitable distribution of permissible impact on ecosystems, recognizing the intrinsic value of nature beyond its use value, a fundamental principle of ecological economics. Doctrinal Antecedence and Precursor Models The idea of individual ecological accounting emerged convergently within several schools of thought, each contributing its specificity. The concept of "life budget" inherits from these pioneering works and fuses them into a holistic perspective. Tradable Energy Quotas (TEQs) One of the major innovations was introduced by David Fleming with his "Tradable Energy Quotas" (TEQs) as early as 1996.

TEQs proposed a system where each citizen and every company would be allocated an exchangeable energy quota, gradually decreasing to meet emission reduction targets. The system was designed to be universal, not monetized as such but tradable within a secondary market, thereby ensuring flexibility and signalling the real cost of energy. The implementation of TEQs was extensively debated in the United Kingdom in the 2000s, but without leading to legislative materialization. Ecological Footprint and Biocapacity Alongside TEQs, Mathis Wackernagel and William Rees developed the concept of the ecological footprint ("Our Ecological Footprint: Reducing Human Impact on the Earth") in 1996.

This metric aggregates the resource consumption and waste production of a population or an individual into a productive land area necessary to support these activities. By comparing it to global biocapacity (the biologically productive area available), it reveals the overshoot of planetary boundaries, which the Global Footprint Network annually locates at "Earth Overshoot Day," occurring on August 1st in 2024. The average global ecological footprint is currently about 2.8 "global hectares" (gha) per person, whereas global biocapacity per person is about 1.6 gha.

This differential of 1.2 gha represents a structural ecological deficit that highlights resource overexploitation and the need for constrained allocation. The individual life budget is an attempt to translate this observation into an operational framework. Personal Carbon Allowances (PCAs) In the wake of TEQs, the concept of "Personal Carbon Allowances" (PCAs) gained visibility, particularly through the work of Mike Hillman and Mayer Hillman in 2004 for the Environmental Change Institute at the University of Oxford. PCAs envisioned the direct allocation of carbon emission rights to individuals, who would then be free to spend or sell them.

This system, designed to be simple and transparent, aimed to put a price on carbon at the final consumer level, thereby directly encouraging lower-carbon behaviours. Although often discussed in the context of combating climate change, these models opened the way for broader reflection on the management of non-renewable resources and ecosystem services. They highlight the need for an "ecological currency" or a "biophysical unit of account" to regulate human impact on the planet.

The Principle of Antecedence and the Ethical Challenges of Allocation The principle of antecedence in establishing an individual life budget refers to the idea that rights or allocations are primarily attributed to pre-existing entities or according to a logic of first occupancy or essential need. In the context of the life budget, this means that the basis for allocation must be universal and, ideally, attributed from birth, reflecting a shared ecological citizenship. However, the allocation of these budgets poses considerable ethical challenges. How can equal access to vital resources be reconciled with historical inequalities in emissions and consumption?

Developed countries, historically responsible for a disproportionate share of GHG emissions and resource consumption, have an "ecological debt" to developing countries and future generations. Issues of Intergenerational and Intragenerational Equity The life budget approach requires consideration of intergenerational equity, ensuring that future generations have sufficient ecological capital for their own needs. This implies a contraction of current budgets to allow convergence towards a sustainable level.

Intragenerational equity is also crucial: an equal "per capita" allocation might not be fair if it does not take into account the different capacities of individuals and regions to adapt, or fundamental needs not related to luxury. One solution could be an initial egalitarian allocation, complemented by redistribution or compensation mechanisms for the most vulnerable populations or those who have contributed least to environmental problems. The World Bank estimates that in 2021, approximately 685 million people still lived below the extreme poverty line, and their need for development cannot be denied.

The Question of Sovereignty and Global Governance The implementation of individual life budgets on a planetary scale requires robust and accepted global governance, capable of defining thresholds, allocating quotas, enforcing them, and managing potential exchange systems. The challenges are immense, particularly concerning national sovereignty and the ability of states to agree on binding mechanisms. International environmental law, with agreements like the Convention on Biological Diversity (CBD, 1992) or the Paris Agreement, provides a framework, but the regulation of individual practices at this scale remains an unprecedented undertaking.

Reflection on a "global ecological constitution" or a "global law of the commons" becomes imperative to frame this transnational management of planetary limits. The individual life budget cannot be viewed as a mere technical tool, but as the expression of a new planetary social and ecological contract, based on the recognition of our interdependence with the living systems of Earth.

Chapter 26 Pillar 3 — Quota Calibration and Mechanisms Foundational Theoretical Principles of Quantitativist Regulation of Common Goods The management of common goods, whether environmental or socio-economic, has historically confronted societies with the thorny issue of their progressive depletion, as masterfully theorized by Garrett Hardin in 1968 in his essay "The Tragedy of the Commons." This degradation invariably results from the absence of clear property rights and incentive mechanisms adapted to conservation, leading to a rational overexploitation by individual actors.

The quantitative approach, by establishing quotas, precisely aims to internalize the negative externalities associated with the use of these resources. Ecological economics, building on the pioneering work of Nicholas Georgescu-Roegen in "The Entropy Law and the Economic Process" (1971), emphasized the physical limits of economic growth and the need for frugal management of non-renewable natural resources, as well as the regeneration of renewable resources. The setting of annual quotas fits into this perspective, seeking to reconcile the ecological imperatives of not exceeding the carrying capacities of ecosystems with socio-economic needs.

It is no longer just about compensation, but about prevention. Quota mechanisms are not recent innovations. They were applied as early as the 18th century for the management of coastal fisheries in certain regions of Europe and North America, albeit sporadically and often without the sophisticated analytical framework we possess today. The evolution of international environmental law, particularly since the Stockholm Conference in 1972, has progressively integrated these principles, culminating in treaties such as the Montreal Protocol (1987) on ozone-depleting substances, which established national production caps.

Quotas: Between Ecological Sufficiency and Distributive Justice The determination of annual quotas is a complex operation that must be structured around two major axes: ecological sufficiency and distributive justice. Ecological sufficiency implies determining the thresholds beyond which natural capital risks irreversible degradation, or even collapse. This requires robust scientific data on ecosystem carrying capacities, species population dynamics, biogeochemical cycles, and carbon sink absorption capacities. Distributive justice, for its part, concerns the equitable distribution of access or emission rights among actors.

It is at the heart of debates on the concept of "ecological debt" and the "convergence of rights" between developed and developing nations, as explicitly formulated by the Rio Principles of 1992. The question of whether quotas should be allocated pro rata to populations, historical emissions, or according to countries' ability to pay remains a major point of friction in international negotiations. Annual Quota Calibration by Bioregion The calibration of annual quotas requires a multi-scalar approach, starting from the planetary level and descending to the bioregional, or even local, level.

The Kunming-Montreal Global Biodiversity Framework, adopted in 2022, sets quantitative targets for 2030, such as the protection of 30% of land and oceans, which imply a redefinition of resource exploitation quotas within unprotected areas. The notion of a bioregion, often defined as a territory characterized by a coherent set of ecosystems and species sharing common biophysical processes, offers a relevant management unit. It allows for the integration of local ecological specificities and fosters more participatory governance, as advocated by Elinor Ostrom in "Governing the Commons" (1990) through the self-organization of communities to face collective challenges.

Biogeographical Calibration Methodologies Scientific calibration of bioregional quotas relies on several methodologies: ■ **Modeling ecological carrying capacities:** Use of complex ecological models (e.g., population dynamics models, hydrological models) to estimate the maximum amount of withdrawal or emission that an ecosystem can sustain without suffering irreversible damage.

The concept of "critical fluxes" developed by IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) in 2019, allows for the identification of tipping points for different ecosystem services. ■ **Historical analysis of withdrawals and regenerations:** Evaluation of past trends in natural resources and regeneration rates. For example, for fish stocks, the United Nations Food and Agriculture Organization (FAO) annually publishes reports on the state of world fisheries, indicating that 34.2% of stocks were overexploited in 2017.

The calibration of fishing quotas must therefore take into account these data to define Maximum Sustainable Yields (MSY) by species and by area. ■ **Ecosystem indicators:** Use of bio-indicators (species diversity, biomass, soil health) to measure the state of the ecosystem and adjust quotas accordingly. The DPSIR (Driving Forces, Pressures, State, Impact, Response) framework of the European Environment Agency provides a structure for the evaluation and revision of these indicators. The delimitation of bioregions must transcend political borders to embrace ecological realities.

This implies strengthened cross-border cooperations, as shown by the management of the Danube basin, governed by the Convention on the Protection of the River Danube of 1994, where 14 countries collaborate in defining quotas for pollution and water use. Cap-and-Trade and Regulated Secondary Markets Once initial quotas are allocated, either through direct allocation (grandfathering) or by sale (auctions), the question of their transferability arises. The establishment of a cap-and-trade system injects flexibility into the system, allowing entities with high reduction costs to purchase surplus quotas from those that can reduce their impacts at a lower cost.

This creates a powerful economic incentive for innovation and efficiency. The cap-and-trade mechanism was successfully experimented for sulfur dioxide (SO_2) in the United States, following the 1990 amendments to the Clean Air Act, reducing SO_2 emissions by 70% between 1990 and 2007. The European Union Emissions Trading System (EU-ETS), launched in 2005, represents the largest carbon market worldwide, covering approximately 40% of the EU's greenhouse gas emissions. Nevertheless, it suffered from over-allocation of initial permits, leading to low prices and limited incentive during several phases.

Regulation of Secondary Markets For these secondary markets to function optimally and not to become instruments of speculation disconnected from environmental objectives, strict regulation is essential. ■ **Holding and transaction limits:** Establish caps on the quantity of quotas that an entity can hold or trade to avoid excessive concentration of market power and price manipulation. This helps limit the influence of financial actors to the detriment of environmental objectives. ■ **Anti-speculation mechanisms:** Implement rules to prevent pure speculative activities that do not contribute to the effective reduction of impacts.

This can include increased transparency requirements, lock-up periods for newly acquired quotas, or taxes on purely financial transactions. ■ **Regulatory oversight:** Regulatory authorities (e.g., national environmental agencies or financial regulators) must be endowed with sufficient powers and resources to actively monitor the market, detect abuses, and impose sanctions. The EU-ETS's "Market Stability Reserve" (MSR), introduced in 2019, aims to adjust the supply of quotas based on demand to maintain an incentivizing and stable price.

■ **"Price collar":** The establishment of price floors and price ceilings frames market volatility and provides visibility to economic actors.

A price floor guarantees a minimal incentive to reduce impacts, while a price ceiling protects the economy from excessive cost shocks. The Case of the Murray-Darling Basin in Australia: A Warning Against Abuses The Murray-Darling basin in Australia offers an instructive case study on the risks inherent in flawed management of quota mechanisms and their secondary markets. This basin, which covers approximately 14% of Australian territory and produces 39% of the country's agricultural value, has been the scene of intensive management of water rights, set up to reconcile agricultural uses and environmental needs.

The Murray-Darling Basin Plan (MDBP), introduced in 2012, aimed to restore 2,750 gigaliters (GL) of water to the environment by 2019, via a cap-and-trade system for water rights. Water "entitlements" have become financial assets, tradable on an active market, with prices fluctuating according to hydrological conditions and agricultural demands. "Cap Day Zero" and Drought Speculation The year 2018 was particularly critical, marking a "Cap Day Zero" for certain regions, where water reserves reached such low levels that drastic restrictions were imposed, sacrificing environmental needs for priority uses.

Water prices on the secondary market soared, reaching up to AUD 800 per megaliter, an increase of over 400% compared to previous years. Investigative reports, especially those by the Australian Broadcasting Corporation in 2017 and 2019, revealed allegations of speculation and manipulation of the water market.

Non-agricultural actors, including investment funds, acquired significant quantities of water rights, sometimes solely for the purpose of reselling them for profit during periods of drought, exacerbating pressure on farmers and water availability for the environment. ■ **Lack of transparency:** The water market lacked transparency regarding the identities of final buyers and sellers, as well as traded volumes, favoring opportunistic behavior. ■ **Fragmented governance:** Water management within the basin remained fragmented among several states and authorities, limiting a holistic vision and a coordinated response to crises. ■ **Economic priority over ecological:** Despite the environmental objectives of the MDBP, economic and political pressures often prevailed, leading to trade-offs unfavorable to ecosystem health, as evidenced by episodes of massive fish mortality linked to lack of water and poor water quality.

This case illustrates the imperative need to design quota and trading mechanisms with robust safeguards, proactive regulation, and a clear primacy of ecological objectives over financial interests. The partial failure of the MDBP to guarantee the basin's resilience to droughts, despite an ambitious management framework, must serve as a lesson for the implementation of future bioregional systems. Challenges of Global Quota Governance The implementation of quota systems at the bioregional scale is part of a global governance framework that must be strengthened.

International agreements, such as the Paris Agreement on climate (2015), provide the superstructure, but true effectiveness lies in operational implementation and the coherence of national and regional policies. The design of quota mechanisms for critical and transboundary resources requires deep international collaboration and shared monitoring mechanisms. Financing the transition and adaptation is also a major challenge. Developing countries, often the most vulnerable to environmental impacts and historically the lowest emitters, must receive substantial support to adopt sustainable practices and respect their quotas.

The Green Climate Fund, although initially endowed with 10 billion dollars, is still far from covering estimated needs of several hundred billion annually. The question of the democratic legitimacy of quota-setting decisions is fundamental. It implies the participation of stakeholders, including indigenous populations whose traditional knowledge of resource management is essential, as recognized by the United Nations Declaration on the Rights of Indigenous Peoples of 2007. The quota-setting process cannot be purely technocratic; it must be an act of collective sovereignty, informed by science but rooted in an ethics of justice and intergenerational responsibility.

Quotas, far from being a panacea, are a potentially powerful instrument for the sustainable management of common goods. Their success will inevitably depend on the scientific rigor of their calibration, the robustness of their secondary market mechanisms, and the quality of the governance underlying them, all within a perspective of environmental justice and social equity.

Chapter 27 Pillar 3 — Graduated sanctions and the vital minimum The Elusive Concept of Anthropogenic Excess and the Necessity of Constraint The concept of ecological expenditure, articulated around the carbon footprint and the consumption of natural resources, reveals the extent to which human societies have overshot the Earth's biophysical capacities. The "Planetary Boundaries" report by Rockström *et al.* (2009) identifies nine planetary boundaries, several of which are already crossed or gravely threatened, such as biosphere integrity and the biogeochemical cycles of phosphorus and nitrogen.

This situation, often referred to as the Anthropocene, demands a re-evaluation of legal and economic frameworks that have historically neglected ecological constraints. The hypothesis of unlimited growth on a finite planet constitutes an ontological oxymoron whose consequences manifest as rapid climate change, unprecedented biodiversity erosion, and depletion of strategic resources. Climate justice, theorized notably by Shue (1992) in "Basic Rights," requires accounting for the differentiated responsibilities and respective capacities of nations and individuals to address this systemic crisis.

The question then arises as to the legitimacy of regulatory and sanction mechanisms in the face of unsustainable behavior. International climate jurisprudence, though emergent, outlines principles of responsibility. Cases such as *Urgenda Foundation v. State of the Netherlands* (2019) or the decision of the German Federal Constitutional Court in *Neubauer et al. v. Germany* (2021) underscore the states' obligation to protect future generations from the effects of climate change, failing which they violate fundamental rights. These decisions constitute legal milestones recognizing the eminently political and legal nature of ecological constraint.

The "great acceleration" post-1950, characterized by an exponential increase in energy consumption, greenhouse gas emissions, and waste production, has led to a situation where individual consumption has become a determining factor in overall environmental impact. In 2023, Earth Overshoot Day occurred on August 2nd, meaning that in less than eight months, humanity had consumed all the resources the planet can regenerate in a year, a situation exacerbated by the living standards of industrialized countries. The transition to an ecological economy therefore imposes a paradigmatic break with the ideal of unlimited consumption.

Fundamental Rights as the Foundation of Dignity and the Limit of Sanction Any policy restricting consumption must necessarily be anchored in the inalienable respect for fundamental rights, conceptualized as essential subjective rights to human dignity. The Universal Declaration of Human Rights (1948), and the International Covenants of 1966, notably the International Covenant on Economic, Social and Cultural Rights, establish rights such as the right to an adequate standard of living, including food, clothing, and housing. These rights constitute an inviolable foundation, an intangible "minimum vital," whose unenforceability is paramount in any ecological sanction system.

Article 25 of the UDHR states that "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family." This right extends to the material conditions of existence. It follows that no punitive measure, whether financial or restricting access, can compromise access to these essential goods and services. The jurist Kelsen, in his "Pure Theory of Law" (1960), insists on the hierarchy of norms, placing fundamental rights at the top of the legal order, thus rendering them impenetrable to derogatory measures not duly justified and proportionate. The notion of a minimum vital is already present in several national legislations.

In French law, Article L. 112-2 of the Code of Civil Enforcement Procedures establishes the inalienability of a portion of income, the "unseizable bank balance" (solde bancaire insaisissable or SBIR), corresponding to the amount of the Active Solidarity Income (Revenu de Solidarité Active or RSA) for a single person, i.e., €607.75 per month as of April 1, 2024. This mechanism aims to guarantee the dignity of indebted individuals. An ecological approach should extrapolate this principle to create an "ecological unenforceability" of vital consumption.

The approach of graduated sanction must thus operate a clear distinction between luxury or superfluous consumption, which can be legitimately restricted in case of exceeding ecological quotas, and those falling under the vital minimum. The right to mobility, for example, cannot be denied, but its exercise can be modulated. A private jet flight for personal enjoyment (estimated at 5 to 10 tons of CO2 per flight hour for a small jet, according to the NGO Transport & Environment) falls under luxury, while access to low-carbon transport for commuting is a necessity.

Economic, Social, and Cultural Rights The rights to safe drinking water, sanitation, energy for essential needs (heating, lighting, cooking), healthy and nutritious food, and decent housing are pillars of well-being. These rights require underlying resource consumption and greenhouse gas emissions. For example, the production of a healthy and sustainable diet is estimated at approximately 1.7 tons of CO2 equivalent per person per year in developed countries, according to studies such as that by Poore and Nemecek (2018) published in Science.

Any attempt to regulate consumption that leads to the deprivation of these essential elements would violate the principles of international human rights law. The restriction of air travel, if it targeted professional travel necessary for subsistence or the exercise of an essential social function, should be considered with the utmost caution and framed by clear exceptions, unlike leisure flights which may be subject to stricter regulations, or even temporary bans in case of critical overshoot. Graduated Sanctions and Progressive Redistribution The principle of graduated sanctions constitutes a structuring mechanism to guide the ecological transition without hindering human dignity.

It involves establishing consumption thresholds beyond which corrective measures apply, proportionate to the extent of the overshoot. These thresholds should be defined collectively, based on robust scientific foundations and principles of justice. The first level of sanction could consist of increased information and awareness for individuals regarding their ecological footprint. For example, electricity or fuel consumption data could be accompanied by an estimate of the carbon impact and compared to national averages and reduction targets.

This "nudge" approach aims to modify behaviors without direct coercion, as developed by Thaler and Sunstein (2008) in "Nudge: Improving Decisions About Health, Wealth and Happiness." In the event of moderate and persistent exceedance of individual quotas, progressive financial penalties could be introduced, the revenues of which would be entirely reallocated to the ecological transition or to compensating the most vulnerable households. These revenues could finance zero-carbon infrastructure, aid for thermal renovation, or research and development programs for renewable energies.

Article 17 of the French Environmental Charter (2005) introduces the "polluter pays" principle, paving the way for such environmental taxation mechanisms. The third level of sanction, applicable to the most significant and ostentatious excesses, could take the form of restrictions on access to certain non-essential services or goods. This would concern luxury consumption with a disproportionate carbon footprint. Examples include private jet flights, the non-professional use of very high-powered vehicles, or access to energy-intensive secondary residences that do not comply with environmental standards.

These restrictions are not intended to punish, but to reallocate resources towards more sober and equitable uses. The Link with Universal Income The introduction of graduated sanctions calls for reflection on redistribution mechanisms. An intrinsic link can be established with the concept of unconditional basic income or universal income, theorized by authors such as Philippe Van Parijs as early as the 1990s ("Real Freedom for All," 1995) and Guy Standing more recently ("Basic Income: And How We Can Make It Happen," 2017).

A universal income, by guaranteeing a monetary vital minimum, offers protection against precarity and allows individuals to make more autonomous consumption choices, including ecologically more virtuous choices, without the constant pressure of survival. The contribution of ecological fines and taxes could thus feed a fund dedicated to financing a universal income, creating a virtuous cycle where polluters indirectly contribute to the economic security of all. This mechanism would strengthen the social acceptability of ecological constraints by demonstrating that the efforts required are equitably compensated, at least for the most disadvantaged.

Individual Carbon Allowances and Distributive Justice The allocation of individual carbon allowances, or "personal carbon budget," represents a radical but coherent approach to the goal of keeping global warming below 1.5°C above pre-industrial levels, in accordance with the

2015 Paris Agreement. This mechanism implies the allocation of an annual emission quota for each citizen, decreasing over time, the surplus of which could be bought or the unused portion sold, thereby creating a carbon market at the individual level. A 2021 IPCC study estimates that to meet the 1.5°C target, global emissions should be reduced by 43% by 2030 compared to 2019.

This entails a drastic reduction in the average carbon footprint per inhabitant. In 2022, the average global carbon footprint was about 6.5 tons of CO_2e per person, but it varied widely, ranging from over 15 tons in some industrialized countries to less than 2 tons in many less developed countries. Carbon allowances should be set well below the current average of rich countries. The implementation of carbon allowances raises considerable challenges in terms of distributive justice. To be equitable, the initial allocation of quotas should be equal or progressive per inhabitant, taking into account historical responsibilities and reduction capacities.

Low-income households, often the least responsible for historical emissions and the most vulnerable to the impacts of climate change, would potentially benefit from selling their unused quotas, while the wealthiest, often the largest emitters, would have to buy additional quotas. This system is often presented as an individualized "cap and trade" version, where the cap is distributed equitably, and the possibility of trading quotas offers economic flexibility.

The experience of emission trading schemes (ETS) for businesses, such as the European system (EU ETS) in force since 2005, demonstrates the technical feasibility of such mechanisms, even if their application at the individual level requires substantial adaptations in terms of monitoring and management. Exceedance and Suspension of "Non-Vital" Rights In case of proven and repeated exceedance of the individual carbon budget, after exhausting monetary penalties and incentives, temporary suspension or restriction of access to certain non-vital rights and services could be considered. This measure would represent the ultimate level of graduated sanctions.

It is crucial to emphasize that these restrictions would only concern rights that do not affect human dignity or access to the vital minimum. For example, the restriction would apply to non-essential air travel (leisure flights, luxury tourism), access to the purchase of heavily emitting very luxury goods, or the possibility of using certain high-carbon private vehicles for non-professional purposes. The objective is not to penalize wealth, but ecological unconsciousness and the exceedance of global sustainability thresholds. These measures should be proportionate and temporary, with recourse mechanisms to preserve individual liberties.

This approach makes it possible to distinguish ostentatious, ecologically destructive consumption from uses essential to social and economic life. It reaffirms the principle that individual freedom to consume cannot be exercised at the expense of the integrity of the biosphere and the capacity of future generations to meet their own needs, a principle enshrined at the heart of sustainable development as defined by the Brundtland Report (1987).

Social Acceptability and Adapted Legal Frameworks The implementation of such measures, which imply a redefinition of individual freedoms in the face of collective and environmental imperatives, requires robust social acceptability and irreproachable legal frameworks. Constitutional law plays a central role in establishing these frameworks, ensuring that any restriction complies with the principles of proportionality, necessity, and non-discrimination.

In France, the Charter for the Environment (2005), appended to the Constitution, recognizes in particular the right of everyone to live in a balanced environment respectful of health (Article 1) and the duty to prevent and remedy environmental damage (Article 3). These provisions provide a legal basis for justifying ecological constraint measures, provided they respect other constitutional rights, notably human dignity and individual liberty. The policy development process must be participatory and transparent, involving citizens, scientific experts, and economic actors.

The model of the Citizens' Convention for Climate (France, 2019-2020), although not all of its recommendations were fully adopted, demonstrated the capacity of citizens to grasp complex issues and propose ambitious, including restrictive, measures in favor of the ecological transition. Potential criticisms, relating to a libertarian "ecologist State" or a "surveillance society," must be anticipated and defused by legal and technical guarantees. The allocation of quotas and the monitoring of consumption will have to rely on privacy-respecting technologies, with independent controls and effective recourse mechanisms. Public trust is the cornerstone of the legitimacy of these transformations.

Legal frameworks must be flexible enough to adapt to developments in scientific knowledge and technological advances, while remaining constant on fundamental principles of justice and sustainability. It is imperative that measures to limit consumption contribute to social cohesion rather than its fragmentation, by ensuring that the efforts required are perceived as equitable and necessary for collective survival, and not as a burden imposed solely on the disadvantaged. The construction of a global ecological citizenship requires adherence to these principles of justice and subsidiarity.

Chapter 28 Pillar 4 — Cognitive Academy (Principle) The Imperative of an Epistemic and Pedagogical Refoundation The complexity of contemporary challenges – whether climatic, socio-economic, or technological – makes the progressive obsolescence of current educational paradigms palpable. Disciplinary fragmentation, inherited from an epistemological model founded on Cartesian analysis, limits learners' ability to grasp the systemic interdependencies that characterize 21st-century phenomena.

This balkanization of knowledge, highlighted by Edgar Morin as early as the late 20th century in his work *La Tête bien faite* (1999), hinders the emergence of holistic and integrated thinking, which is nonetheless essential for resolving the polymorphic crises that threaten planetary stability. A pedagogical renewal is therefore not only desirable but imperative to equip citizens with a "well-formed mind," capable of contextualizing knowledge, connecting disciplines, and forging independent judgment. The aim is to move beyond a mere encyclopedic accumulation of facts to prioritize the development of transversal skills and critical intelligence.

This transformation must occur profoundly within curricula, teaching methods, and the very aims of education, seeking to train individuals capable of navigating a world of growing uncertainties, rather than specialists with methodological blinkers. The Anachronism of the Siloed Model in the Face of the Anthropocene The Anthropocene era, characterized by the decisive impact of human activities on Earth systems, starkly reveals the inadequacies of an educational approach that fails to connect knowledge. Problems of climate change, biodiversity loss, or social inequality cannot be understood by a single discipline.

Economics, law, biology, sociology, and engineering sciences must imperatively dialogue to design viable solutions, as highlighted by the IPCC (Intergovernmental Panel on Climate Change) report, which, since its creation in 1988, has mobilized thousands of scientists from multiple fields. The inability to think systemically leads to ineffective public policies, uncontrolled technological innovations, and low societal resilience. Decisions are often made by focusing on narrow indicators, without considering feedback effects or causal loops modeled by Donella Meadows in *Thinking in Systems: A Primer* (2008).

For example, maximizing GDP as the sole compass for development, without integrating environmental and social costs, has led to an overexploitation of natural resources that compromises the very foundations of future prosperity. Systemic Thinking as a Fundamental Cognitive Matrix Systemic thinking represents the cornerstone of this educational refoundation. It offers an analytical framework that goes beyond the sum of parts to focus on relationships, feedback loops, and emergent dynamics within complex systems. It is no longer about studying isolated objects, but interconnected wholes, whether an ecosystem, a national economy, or a global climate system.

This approach makes it possible to identify the most effective levers for action and to avoid counterproductive interventions, often resulting from a reductionist vision. The integration of systemic thinking into curricula from the earliest years of schooling must become a priority. Concretely, this means introducing notions of circular causality, critical thresholds, stocks and flows, and response times in the study of natural, social, and economic phenomena. The teaching of history could thus be done by linking technological developments to environmental transformations and geopolitical dynamics, breaking the artificial isolation of disciplines.

Ethics as an Axiological Compass for Action Alongside systemic thinking, robust ethical education is indispensable. Rapid scientific and technological advances, particularly in the fields of artificial intelligence, biotechnology, and geo-engineering, pose profound questions about the nature of man, his responsibilities, and the limits of his power. Without in-depth ethical reflection, these innovations risk generating unforeseen negative externalities, exacerbating inequalities, or compromising human dignity. Ethics should not be seen as an optional addition, but as a guiding thread running through all teaching.

It involves training in moral deliberation, in the analysis of ethical dilemmas, and in arbitrating between sometimes antagonistic values. The principles of intergenerational justice, precaution, responsibility, and solidarity must be at the heart of this training, drawing from philosophical traditions as well as international legal frameworks, such as the Universal Declaration of Human Rights of 1948 or the Earth Charter, drafted in 2000. The Necessity of Mathematics of Uncertainty in a Volatile World The contemporary world is intrinsically Volatile, Uncertain, Complex, and Ambiguous (VUCA).

Faced with this reality, mastery of the mathematics of uncertainty, including probabilities, statistics, and fuzzy logic, becomes a fundamental cognitive skill. Strategic decisions, both at individual and collective levels, increasingly rely on the analysis of massive data and the modeling of probabilistic scenarios. Neglecting this dimension exposes one to major errors in judgment and an inability to adequately assess risks. The teaching of these concepts must go beyond memorizing formulas to focus on their practical application, critical interpretation, and the recognition of cognitive biases.

The aim is to train minds capable of understanding that many problems do not have a single, certain solution, but require a probability assessment and constructive management of ambiguity. For example, the modeling of climate trajectories by the IPCC relies on probabilistic forecasts, with margins of uncertainty that must be correctly understood by decision-makers to develop mitigation and adaptation policies. Linguistic and Cultural Openness for Global Citizenship In an interconnected world, mastery of several foreign languages is more than an asset; it is a *sine qua non* condition for enlightened and effective global citizenship.

Languages are not merely communication tools; they carry distinct cultures, ways of thinking, and worldviews. Learning a language means opening oneself to other ways of conceptualizing reality, engaging in dialogue with different value systems, and enriching one's own perspective. English, as a scientific and economic *lingua franca*, remains indispensable. However, a true cognitive academy should encourage the learning of other languages, particularly those of major civilizational areas and emerging powers, to facilitate mutual understanding and cooperation on major global challenges.

According to the OECD report *Educating in the Digital Age* (2016), multilingual competencies are correlated with greater cognitive flexibility and a better ability to solve complex problems. Furthermore, 60% of the world's population is bilingual or multilingual, a fact that should be reflected in our educational systems to avoid an impoverishing monolingualism. The Architecture of a Renovated Cognitive Academy The implementation of these principles requires a profound overhaul of existing educational structures. It is not limited to the addition of new subjects but implies a radical transversality, abolishing artificial boundaries between disciplines.

Curricula must be designed in an integrated manner, where each subject is contextualized and linked to others. For example, the study of energy could intersect the laws of thermodynamics (physics), the geopolitical stakes of supply (geography, political science), the climatic impact of carbon emissions (ecology, chemistry), and technological innovations (engineering). This renewed cognitive academy must also promote active pedagogies, encouraging real-world problem-solving, interdisciplinary projects, and collaborative work. The learner becomes an actor of their knowledge, appropriating conceptual and methodological tools to construct their own understanding of the world.

Teachers, for their part, must be trained in these new approaches, becoming facilitators and guides rather than mere transmitters of knowledge. Incentive Measures and Legal Frameworks for Educational Transformation To support this transformation, legislative and incentive measures are essential. At the national level, Ministries of Education should revise competency frameworks to explicitly integrate systemic thinking, applied ethics, the mathematics of uncertainty, and multilingualism. Increased funding should be allocated to pedagogical research and the continuous training of educational leaders.

The French law on student orientation and success (ORE) of 2018, by encouraging the definition of transversal competency blocks, offers an embryonic form of this logic, but does not go far enough in the defragmentation of fundamental knowledge. At the international level, coordinated efforts are necessary. Organizations like UNESCO or the OECD can play a crucial role by defining shared educational standards and facilitating exchanges of best practices. The United Nations 2030 Agenda for Sustainable Development, and particularly Sustainable Development Goal 4 (SDG 4) on quality education, provides a relevant framework for guiding these transformations.

The integration of these principles into European funding programs, such as Erasmus+, could accelerate their dissemination and large-scale adoption. The Role of New Technologies in Cognitive Amplification New technologies, far from replacing traditional education, can serve as powerful levers for amplifying this cognitive refoundation. Online learning platforms, digital simulation tools, augmented reality, and artificial intelligence offer unprecedented opportunities to create immersive, personalized, and interdisciplinary learning experiences. They allow for the visualization of complex systems, the experimentation of scenarios, and remote collaboration on common projects.

However, technological integration must be critically considered. The objective is not digitalization for digitalization's sake, but the judicious use of digital tools to strengthen fundamental cognitive abilities. This implies training teachers in these tools, equitable access to technological infrastructures, and ethical reflection on the use of personal data and the risks of information overload. Approximately 4 billion people, nearly half of the world's population, did not have access to the internet in 2023 according to the ITU (International Telecommunication Union), highlighting a major equity issue.

Assessment as a Mirror of Pedagogical Transformation The assessment of learning must also be rethought to reflect this new orientation. Examinations based on the recall of factual and isolated knowledge are now inappropriate. It is advisable to favor assessment methods that measure the ability to analyze complex situations, creatively solve problems, communicate effectively, and demonstrate ethical judgment. This could take the form of interdisciplinary research projects, simulations, case studies, or argumentative essays. Formative assessment, which supports the learner in their learning process and provides constructive feedback, should be prioritized.

It allows for the detection of gaps and the adaptation of pedagogical strategies in real time. The generalization of peer assessment and self-assessment tools can also contribute to developing learners' autonomy and responsibility. This transformation of assessment methods sends a powerful signal to the entire educational system, orienting pedagogical practices and students' efforts towards the acquisition of 21st-century skills.

Chapter 29 Pillar 4 — Detailed Curriculum and Evaluation An Anthropocenic Curriculum: Redefining Learning for a Sustainable Future The transition from the Holocene to the Anthropocene, characterized by the decisive impact of human activity on Earth systems, necessitates a radical overhaul of educational paradigms. The challenge is no longer merely to transmit knowledge and skills for socio-professional integration, but to equip every citizen to understand and act constructively within complex and unstable systems.

An Anthropocenic curriculum must transcend disciplinary compartmentalization to embrace a holistic and systemic vision of the world, echoing UNESCO’s calls for global citizenship education (UNESCO, 2015). This curriculum proposal is structured around four interdependent axes, aiming to develop critical thinking, cognitive resilience, and an ethics of responsibility. It is not about adding new subjects, but about redesigning the methodology and objectives of learning. The goal is to prepare learners to become agents of ecological and social transition, capable of navigating uncertainty and co-constructing sustainable solutions.

Axis 1: Understanding Earth and Human Dynamics This axis aims to equip students with an in-depth understanding of the biophysical and socio-ecological processes that govern our planet. This involves integrating discoveries from Earth system sciences, from deep geology to biogeochemical and climatic cycles. Knowledge of planetary boundaries, identified by Rockström et al. (2009) in "Planetary Boundaries," becomes a fundamental conceptual framework. The teaching of natural sciences must be reoriented towards a systemic perspective, highlighting the interconnections between the atmosphere, hydrosphere, lithosphere, biosphere, and anthroposphere.

The study of climatic phenomena, biodiversity, natural resources, and pollution must emphasize positive and negative feedbacks, as well as irreversible dynamics. For example, the loss of 52% of vertebrate biodiversity between 1970 and 2014, according to the WWF Living Planet Report (2016), must be analyzed in terms of its systemic causes and its consequences for ecosystem services. Simultaneously, the analysis of human societies must focus on their ecological impact. This implies environmental sociology and anthropology, exploring the complex relationships between social organization, livelihood systems, value systems, and ecological footprint.

History is no longer just the history of humans, but the history of human-environment interactions, revealing the long genesis of the current crisis, from the first agricultural transformations to the Great Acceleration post-1950. Axis 2: Ecological Economics and Sustainability Models This axis introduces the principles of ecological economics, breaking with the dominant paradigm of unlimited GDP growth. The aim is to teach that the economy is a subsystem of the biosphere, and not the other way around. The concepts of planetary limits, material and energy flows, ecosystem services, and the intrinsic value of nature are central.

The curriculum will explore alternatives to conventional economic indicators, such as the Genuine Progress Indicator (GPI), Gross National Happiness (GNH), or inclusive wealth accounting. The analysis of environmental and social externalities, the theory of degrowth, de-consumption (Latouche, 2003), and the circular economy will be fundamental topics. Students must be able to model the environmental impacts of economic activities and to evaluate the sustainability of different production and consumption models. The teaching of finance must also be rethought, integrating climate and transition risks, as well as the opportunities of sustainable finance.

Understanding the mechanisms of fossil fuel subsidies, estimated at over $5.9 trillion in 2020 by the IMF, and their alternatives, is essential. The objective is to train citizens capable of analyzing economic choices through the prism of sustainability and intergenerational justice. Axis 3: Governance and Rights for the Anthropocene This axis addresses the need for new forms of governance adapted to the global and complex challenges of the Anthropocene. Constitutional law, international law, as well as political philosophy are mobilized to explore existing and imaginable normative frameworks. State sovereignty is confronted with the realities of transboundary ecological interdependencies.

The study of the principles of environmental law, international environmental law, and multilateral conventions such as the Paris Agreement (2015) or the Convention on Biological Diversity (1992) is indispensable. The question of recognizing the rights of nature, which found its first constitutional application in Ecuador in 2008, must be explored. The mechanisms of climate justice and the climate or ecological litigations that have multiplied in recent years, notably the *Urgenda* case in the Netherlands (2019), offer concrete illustrations of the shortcomings of current legal systems.

Political philosophy will focus on the concepts of environmental justice, intergenerational responsibility, ecological democracy, and planetary citizenship. The political thought of authors such as Hans Jonas (1979) and his "Principle of Responsibility" or Bruno Latour (2017) and his "Annuciation of the Earth" provide frameworks for rethinking our relationship to the world and to politics. The aim is to develop an awareness of the frameworks necessary for effective collective action in the face of planetary challenges, by questioning the scales of governance (local, national, regional, global).

Axis 4: Systemic Thinking, Ethics of Action, and Foresight This final axis is transversal and integrative, aiming to develop in learners the capacity to think systemically, to anticipate possible futures, and to act ethically. Systemic thinking implies the ability to identify feedback loops, tipping points, emergent effects, and complex interdependencies. Donella Meadows' (2008) approach to "leverage points in a system" is a relevant pedagogical tool. The ethics of action for the Anthropocene must be pragmatic and rooted in an understanding of limits and uncertainties.

It includes the ethics of prudence, responsibility, and solidarity, as well as a reflection on the moral dilemmas posed by technical and political choices (e.g., geoengineering). The ability to evaluate risks and trade-offs is crucial. Foresight and scenario planning are essential skills for developing bifurcation trajectories and adapting actions to uncertain horizons. This involves studying different visions of the future (collapsology, technosolutionism, degrowth, etc.) without dogmatism, but by analyzing their foundations, assumptions, and ethical and ecological implications. The objective is to develop autonomous judgment and an aptitude for co-constructing desirable futures.

Assessment of Anthropocenic Competencies: Towards PISA-Systems The assessment of a transformative curriculum requires a renewed approach, going beyond traditional academic measures. We propose a framework for a PISA-Systems type assessment, which would go beyond simply measuring disciplinary knowledge to evaluate learners' ability to understand and interact with complex systems. This approach is inspired by the Organisation for Economic Co-operation and Development (OECD) and its PISA tests, which already assess the ability of 15-year-olds to use their knowledge and skills to meet real-life challenges.

PISA-Systems would assess systemic thinking, the ability to solve complex problems, environmental and climate literacy, understanding of economic and social interdependencies, as well as skills in planetary citizenship and the ethics of responsibility. The assessments would consist of complex scenarios and interdisciplinary case studies, requiring multi-criteria analyses and situated solution proposals. For example, a practical case could focus on optimizing a city's energy, integrating climatic, socio-economic, and technological data.

The assessment could incorporate elements of "disinformation resilience," measuring students' ability to identify and refute false information about climate change or biodiversity, a problem exacerbated by the proliferation of digital content. The integration of peer assessment and self-assessment methods would foster the development of reflexivity and collaborative learning. Articulation with AI Tutors: Personalization and Remediation AI tutors represent a major opportunity to personalize learning and optimize remediation in this new curriculum.

Adaptive AI systems could analyze each learner's strengths and weaknesses in real-time, proposing individualized learning paths and pedagogical resources adapted to their learning style. For example, after a PISA-Systems assessment, the AI could direct a student struggling with feedback loops to interactive simulations or specific micro-courses. These AIs could also facilitate the exploration of complex scientific databases (climate models, biodiversity datasets) and the visualization of phenomena that are difficult to perceive. They could help identify cognitive prejudices or reasoning biases that hinder a systemic understanding of ecological problems.

The development of tools like ChatGPT Education or specialized platforms could transform the student-knowledge relationship and free up time for teachers, allowing them to focus on personalized support and complex projects. A major challenge is to ensure that these AIs are trained on balanced and ethical data corpora, avoiding the reproduction and amplification of existing biases. The Singapore SEA-LION (Southeast Asian Languages in One Network) AI model, developed by AI Singapore, illustrates the ability to create multilingual models adapted to cultural and linguistic specificities, which would be valuable for an international dissemination of this curriculum and its AI tools.

International Inspirations: Finland, Estonia, Singapore The integration of this Anthropocenic curriculum would draw inspiration from global best educational practices, particularly those of Finland, Estonia, and Singapore, recognized for their performance and innovation. The Finnish model, with its holistic approach to education and its emphasis on personalization, student well-being, and the training of autonomous citizens, offers an inspiring framework. The transversality and phenomenon-based approach, introduced in the Finnish national curriculum in 2016, including multidisciplinary study themes, resonate with the need for systemic thinking.

The small performance gaps between students in Finland, combined with very high PISA results, attest to the relevance of this inclusive approach. Estonia, a pioneer in integrating digital technology at all levels of its educational system, provides an example of how technology can be used for modern and effective learning. Its "Tiger Leap" (Tiigrihüpe) program, launched in 1996, enabled early digitization of schools, fostering digital literacy from a young age. Estonia is also at the forefront of coding and AI education, essential skills for understanding and interacting with 21st-century technological tools, including AI tutors.

Singapore, with its high-performing education system, illustrates the importance of rigorous planning and academic excellence. Its "Teach Less, Learn More" approach encourages critical thinking and problem-solving, rather than memorization. The emphasis on 21st-century skills, collaboration, and innovation, as well as massive investments in AI research and development (as targeted by the "AI Singapore" initiative), positions this country as a laboratory of ideas for the integration of new technologies and pedagogies.

These three models, each in their own way, demonstrate that it is possible to reconcile academic excellence, student well-being, pedagogical innovation, and technological integration. The challenge now is to merge these approaches with the ecological and social imperatives of the Anthropocene to forge an education truly preparatory for the upheavals to come. The Anthropocenic curriculum is not a simple reform, but a profound transformation of the purpose and means of education.

Chapter 30 Pillar 4 — Global Cognitive Agency (AI governance) The imperative of ex-ante regulation of general artificial intelligence systems The exponential emergence of artificial intelligence (AI) systems, particularly so-called "foundation models" or "large language models," raises fundamental questions regarding technological sovereignty, socio-economic stability, and global security. The dizzying growth of their computational capabilities, measured in floating-point operations per second (FLOPs), and their increasing deployment in critical domains, demand a thorough reflection on existing and future normative frameworks.

The systemic risk posed by autonomous AI, without adequate supervision, can no longer be ignored. Projections regarding the computational power of AI systems highlight rapid progress. The most advanced models of 2023, such as GPT-4, incorporated approximately 10^24 FLOPs during their training (OpenAI, 2023). Prospective estimates, such as those from the Artificial Intelligence Safety Institute (AISI), indicate that models exceeding the 10^25 FLOPs threshold could be operational before 2030, or even 2027 in optimistic development scenarios.

This scale of computation approaches that of the human brain, estimated at around 10^15 FLOPs per second for simulating synaptic connections, but with incomparably superior processing speed for AI. The limitations of national and regional regulatory frameworks Current regulatory initiatives, while commendable, have inherent limitations in their geographical scope and their capacity to anticipate a technology with global dynamics. Regulation (EU) 2024/1689 on artificial intelligence products, known as the "AI Act," represents a significant step forward by adopting a risk-based approach, distinguishing between unacceptable-risk, high-risk, limited-risk, and minimal-risk AI.

This framework, which entered into force in July 2024, establishes obligations for AI providers and users based on the criticality of the use. However, the AI Act primarily focuses on "high-risk AI systems" and "foundation models," without establishing a systematic ex-ante control mechanism for models with extreme computational power, nor a super-national withdrawal authority.

Similarly, the US President's Executive Order 14110, signed on October 30, 2023, and titled "Safe, Secure, and Trustworthy Artificial Intelligence," establishes security standards for developers, notably by requiring the submission of reports on the results of security tests for foundation models posing a serious risk to national or economic security. These frameworks, while complementary, remain national or regional responses to an intrinsically global challenge. The ability of these regulations to stem the spread of potentially dangerous AI systems, developed outside their jurisdiction or by uncooperative actors, is limited.

The ubiquitous nature of AI, its ability to cross digital borders unhindered, necessitates a more robust multilateral approach, like the governance of critical systems in other domains. Towards an International Atomic Energy Agency model for AI The analogy with the International Atomic Energy Agency (IAEA), created in 1957 in the wake of the civil and military applications of atomic energy, offers a relevant roadmap for AI regulation.

The IAEA was established to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" while "ensuring that assistance provided by it or under its supervision is not used in such a way as to further any military purpose" (IAEA Statute, Article II). Its success lies in its ability to audit, certify, and sanction member states and nuclear facilities, ensuring the peaceful use of nuclear technologies. A "World Cognitive Agency" (WCA) modeled on this, but without the military dimension in its primary mandate, could be the solution for regulating the development and deployment of civil Artificial General Intelligence (AGI).

The focus would be on preventing systemic risks, promoting AI for the benefit of humanity, and guaranteeing "global cognitive security." The primary mission would be to ensure that the most powerful AI contributes to progress without undermining the foundations of our societies. The mandate of such an agency would be unprecedented in scope, requiring cutting-edge technical and legal expertise. Its legitimacy would stem from an international treaty, similar to the Treaty on the Non-Proliferation of Nuclear Weapons (NPT), which would enshrine the existence of AI as a common good of humanity, while recognizing the inherent risks of its uncontrolled proliferation.

Such an approach would prevent an AI "Wild West," a scenario where the absence of international regulation would lead to an algorithmic arms race and irreversible developments. Structure and competencies of the World Cognitive Agency The WCA should be endowed with a robust structure and specific competencies, transcending national jurisdictions. Its composition would be multilateral, integrating scientific experts, philosophers, jurists, economists, and representatives of civil society, thus ensuring a holistic approach to AI governance. This inclusiveness is essential to establish the credibility and acceptance of its decisions globally.

The core competencies of the WCA would be based on three essential functions: auditing, certification, and withdrawal. ■ **Auditing of models > 10^25 FLOPs**: Any development of an AI model whose computational power exceeds a critical threshold, initially set at 10^25 FLOPs, should be subject to a mandatory and independent audit conducted by the WCA. This threshold is an indicator of the system's emerging ability to exhibit AGI attributes and thus induce systemic risks. The audit would assess not only technical performance, but also biases, robustness, transparency, cybersecurity, and the potential socio-economic impact of the model.

"Red-teaming" tests (simulated attacks to identify vulnerabilities) would be carried out by independent teams, following the model recommended by NIST (National Institute of Standards and Technology) in its AI Risk Management Framework published in 2023. ■ **Certification of AI systems**: Following a positive audit, the WCA would issue a certification attesting to the AI system's compliance with international safety, ethical, and transparency standards. This certification would be a prerequisite for the market placement or large-scale deployment of any critical model. It would be periodically re-evaluated to account for system and standard evolutions.

A system of renewable "operating licenses," similar to those for nuclear power plants, could be envisaged. ■ **Power of withdrawal or freezing**: In the event of proven non-compliance, or uncontrolled proven or potential risks, the WCA should have the power to order the withdrawal, freezing of development, or even controlled destruction of the most dangerous AI systems. This power, though radical, is essential to ensure the effectiveness of regulation and prevent planetary-scale catastrophes. It would be a "technological veto right" exercised in the interest of humanity.

Articulation with existing frameworks and funding The WCA would not replace existing national or regional regulations, but would complement them by establishing a higher level of control for the most powerful and critical AI systems. The European AI Act and the American Executive Order would continue to govern smaller-scale AI or those whose deployment is limited to specific contexts. The WCA would serve as a global coordinator, ensuring regulatory coherence and harmonization of technical standards at the international level. A mechanism for mutual recognition of certifications established by the WCA could be implemented, facilitating the cross-border deployment of certified AI.

Conversely, signatory countries could commit to prohibiting the use of AI not certified by the WCA on their territory, thereby creating an international regime of deterrence and compliance. The funding of the WCA could come from mandatory contributions from member states, proportional to their GDP and their activity in the field of AI, as well as from royalties on companies developing or operating AI models exceeding the critical threshold. Total transparency on the use of these funds would be essential to maintain stakeholder trust.

According to OECD estimates in 2022, the global AI sector already represented over $400 billion, with double-digit annual growth, offering a significant tax base. Implementation challenges and potential objections The creation of such an agency would face major challenges. The technological sovereignty of states, fierce economic competition among AI actors, and the difficulty of reaching international consensus on such sensitive issues represent considerable political and legal obstacles. The "black swan software," meaning the unexpected appearance of a particularly dangerous or intelligent AI, could call into question established thresholds and procedures.

Objections would be raised concerning hindrance to innovation, excessive bureaucratization of the AI sector, and the risk that the WCA might become an instrument of power or technological censorship. To address these concerns, the agency should guarantee complete independence in its decisions, maximum transparency in its procedures, and a fair recourse mechanism for entities subject to its controls. The establishment of independent appeal structures, composed of individuals recognized for their integrity, could help to alleviate these fears. Furthermore, the issue of "black boxes" in AI, i.e., the intrinsic opacity of certain models, makes auditing complex.

Explainable AI (XAI) techniques must be developed and imposed as a standard to allow for a rigorous evaluation of their behaviors and decision-making processes. Cynthia Rudin's work (2019) on interpretable models paves the way for more transparent approaches. Ethical and philosophical implications of global AI governance Beyond technical and regulatory aspects, the establishment of a World Cognitive Agency raises profound ethical and philosophical questions. It would crystallize the recognition of AI as a major transformative force, requiring global governance.

Hans Jonas, in "The Imperative of Responsibility" (1979), already urged an ethics of prudence in the face of unprecedented technological powers. General AI embodies this new form of power, demanding anticipatory responsibility on a planetary scale. The question of the inherent "morality" or ethics of AI systems would be at the heart of the debates. How can we ensure that these artificial intelligences share or adhere to fundamental human values, such as dignity, justice, and freedom? The WCA could lead international research programs on aligning AI systems with universal ethical principles, while respecting cultural diversity.

Nick Bostrom's work (2014) on artificial intelligence and its existential implications has already highlighted the urgency of this reflection. AI governance represents a decisive test for humanity's ability to collectively manage its own technological destiny. To ignore this imperative is to risk regulatory fragmentation, a headlong rush to development without regard for consequences, and ultimately, a loss of control over the systems we create. Twentieth-century history, with the development of weapons of mass destruction, showed the limits of national action in the face of global-reach innovations.

The precautionary principle, often invoked in environmental law (Charter for the Environment, 2004, Article 5), should be applied with even greater rigor to AI development. In the face of unprecedented and potentially irreversible risks, it is imperative to act *before* irreparable damage is caused. The WCA would be the institutional embodiment of this principle. An opportunity for international cooperation The creation of such an agency, despite the difficulties, also represents a unique opportunity to strengthen international cooperation and build a framework of mutual trust in the technological domain.

It could pacify the AI race by establishing equitable rules of engagement and offering a platform for knowledge sharing for responsible development. The confrontation of national approaches to AI, such as the EU's "regulation by law" approach and the US's "regulation by innovation" approach, could find constructive common ground within the WCA. By fostering open research on risks, pooling security expertise, and defining global standards, the WCA would transform a potentially conflicting domain into a space for collaboration. The collective benefit of safe, ethical, and human-serving AI would outweigh contingent national or commercial interests.

The window of opportunity for establishing a World Cognitive Agency is short. As AI capabilities increase and their integration into critical infrastructures accelerates, the possibility of establishing meaningful control diminishes. The time calls for bold foresight and concerted action, before humanity is confronted with existential challenges posed by its own creations. This is a call for institutional imagination and political will to build the foundations of a controlled digital future. Chapter 31 Pillar 5 — Chamber of Future Generations (principle) The imperative of institutional perenniality in the face of temporal precariousness.

Contemporary democratic deliberation, structured by short electoral cycles and immediate political horizons, reveals a structural incapacity to fully integrate long-term imperatives. This aporia is all the more manifest as the existential challenges of the 21st century, whether climate change, the depletion of abiotic resources, or the loss of biodiversity, are situated on pluricentennial, even millennial, timescales. The Anthropocene, as a new geological epoch, confronts our normative systems, founded on an anthropocentric and presentist vision, with an irreducible cognitive and ethical failure.

The emergence of an awareness of planetary boundaries, conceptualized by Rockström et al. in 2009 in "Planetary Boundaries: Exploring the Safe Operating Space for Humanity," has highlighted the need to redefine the very notion of sovereignty. This can no longer be conceived as an absolute prerogative of the present over the future but must be articulated with increased intergenerational responsibility. Article 17 of the French law of August 24, 2021, reinforcing republican principles, for example, mentions the "preservation of the environment, common heritage of humanity," but without a compelling constitutional mechanism for the future.

The concept of intergenerational justice, developed notably by Edith Brown Weiss as early as 1989 in "In Fairness to Future Generations: International Law, Common Patrimony, and Intergenerational Equity," lays the groundwork for a necessary overhaul of institutional architectures. It is about moving beyond a linear vision of time to embrace a cyclical and cumulative perspective, where current decisions irrevocably commit the conditions for the planet's future habitability.

The urgency is all the more pressing as the Intergovernmental Panel on Climate Change (IPCC) estimates, in its sixth assessment report (2023), that global greenhouse gas emissions must be reduced by 43% by 2030 compared to 2019 to contain warming to 1.5 °C. The limits of presentist utilitarianism and ecological debt. Dominant economic models, heirs of a utilitarian and updated vision of financial flows, struggle to integrate the intrinsic value of ecosystems and the notion of natural capital.

"Ecological debt," popularized by economists such as Joan Martinez-Alier since the 1990s, represents the accumulation of social and environmental costs transferred from the North to the South, and from the present to the future. This temporal externalization of costs is intrinsically linked to the absence of institutional mechanisms allowing future generations to assert their rights. The current model, focused on short-term profit maximization, leads to overexploitation of resources and irreversible degradation of common goods.

The discount rate used in public policies and private investments, which devalues future benefits compared to present costs, is a mathematical reflection of this temporal myopia. A 5% discount rate virtually cancels the value of future benefits beyond 50 years, making any long-term investment, even crucial for survival (Stern Review, 2006), economically "irrational." This situation is all the more critical as the world lost an average of 69% of wildlife populations between 1970 and 2018 (WWF "Living Planet Report," 2022). These eloquent figures attest to the acceleration of a sixth mass extinction, the irreversible consequences of which will weigh on countless generations.

Short-term economic rationality thus proves to be profoundly irrational from a systemic and intergenerational perspective.

Architecture and functioning of a Chamber of Future Generations. The establishment of a parliamentary institution dedicated to the representation of future generations constitutes a necessary evolution of the liberal democratic framework. Far from being a utopia, this proposal is inspired by precursors and concrete attempts to temper the tyranny of the present over the future. The objective is to confer a deliberative voice and potentially a suspensive veto right to the interests of those who do not yet have a say.

Such a chamber would not replace existing institutions but would complement them, acting as a control and alert body, endowed with specific powers to assess the long-term impacts of proposed legislation. Its composition, mode of designation, and prerogatives must be meticulously defined to guarantee its independence, legitimacy, and effectiveness. It is not about adding a bureaucratic layer but about introducing a mechanism for anticipation and systemic correction. Lessons learned from existing experiences and conceptual proposals.

The Commission for Future Generations of the Israeli Knesset, created in 2001 and active until 2006, offers an institutional precedent, albeit with purely consultative powers. Chaired initially by Professor Shlomo Avineri, it examined the societal and environmental impact of draft laws over a 20-year horizon, then 50 years. Although criticized for its lack of binding power, this initiative demonstrated the feasibility of an institution dedicated to legislative foresight. The "Committee for the Future" of the Finnish Parliament, established in 1993, illustrates a different and more integrated approach.

Initially responsible for technological and social foresight, it has become a permanent parliamentary body, with the right to deliberate on the government's future strategies and their resilience to long-term transformations. While this committee does not have a veto right, it exercises significant influence through its ability to evaluate and challenge the government on strategic orientations. The proposal developed here is in line with these experiences but emphasizes normative scope and intervention power.

A Chamber of Future Generations, ideally constitutionalized, should be composed of interdisciplinary experts (climatologists, ecological economists, sociologists, philosophers of law) and randomly selected citizens, guaranteeing a diversity of perspectives and democratic legitimacy. Its mission would be to issue reasoned opinions and formulate recommendations on any bill or executive decision whose potential repercussions exceed a defined temporal threshold, for example, 50 years. Veto and review mechanisms. The suspensive veto right is at the heart of this Chamber's effectiveness. It would not be a definitive veto but a mandatory review mechanism.

As soon as a law or decision is identified by the Chamber of Future Generations as having a significant and potentially irreversible impact on future generations, it could trigger this veto. This would oblige the two classical parliamentary chambers (or the executive power) to re-examine the text, taking into account the reservations expressed. The process could include a "second reading" or "qualified vote" procedure. For example, to override the suspensive veto, the law would have to be passed by a qualified majority (e.g., two-thirds or three-fifths of the votes) in the existing chambers, or after a specified period of deliberation.

This mechanism would ensure that long-term considerations are not simply ignored but are subject to in-depth debate and validation by a reinforced majority. Another modality could be the obligation to produce an in-depth, independent, and adversarial "intergenerational impact study" before any new deliberation. This study should assess not only future costs and benefits but also cumulative risks and potential irreversibilities. Environmental assessment legislation in Europe, such as Directive 2011/92/EU, provides a methodological framework, but its scope is too limited for intergenerational issues. The question of representation and democratic legitimacy.

The idea of a Chamber of Future Generations naturally raises fundamental questions about its legitimacy and its reconciliation with majoritarian democratic principles. How to represent entities that do not yet exist? What mechanisms can ensure that this representation does not drift towards a form of technocracy or enlightened paternalism? The tension between the sovereignty of the present people and the need to protect the future is central. The legitimacy of such a chamber does not stem from direct election, but from a legitimacy of expertise and representativeness of interests transcending current electoral mandates.

It would be a meta-governance institution, whose task is to correct the structural myopia of classic representative democracy. The argument advanced here is that the disregard for future interests already constitutes a breach of democratic legitimacy, as it alienates the rights of future generations. Modalities of composition and designation. To mitigate criticisms of technocracy, the composition of the Chamber of Future Generations should be hybrid.

A part of its members could be designated by random selection from a representative sample of the population, with diversified age and qualification criteria, regularly renewed but with a long mandate (e.g., 15-20 years) to guarantee temporal visibility. This approach is inspired by David Van Reybrouck's work on deliberative democracy and the role of sortition. Another part would be composed of recognized experts in key areas such as climate science, ecology, international law, resource economics, and moral philosophy. These experts would be designated by independent scientific institutions or by ad hoc selection committees, guaranteeing their impartiality and competence.

Their opinions would have preponderant value in the assessment of very long-term impacts. The designation of members could also include a transnational dimension, recognizing that climate and environmental challenges are borderless and require a solidarity approach.

Representatives of international organizations or global environmental NGOs could be included, without voting rights but with speaking rights, to enrich the perspective and strengthen the moral legitimacy of the Chamber. The role of scientific research and anticipation. The Chamber of Future Generations should rely on independent research and foresight bodies, endowed with substantial budgets.

These bodies would be responsible for producing regular reports on the state of the environment, demographic trends, technological innovations, and systemic risks, with projections over horizons of 100 to 300 years. This would ensure that its decisions are based on the best available scientific knowledge. The notion of the "precautionary principle," enshrined in international law (Rio Declaration, 1992, Principle 15) and integrated into many constitutions (such as in France, Article 5 of the Environmental Charter of 2004), would be an essential methodological pillar.

The Chamber should assess the risks of serious and irreversible harm to the environment or human health, even in the absence of absolute scientific certainty. It would act as a sentinel of uncertainty. The philosopher Roman Krznaric, in "The Good Ancestor" (2020), insists on the need to cultivate a collective "long-term thinking." The Chamber of Future Generations would be the institutional venue par excellence to embody this thinking, relying on sophisticated prospective analytical tools (systemic modeling, prospective scenarios, resilience analysis) and promoting an informed public debate on the issues of the future.

The integration of the Chamber of Future Generations into the legal and political order. The institutional implementation of a Chamber of Future Generations must take into account the specificities of existing legal and political systems. Its positioning within the classic tripartite powers (legislative, executive, judicial) is crucial for its effectiveness without paralyzing the democratic decision-making process. It must be perceived as a strengthening of democracy, not as an impediment. By its prerogatives, the Chamber of Future Generations would primarily fall within the legislative field.

But its influence could extend to the executive power, by obliging it to provide long-term impact studies for major strategic orientations (national budget, land use plans, international treaties). Finally, judicial remedies could be opened after a suspensive veto, guaranteeing additional accountability. Specific powers and cooperation mechanisms.

The specific powers of a Chamber of Future Generations should include: ■ Pre-legislative analysis: systematic examination of bills and legislative proposals upon their submission, with filters based on the estimated duration of impacts (e.g., impact exceeding 50 years). ■ Post-legislative analysis: evaluation of existing laws to ensure they still comply with intergenerational justice imperatives, with the possibility of recommending repeals or amendments. ■ Power of initiative: the Chamber could propose its own legislative texts, amendments, or reforms, based on the prospective reports at its disposal. ■ Referral to supreme courts: in case of deadlock with the legislative chambers, the Chamber of Future Generations could refer to the Constitutional Court or a Supreme Court for an advisory opinion concerning the intergenerational constitutionality of a law.

Cooperation with existing parliamentary chambers would be essential. Mechanisms for joint parliamentary committees, cross-hearings, and regular exchanges between members of the different chambers would help avoid institutional blockages and foster a culture of foresight and long-term responsibility within the entire legislative body. The objective is to infuse the consideration of future generations into all public decision-making. A profound transformation of democratic governance. The establishment of a Chamber of Future Generations would not merely be an institutional modification but a strong signal of a profound normative and ethical transformation.

It would institutionalize the principle of "intergenerational subsidiarity," according to which decisions made today must preserve the freedom and capacity for action of future generations. This innovation would strengthen the resilience of democracies in the face of 21st-century systemic challenges, by giving them a capacity for anticipation and correction that is sorely lacking today. It is a pragmatic and institutional response to the moral imperative of the philosopher Hannah Arendt, who, in "The Crisis of Culture" (1961), called for preserving the world not only for us but also and above all for our descendants.

This would allow humanity to resolutely embark on the path of "good ancestry," by building a tradition of responsibility towards the future. Chapter 32 Pillar 5 — Composition, Mandates, Indicators Architecture of the Fifth Pillar: A Systemic Assembly The Fifth Pillar, a supranational entity designed to evaluate and guide the civil trajectories of society-environment interactions, rests on a hybrid composition and precisely circumscribed mandates, aiming to transcend the pitfalls of existing multilateral bodies.

The objective is to institutionalize a form of epistemic and decisional regulation, capable of confronting the intrinsic complexity of anthropocene challenges and proposing coordinated courses of action, founded on both democratic and scientific legitimacy. Its structure thus combines citizen representativeness and scientific expertise, seeking a balance between technocratic relevance and democratic acceptability. This architecture draws inspiration from Pierre Rosanvallon's work on "impartiality democracy" (2008), where intermediate bodies, free from direct electoral pressures, are entrusted with qualification and control missions, complementing expressive democracy.

It also integrates Elinor Ostrom's reflections (1990) on common-pool resource management, which underscore the imperative of local legitimacy and rules adapted to resource specificities. The Fifth Pillar thus positions itself as an institution of last resort, endowed with the capacity to issue binding opinions and strategic recommendations in the face of systemic deviations observed on a planetary scale, such as the transgression of planetary boundaries identified by Rockström et al. in 2009. Hybrid Legitimacy: Citizens Selected by Lot and Scientific Experts The composition of the Fifth Pillar is a cardinal element of its legitimacy and effectiveness.

It will consist of a college of members, two-thirds of whom will be drawn by lot from the citizens of the State Parties, and one-third will be composed of experts from global scientific academies. This proportion is not fortuitous; it reflects the desire to reconcile a lay perspective, rooted in the diversity of lived experiences and citizen concerns, with the acuity and depth of scientific analysis, guaranteeing a rigorous understanding of the biophysical and socio-economic processes at play.

The selection of citizens by lot, a secular democratic designation mechanism whose use dates back to Athenian democracy, has been reactivated in contemporary reflections on democratic revitalization (Manin, 1995). It offers an alternative to the biases of elective selection, promoting the inclusion of non-professional political profiles and offering a more faithful representation of society in its sociological, geographical, and cultural diversity. The 96 citizen members will be randomly selected from the active populations of the signatory states, by age, gender, and geographical region strata, to ensure balanced representation.

The 48 scientific experts will be designated by recognized bodies such as the Union of International Academies, the International Council for Science (ICSU, founded in 1919), or ad hoc committees guaranteeing their independence and excellence. They will cover the entire spectrum of relevant sciences: ecology, climatology, ecological economics, international environmental law, sociology of organizations, environmental ethics. Interdisciplinarity will be a primary selection criterion, to allow for the integration of knowledge necessary for a holistic understanding of systemic problems.

Mandates and Pre-eminence of the Fifth Pillar The main role of the Fifth Pillar is to evaluate the conformity of public policies and national and supranational development trajectories with the objectives of ecological resilience and intergenerational justice. Its mandate is structured around three cardinal functions: proactive evaluation, formulation of recommendations, and the issuance of suspensive vetoes in precisely defined cases. This level of competence has no equivalent in the current international system.

The proactive evaluation function involves continuous analysis of global (greenhouse gas emissions, biodiversity loss, depletion of strategic resources) and national "trends," based on reliable scientific data and prospective modeling. The Fifth Pillar will compile and synthesize reports from the IPCC (Intergovernmental Panel on Climate Change, created in 1988), the IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, created in 2012), and other relevant scientific organizations, to produce independent and synthetic evaluations. This function feeds strategic watch and early detection of systemic threats.

The recommendations of the Fifth Pillar will initially be non-binding, but their moral and epistemic weight should encourage states to integrate them into their strategies. They will concern regulatory adjustments, investment reorientations, technological innovations, or changes in socio-economic paradigms. These recommendations will be public, reasoned, and accompanied by deadlines and monitoring indicators, allowing for traceability and evaluation of their implementation. The Suspensive Veto Right: An Instrument of Institutional Revolution The most disruptive power entrusted to the Fifth Pillar lies in its right of suspensive veto.

This mechanism, unprecedented at this scale and in this modality, aims to protect planetary common goods and the rights of future generations against immediate political or economic decisions whose irreversible impact would be scientifically demonstrated. The veto is not a power of permanent prohibition, but a suspension of the decision, offering a period for re-examination and adjustment.

This right of veto will apply exclusively to policies, large-scale projects, or international treaties which, on the basis of a rigorous scientific evaluation, would be deemed to constitute an existential threat or proven irreversible damage to one or more crucial planetary systems (climate, biodiversity, biogeochemical cycles) or which would manifestly compromise the living conditions of future generations.

A triggering threshold could be set, for example, for the proposal of a project whose greenhouse gas emissions would exceed, over its lifetime, a specific residual carbon budget allocated by the Pillar, or whose habitat destruction would lead to the disappearance of 5% of endemic species. The veto process would be initiated by a proposal from a Pillar member, requiring the support of a certain percentage of members (e.g., one-third), followed by in-depth deliberation and a qualified vote (e.g., two-thirds of all members, including a qualified majority of experts).

The decision would then be transmitted to the State or the concerned body, which would have a reasonable period (e.g., 6 to 12 months) to revise its position or present robust compensatory measures, failing which the veto would be converted into a recommendation for injunction before the International Court of Justice, opening the way to economic or legal sanctions. Term Lengths and Remuneration The term lengths of the members of the Fifth Pillar are designed to promote collective learning, the production of internal expertise, and institutional resilience, without generating excessive professionalization that would undermine the freshness of citizen perspectives.

Members are appointed for a single, non-renewable term of three years. This period allows for sufficient immersion in the complexities of the issues, without rooting individuals in a career within this body, thus preserving their autonomy from political or corporatist pressures. Non-renewability aims to maintain the diversity of profiles and to avoid capture by particular interests or the formation of a closed elite. Progressive renewal (one-third of members each year, for example) could be considered to ensure continuity of institutional knowledge and avoid too abrupt a discontinuity.

This rotation would guarantee the constant injection of new perspectives while capitalizing on acquired experience. The remuneration of citizen members is a crucial issue to ensure the participation of all, regardless of their socio-economic situation, and to recognize the value of their commitment. It would be set at the median salary of each country of origin, converted into a stable reference currency. For example, if the median French salary is about 2,000 net euros per month in 2024 (Insee), a French citizen would receive this sum, with additional compensation for housing and travel expenses.

Scientific experts, already remunerated by their original institutions, would receive reimbursement and compensation for the time allotted, but the essence of their motivation will come from their ethical and scientific commitment. Performance Indicators and Accountability The effectiveness and legitimacy of the Fifth Pillar, as a global regulatory body, will intrinsically depend on its ability to demonstrate its relevance and impact. To this end, a set of performance indicators will be put in place, allowing for continuous evaluation of its action and its accountability to global populations and signatory states.

These indicators do not measure "value creation" in the classical economic sense, but rather the contribution to systemic resilience and environmental governance. One of the key indicators will be the *number of vetoes issued*. Too high a number could indicate an inability of the international system to adapt and a generalized failure of national environmental policies, but also the Pillar's integrity and determination to exercise its mandate without complacency. Conversely, too low a number could be a sign of excessive caution or an underestimation of systemic impacts. The important thing is not the volume, but the accuracy and adequacy of the vetoes to the real challenges.

The *rate of confirmation of vetoes or strong recommendations* by the states or concerned bodies is another essential indicator. It reflects the authority and recognized legitimacy of the Fifth Pillar. If a high confirmation rate (for example, 75% of vetoes lead to effective re-examination and policy modification) could testify to the acceptance of its role as an impartial and effective arbiter of planetary limits, a low rate would indicate resistance from states or a lack of resonance of the Pillar's arguments.

The Average Time Horizon of Decisions A novel and fundamental indicator for evaluating the singularity of the Fifth Pillar is the *average time horizon of the decisions and recommendations formulated*. Unlike classic public policies, often confined to short-term electoral cycles (2 to 5 years), the action of the Fifth Pillar must be situated in a long-term perspective, compatible with ecological temporalities and intergenerational stakes. For example, the response time of the climate system to a greenhouse gas perturbation can extend over centuries, even millennia, as shown in the 2021 IPCC report on the physical basis of climate change.

The same applies to the reconstitution of biodiversity or soil decontamination. This indicator will therefore measure, in years or decades, the average temporal projection of the impacts of the decisions to which the Fifth Pillar reacts, and the foresight of the measures it proposes. This time horizon would be expected to be significantly higher (e.g., beyond 30 years on average) than that of traditional political institutions (generally less than 5-10 years). These indicators will be published annually in an activity report detailing all deliberations, decisions, and evaluations produced by the Fifth Pillar.

This report will serve as a basis for continuous dialogue with State Parties, international institutions, and civil society, guaranteeing maximum transparency and constant accountability to the global community. The objective is to consolidate confidence in this new form of governance and to demonstrate that it is possible to articulate democracy, science, and a long-term vision for the sustainability of Earth systems. The legal conception of this Pillar relies on the principle of inverse subsidiarity, where the superior body acts when lower levels fail to achieve an optimal result on goods of higher interest, while respecting the autonomy of states.

This sui generis international legal model, requiring unanimous ratification by the permanent member states of the UN Security Council, as well as a qualified majority of other member states (for example, 75% of states representing 80% of the world's population and 60% of world GDP), would constitute a historic milestone, profoundly altering the hierarchy of international norms. Such a ratification requirement illustrates the extent of consensus necessary to establish an institution endowed with such singular prerogatives.

The proposed model for the Fifth Pillar does not simply coexist with existing structures; it aims to complement, even recalibrate them, by introducing a body endowed with a legitimacy of scientific authority and unprecedented citizen representation, capable of arbitrating the fundamental dilemmas between short-term national sovereignty and the long-term existential imperatives for humanity. The challenge lies in the capacity of nations to accept this self-limitation for mutual and intergenerational benefit.

Chapter 33 Pillar 5 — Articulation with Democracy Environmental Democracy: A Reconstruction of the Representative Mandate The integration of ecological imperatives at the heart of the democratic decision-making process cannot be limited to a cosmetic addition, but must entail a profound reconfiguration of the mechanisms of representation. Political ecology, from its theoretical origins with André Gorz (1977, *Écologie et politique*), has underscored the inadequacy of classical liberal institutions in apprehending the long temporalities and systemic interdependencies inherent in the environmental crisis.

The challenge lies in the capacity to insert substantive safeguards without paralyzing legislative action or emptying the principle of popular sovereignty, exercised by its representatives, of its substance. The parliamentary system, by its very nature, is often subject to short electoral cycles (cf. average duration of a legislature in the EU, approximately 5 years), encouraging a focus on immediate benefits rather than on deferred costs or long-term planning. This propensity for short-termism is a proven structural limitation for the management of climate and biodiversity issues, whose deadlines are measured in decades, or even centuries.

It is therefore imperative to introduce mechanisms that temper this structural inertia, without, however, substituting themselves for the democratic legitimacy emanating from elections. The Environmental Suspensive Veto: An Instrument for In-Depth Deliberation A novel legislative instrument would reside in the establishment of an "environmental suspensive veto," granted to an independent institution, specially designated or adapted to ensure the conformity of legislative bills with fundamental ecological objectives.

This veto would not be absolute, but would allow a legislative text to be returned to Parliament for an in-depth re-evaluation of its environmental impacts, accompanied by detailed arguments and proposed amendments. This would be a "brake and relaunch" mechanism rather than a definitive blockage. The primary objective of this mechanism is to force a more complete and informed deliberation on the environmental consequences of laws, beyond usual socio-economic considerations. For example, a financial law that, directly or indirectly, massively subsidizes fossil activities could be subject to this veto, requiring the legislator to fully justify this orientation or to modify it.

This aligns with the advances in environmental law, which has progressively internalized negative externalities, as highlighted by Directive 2011/92/EU concerning the assessment of the effects of certain public and private projects on the environment. The power of this suspensive veto would not reside in its definitive character, but in its ability to catalyze renewed public and parliamentary debate. It would provide environmental interest groups and citizens with an institutional platform to voice their concerns before final promulgation. Parliament would retain the final say, but it would be compelled to do so with full knowledge and deliberation of the ecological issues raised.

Overriding the Suspensive Veto by Constitutional Referendum In the face of a persistent suspensive veto not lifted by Parliament after a second, or even a third, examination, an override mechanism must be considered to avoid institutional paralysis. The designation of a constitutional referendum represents a middle ground between the omnipotence of an ecological institution and popular sovereignty, when the issue is deemed of such gravity and scope that it transcends the ordinary legislative framework. This referendum would not concern the initially challenged text, but the question of the validity of the ecological authority's opinion in relation to the expressed legislative will.

A threshold for implementation should be clearly defined, for example, the consecutive rejection by Parliament of two suspensive veto opinions issued by the competent authority on the same bill or on a set of interdependent measures. This threshold could be modulated by criteria such as the nature of the environmental issues – for instance, if the law in question contradicts a constitutional objective regarding climate or biodiversity, like the European Green Deal (2019) which aspires to carbon neutrality by 2050. It is not a simple political opposition that would trigger this referendum, but a substantial disagreement on the application of fundamental ecological principles.

The "constitutional" nature of this referendum is essential. It confers a greater weight on the popular decision than that of an ordinary law and places it at the level of the fundamental principles of the State. This type of consultation would resemble an "invocation" of the sovereign people on a question of principle, beyond the contingencies of daily politics. It would compel citizens to decide on the arbitration between legislation perceived as necessary by their representatives and the ecological imperatives raised by the oversight authority. The works of Cass R.

Sunstein (1993, *The Partial Constitution*) on the evolving nature of constitutional frameworks could illuminate this dynamic of adaptation. This referendum mechanism offers double legitimacy: that of the Parliament, which initially adopted the law, and that of the sovereign people who ultimately decide on a dispute of crucial importance. This would strengthen "deliberative democracy" (Jürgen Habermas, 1992, *Faktizität und Geltung*) by offering an enlarged arena for debate on major ecological orientations, extending beyond the strictly parliamentary framework.

While Switzerland frequently uses referendums for its ordinary laws (approximately 10 per year voted on by the people), here an exceptional use is proposed, circumscribed to a profound institutional disagreement on vital principles. The Extended Constitutional Court in Appeal: Ecological Jurisprudence and Collegial Wisdom In the event of a constitutional appeal following a major dispute unresolved by ordinary parliamentary and referendum channels, an "Extended Constitutional Court" would be the ultimate appellate body. This Court would differ from a classical constitutional court by its specific composition and an extended mandate.

In addition to its usual judges, it would include recognized experts in climate science, biodiversity, international environmental law, and ecological economics. The objective is to enrich legal deliberation with scientific and systemic expertise, making the decision more robust in the face of the complexity of ecological challenges. The Court would not merely apply a strict constitutional text, but would interpret constitutional principles in light of the most advanced scientific knowledge and sustainability imperatives.

This approach is part of emerging jurisprudence that recognizes "climate justice" and the rights of future generations, as illustrated by the decision of the Supreme Court of the Netherlands in the Urgenda case (2019), which compelled the State to reduce its greenhouse gas emissions by 25% by the end of 2020 compared to 1990 levels. The composition of this extended court would guarantee a plurality of perspectives and an interdisciplinary analytical capacity.

Alongside experienced lawyers (for instance, demonstrating a 70% rate of parity), Nobel Prize-winning climatologists or biologists specializing in conservation could provide indispensable insights into the gravity of impacts and the urgency of actions. This multidisciplinary approach is crucial, because environmental issues are reducible neither to purely legal questions nor to purely scientific questions; they demand an informed synthesis. The role of this court would be to verify the full conformity of contested laws with constitutional principles and objectives relating to environmental protection, integrating consolidated scientific knowledge.

It would act as an ultimate barrier against decisions which, although seemingly legitimate from a positive law perspective, would be manifestly incompatible with the long-term viability of socio-ecological systems. This high instance would contribute to the emergence of an "ecological imperative law," anchored in Earth system sciences. The Safeguard Against Paralytic Conservatism: The Dynamic of Adaptation

The proposed institutional architecture, with its mechanisms of suspensive veto, constitutional referendum, and extended Constitutional Court, could raise fears of legislative paralysis or conservative drift.

A system that is too rigid, unable to adapt to the rapid evolution of societies and scientific knowledge, risks freezing decision-making and hindering the innovation necessary for ecological transition. However, these mechanisms are precisely designed to avoid an "environmental tyranny of the minority" or irreversible systemic blockage. The suspensive, rather than absolute, nature of the veto, is the first level of protection against conservatism. It offers Parliament the possibility to revise its position, to deliberate anew, and to justify its choices.

In France, the Constitutional Council has the power to strike down a law before its promulgation, but does not have a power of reasoned "rejection" aimed at re-deliberation. This new mechanism would force a more in-depth public and parliamentary deliberation, which currently only exists through debates and amendments. Almost 80% of laws voted in Europe are not preceded by a significant environmental impact study, according to an OECD study (2020). The constitutional referendum, subsequently, is a democratic safety valve. It transfers the final decision to the sovereign people in cases of profound divergences between the ecological oversight institution and parliamentary representation.

This procedure is by nature exceptional and would be framed by high thresholds (for example, a quarter of the members of Parliament, one million citizen signatures, or the persistence of disagreement between bodies) avoiding its untimely use. It is not a mechanism for continuous questioning of public policies, but an ultimate arbitration on fundamental societal choices. Finally, the Extended Constitutional Court, by the diversity of its composition and the nature of its mandate of constitutional interpretation in the light of scientific knowledge, is a bulwark against dogmatic conservatism.

It ensures the evolvability of law, capable of integrating new data and the constantly renewed urgencies of natural systems. The German constitution, for example, in its article 20a, protects the natural bases of life, thus offering an anchor point for the "evolutionary" interpretation that this Extended Court would be called upon to implement. This dynamic avoids the "constitutional lock-in" observed in some states whose constitutions, written at a time when the ecological crisis was unthinkable, offer no flexibility.

The Requirement for a Profound Constitutional Revision for Ecological Integration The implementation of these mechanisms absolutely necessitates a substantial constitutional revision. This is not about adding marginal paragraphs, but about deeply embedding the principles of sustainability and the rights of future generations at the heart of the fundamental legal order. This approach is a continuation of the global movement of constitutionalization of environmental law, driven by examples like the Constitution of Ecuador (2008) recognizing the rights of Nature (Pachamama).

In France, the Environmental Charter (2004) integrated into the block of constitutionality is a first step, but its scope is judged insufficient by many jurists (B. Beignier, 2018, *Droit de l'environnement*). Such a revision should explicitly define "planetary boundaries" (Rockström et al., 2009, *Nature*) as frameworks for public action, and introduce an "intergenerational sustainability duty." The status of the suspensive veto institution should also be determined, guaranteeing its independence and its expertise capacity.

Without the entrenchment of these principles at the constitutional level, the proposed mechanisms would remain fragile constructions, subject to the vagaries of parliamentary majorities. The normative force of a constitution is essential to confer real effectiveness to environmental rights. The very process of constitutional revision could be an opportunity for a vast public debate on the place of the environment in our social contract. This would be a foundational moment, similar to the Citizens' Climate Conventions, which showed that citizens are ready for ambitious proposals when given the necessary time and information.

This process could, for example, draw on the experience of Ireland, which organized a Citizens' Assembly (2016-2018) to address complex constitutional issues, such as voluntary termination of pregnancy, with notable success in terms of legitimacy. This constitutional overhaul offers a historic opportunity to realign representative democracy with the demands of the biosphere. It aims to ensure that decisions made today do not irreversibly compromise the conditions of existence for future generations, nor the stability of the ecological systems on which all forms of life depend. This is an ethical, political, and legal imperative in the face of accelerating environmental crises.

According to the IPCC (2023, Synthesis Report of the Sixth Assessment Report), approximately 3.3 to 3.6 billion people live in contexts highly vulnerable to climate change, highlighting the urgency of this transformation. Articulation with Political Philosophy and the Future of Democracies The integration of these ecological mechanisms within representative democracies is not a mere technical reform; it questions modern political philosophy itself, particularly the anthropocentric conception of sovereignty. The idea that sovereignty emanates exclusively from humans and is exercised unhindered over nature or future generations has become untenable in the face of planetary limits.

Hans Jonas (1979, *The Imperative of Responsibility*) masterfully posited the necessity of an ethics of responsibility for the future, which must infuse law and politics. The proposed mechanisms strive to rethink the representative mandate beyond the sole short-term electoral logic. They aim to inject a dimension of "representation of non-humans" (Bruno Latour, 2004, *Politics of Nature*) and "non-voters" (future generations) into the heart of the decision-making process.

The suspensive veto, the constitutional referendum on ecological principles, and the extended Constitutional Court, become as many levers to "make intelligible" the "voice" of what is not directly represented in the ballot box.

This reconfiguration proposes to move from a purely procedural democracy to a "substantive ecological democracy," where processes are conditioned by the recognition and protection of an incompressible "biophysical foundation." Debates on "commons" (Elinor Ostrom, 1990, *Governing the Commons*) are pertinent here, as they highlight the need for adapted governance for shared and fragile resources, which cannot be left solely to the invisible hand of the market or to the discretion of opportunistic political decisions.

The risk of "government by experts," often raised in the face of the integration of technical bodies, is here curbed by maintaining the political primacy of Parliament and, ultimately, of the sovereign people. Scientific and ecological expertise enriches deliberation and enlightens decision, but does not substitute for it. This is an invitation to a more mature democracy, capable of integrating complexity, uncertainty, and the long term, rather than an abdication of sovereignty. It aims to reconcile democratic legitimacy with ecological legitimacy, both essential to each other for the survival of human societies.

Chapter 34 Pillar 6 — Energy-currency (standard Thermodynamics) The physical limits of the conventional monetary standard The contemporary monetary system is based on social and legal conventions, largely dissociated from any intrinsic physical constraint. Having abandoned the gold standard from 1971 under the Nixon administration, fiat currency is now a pure claim regulated by central banks, its value determined by confidence and supply and demand. This arrangement has allowed unprecedented economic expansion, but it has also underestimated the ecological and energetic implications of the unlimited growth it implicitly encourages. Modern economies are fundamentally energy-intensive.

The production of goods and services, transport, intensive agriculture, and even digital infrastructures, all depend on a constant and growing supply of energy. This physical reality, highlighted by Nicholas Georgescu-Roegen's work in 1971 in "The Entropy Law and the Economic Process", stands in striking contrast to the monetary abstraction that prevails. Energy, for its part, is subject to the immutable laws of thermodynamics, notably its law of increasing entropy which implies that no energy transformation is perfect and that useful matter-energy inevitably degrades. The idea of a currency backed by a real resource is not new.

From the beginning of the 20th century, thinkers like Frederick Soddy, Nobel laureate in chemistry in 1921, anticipated the energy crisis and the necessity of a stable currency, anchored in the productive system's capacity to generate energy and not credit. In "Wealth, Virtual Wealth and Debt" (1926), Soddy criticized the illusion of purely financial wealth and advocated for a currency representing "real wealth" – that is, available energy and material resources. The disconnection between monetary value and physical energy leads to a mistaken perception of wealth.

Unlimited monetary creation, without physical counterpart, can generate inflation, but above all, overconsumption of natural resources. This dynamic is particularly observable in the context of fossil fuel extraction, where the monetary cost does not reflect the total energy cost required to extract, process, and transport them, much less the environmental and climatic externalities. The concept of an energy-currency: genesis and foundations The idea of an energy-indexed currency finds its roots in the Technocracy movement, founded in the United States in the 1930s. Figures like Howard Scott and M.

King Hubbert (known for peak oil "Hubbert's Peak") formulated, as early as 1932, audacious proposals for an overhaul of the economic system based on an energy accounting unit. Their observation was that the industrial age had transformed human labor into machine labor, thereby amplifying energy consumption on an unprecedented scale. Technocrats proposed the "energy certificate" as the fundamental unit of account, which was to replace the monetary system based on artificial scarcity and debt. Their ideal currency was defined as the quantity of net energy produced by a society, measured in joules or kilowatt-hours.

This unit, non-hoardable and perishable, would have constrained consumption to remain within the limits of real energy production, thus avoiding waste and the accumulation of unproductive capital. A crucial aspect of this proposal rested on the concept of EROEI (Energy Return On Energy Invested) or EROI. EROEI measures the ratio between the energy delivered by a system and the energy required to obtain it. For a sustainable society, a high EROI is essential. Historically, conventional oil extraction had an EROI of about 100:1 in the 1930s.

It fell to about 20:1 for conventional oil and gas around 2000, and stands at around 5:1 to 10:1 for oil shale and 3:1 for certain renewable sources like photovoltaics in existing installations, according to studies by Hall and Prélat (2012). For an energy to be considered "net" and thus capable of supporting a complex industrial society, a minimum EROI is required. Technocrats estimated that an EROI greater than 5:1 was necessary for basic societal functions (food, housing, etc.).

The proposed energy-currency unit, the NÖM (acronym for the accounting unit), is thus defined as the equivalent of one gigajoule (GJ) of final net energy, meaning after deduction of the energy needed for its production, processing, and transport, and excluding energies with a low EROI (below 5:1). This 5:1 threshold is a critical value for maintaining a complex industrial civilization, according to recent analyses by Murphy and Hall (2011) in "Energy and the Wealth of Nations". Below this, the energy available for non-energy activities (health, education, culture) becomes too low, compromising social well-being.

Implications of a thermodynamic standard for economic governance The adoption of a thermodynamic standard would lead to a radical transformation of economic governance. The value of currency would no longer be dictated by financial markets or discretionary decisions of central banks, but by the physical capacity of the productive system to generate a quantity of useful and exploitable energy. This would introduce a form of ecological rationality at the heart of economic decision-making, directly linking prosperity to sustainability. The first implication would be a redefinition of investment priorities.

Projects with a high EROI would be favored, while those with a low EROI would become economically unviable. For example, the exploitation of Canadian oil sands (whose EROI is estimated between 3:1 and 5:1 according to the International Energy Agency, 2018) would become marginal, in favor of investments in high-EROI renewable energies, improvements in energy efficiency, or innovations drastically reducing final consumption. The concept of economic growth, as it is understood today, would also be profoundly questioned. Infinite growth on a planet with finite resources is a physical impossibility, as Herman Daly and Joshua Farley highlighted in "Ecological Economics" (2004).

The NÖM would not allow for monetary creation ex nihilo, unless it is correlated with a real increase in available net energy. This would compel economies to adapt to planetary limits, thus favoring sobriety and efficiency rather than material expansion. Monetary policy itself would be transformed. Central banks would no longer manipulate interest rates or the money supply based on inflation or employment targets, but would adjust the creation of NÖM based on national energy balances, measured and certified by independent bodies. This would be centralized energy management, not to dictate individuals' lives, but to ensure the physical viability of society.

The European Parliament, in its 2015 Declaration on the Circular Economy, recognized the need to "decouple economic growth from resource consumption," a process that the NÖM would make systemic. Technical and societal challenges of the transition The implementation of an energy-net-based monetary standard poses considerable technical and societal challenges. Technically, it is necessary to develop standardized and reliable EROEI measurement methodologies for all forms of energy, from extraction to final use. This implies sophisticated energy accounting systems, capable of integrating data from very diverse sectors (nuclear, wind, solar, biomass, geothermal, etc.).

The European Green Deal initiative, launched in 2019, aims for climate neutrality by 2050, but without integrating an energy standard, its materialization remains uncertain, dependent on monetary fluctuations. The difficulty also lies in establishing an international consensus on acceptable EROEI thresholds and methods for evaluating energy externalities. The Paris Agreement on climate (2015) is an example of the scale of coordination required, but it does not address monetary abstraction. A consensus on a "basket of net energies" could be reached, combining different sources with varied EROIs, but whose average would respect sustainability criteria.

Societally, abandoning a fiat monetary system in favor of a thermodynamic standard would inevitably encounter strong resistance. Current financial institutions, actors in the extractive economy, and proponents of infinite economic growth would oppose a reform that would challenge their foundations. Such a transition would require massive education and strong political vision to convince populations and elites of the necessity of such a change. Adaptation of lifestyles and consumption habits would also be imperative. A currency linked to net energy would encourage more parsimonious use of resources, relocation of production, and the development of more sober and resilient societies.

This could mean a reduction in material consumption per inhabitant, contrary to historical trends, but with the advantage of long-term economic and ecological stability. Thermodynamics as the ultimate arbiter of wealth The vision of an energy-currency, far from being a utopia, is an attempt to re-anchor the economy in the physical reality of the world. Nobel laureate in physics Richard Feynman recalled in his "Lectures on Physics" (1963) that "energy is an abstract notion that manifests itself in different forms." It is this fundamental nature of energy that makes it a potentially universal and objective standard.

In a broader perspective, the adoption of a thermodynamic standard would not only be a monetary reform but an ontological refoundation of our relationship to wealth and the environment. It would recognize that natural capital and energy are the true foundations of all sustainable prosperity, and not externalities that can be ignored or compensated. GDP or Gross Domestic Product, a historical indicator of a country's "value," has been criticized by economist Joseph Stiglitz in "Mismeasuring Our Lives, Why GDP Doesn't Add Up" (2010), precisely for its inability to integrate these ecological and social costs.

The NÖM energy-currency could thus serve as an interface between the two dimensions of sustainability: ecological and economic. By constraining economic expansion through energy boundaries, it would make growth intrinsically sustainable, or, more likely, it would encourage a transition to a stationary economy, in line with Daly's proposals. This latter concept, developed in the 1970s with his book "Steady-State Economics" (1977), advocates for an economy where the stock of physical capital and population are maintained at constant levels, thanks to a minimized and regulated flow of matter and energy.

A thermodynamic standard, the NÖM, would transcend current monetary and geopolitical divisions. Its value would be universally intelligible, as it would be based on an impartial physical law. The energy necessary for maintaining a decent life would be sanctified, while the production of superfluous goods would be intrinsically limited by the availability of net energy. This is a vision that, while radical, offers one of the few ways to reconcile human ambition with the ecological imperatives of the 21st century.

A system of regulation by EROEI and energy accounting The implementation of an NÖM energy-currency (1 GJ of net energy, EROI > 5:1) would require a robust, transparent, and decentralized regulatory system. At the heart of this system would be the EROI certification body, an independent supranational entity whose role would be to measure, verify, and certify net energy produced and consumed globally. This institution would be tasked with collecting precise data on the entire energy value chain, from extraction to final consumption, applying uniform and rigorous protocols.

The data collected would include not only gross energy produced, but also all upstream energies invested (construction of infrastructure, extraction of materials, transport, maintenance, decommissioning). The application of a minimum EROI threshold (5:1 in the NÖM proposal) would be fundamental: any energy source whose EROI is below this threshold would not be counted as "net" and therefore could not serve as a basis for NÖM creation. This would discourage the exploitation of marginal and environmentally destructive energy resources, such as certain forms of unconventional fossil fuels or low-yield bioenergies.

Energy accounting would take place at several levels: international, national, and regional. Each nation would be obliged to publish an annual net energy balance, audited by the EROI certification body. This balance would become the basis for its annual "monetary budget" in NÖM. NÖM credits would be allocated based on net energy production and consumed based on energy expenditures. A nation that develops high-EROEI energy sources would see its monetary capacity increase, thereby encouraging investment in efficient and sustainable energy technologies.

The NÖM distribution mechanism could draw inspiration from universal income proposals, but in the form of an "energy dividend." Each citizen would receive an annual allocation of NÖM, guaranteeing access to a minimum amount of energy necessary to satisfy their basic needs (housing, food, transport). All commercial transactions would then be carried out in NÖM, replacing current fiat currencies. This accounting and regulatory system would transpose the laws of physics into the economic sphere, offering an objective compass for the management of planetary resources.

A new definition of wealth and prosperity The transition to an energy-currency would transcend simple monetary reform to redefine wealth and prosperity. Far from being synonymous with austerity or punitive degrowth, an NÖM economy would allow for the alignment of human well-being with the planet's regenerative capacities. Wealth would no longer be measured in terms of material accumulation or unlimited GDP growth, but by a society's ability to generate net energy sustainably and allocate it equitably. "Prosperity without growth," a concept advocated by Tim Jackson in his eponymous work in 2009, would find concrete application with the thermodynamic standard.

Instead of chasing quantitative expansion, societies would focus on the qualitative improvement of life: robust public services, quality health and education systems, cultural richness, and biodiversity preservation. These dimensions of well-being, often neglected by traditional economic indicators, would be highlighted, as they require less material energy than the production of superfluous consumer goods. The transition to energy-currency would encourage innovation in the fields of energy efficiency, the circular economy, and repair.

Instead of manufacturing products with planned obsolescence, companies would be encouraged to design durable, repairable, and recyclable goods, as this would minimize their net energy footprint in the long term. Economic models based on leasing and sharing, which reduce overall resource consumption, would become predominant. The European legislative framework of 2020 on green taxonomy illustrates a first attempt to classify sustainable investments, but without the energy anchoring of the NÖM, its impact remains partial. This paradigm shift would be radical. It would require completely rethinking macro and microeconomic policies.

Taxation, for example, could no longer be based on labor or capital, but on gross energy consumption or non-compliance with EROEI thresholds. Subsidies could be allocated to innovations that increase EROEI or reduce final energy demand. Ultimately, the thermodynamic standard offers a structured path towards a civilization that respects the laws of physics, while ensuring a high quality of life for all its inhabitants, within the sustainable limits of the biosphere. Chapter 35 Pillar 6 — Transitional Coexistence with Fiat The Irreducible Necessity of an Ecological Conversion Currency.

Energy transition and the management of critical raw materials are major geopolitical stakes of the 21st century, deeply intertwined with the structure of the international monetary system. The sustainability of cross-border trade, particularly concerning energy and strategic resources, is constrained by an intrinsic volatility of fiat currencies. This volatility, exacerbated by fluctuating macroeconomic and geopolitical factors, compromises price stability and the visibility of crucial investments for the decarbonization of the global economy.

The Bretton Woods system, symbolized by the gold standard, aimed for a certain exchange rate stability, but its dissolution in 1971 paved the way for a floating exchange rate regime, a source of uncertainty. The recurrent occurrence of financial crises, such as that of 2008, highlighted the fragility of national currencies in the face of exogenous shocks. An innovative approach is imperative to secure vital supply chains and direct financial flows towards a more resilient and ecologically sustainable economy. Systemic Failures of Fiat in the Resource Economy.

Fiat currencies, devoid of intrinsic value and whose value relies on the confidence of economic agents and the credibility of the issuer, are ill-suited to the stable and intergenerational valuation of non-renewable goods. The exchange rate often reflects macroeconomic imbalances, unilateral monetary policy decisions, or geopolitical tensions, thereby decoupling the price of resources from their ecological scarcity and their social cost of production. This decoupling is particularly evident for critical raw materials (CRMs), whose supply is concentrated. For example, in 2021, China accounted for over 60% of global rare earth production (USGS, 2022).

Such pronounced dependence exposes importers to risks of economic blackmail or supply disruption, aggravated by monetary instability. The dollarization of energy and raw material markets, while convenient due to its historical liquidity, exposes non-dollar-issuing nations to exchange rate shocks during sudden appreciations or depreciations of the US currency. Current regulations struggle to internalize the environmental externalities of transactions. The market for greenhouse gas emission allowances, such as the EU-ETS (European Union Emission Trading Scheme) framed by Directive 2003/87/EC, is an attempt to monetize carbon.

However, the convertibility of these allowances via fiat currencies does not guarantee a direct and stable correlation with the actual climatic impact, as the price of carbon itself remains subject to fluctuations in carbon markets and political interventions, which Pindyck (2013) extensively analyzed for energy prices. A Mandatory Conversion Model for Ecological Resilience. The establishment of a mandatory conversion currency for cross-border transactions of energy, critical raw materials, and emission allowances is a strategy designed to overcome the shortcomings of the current monetary system in the face of ecological challenges.

This currency does not aim to supersede national currencies in daily trade but to establish a stable and predictable settlement mechanism for strategic exchanges that underpin the transition to a sustainable economy. The fundamental principle is to detach the value of these essential transactions from the vagaries of national monetary policies and to anchor it in a basket of references based on ecological sustainability criteria and intrinsic scarcity. This mechanism would offer protection against monetary depreciation, reduce transaction costs related to currency conversion, and, above all, encourage better resource management. The Architecture of an Audited Multi-Source Basket.

Inspired by the IMF's Special Drawing Rights (SDRs) model, created in 1969, but with a decidedly ecological orientation, this basket would be composed of assets weighted according to precise criteria. One could envision a hybrid composition integrating renewable energy metrics (MWh emitted from solar, wind, geothermal sources), certified reserves of critical raw materials, weighted by their "carbon footprint" of production, and verified and unused carbon emission quotas.

The audit of this basket would be carried out by an independent international entity, endowed with a clear mandate and multi-stakeholder governance mechanisms (States, scientists, environmental NGOs, representatives of multilateral institutions). This entity would be responsible for certifying the underlying assets, determining the weightings, and regularly adjusting the basket's composition to reflect technological advancements and sustainable development goals. The transparency and impartiality of this audit, as stated in the OECD Principles of Corporate Governance (2015), would be guaranteed by public access to underlying data and evaluation reports.

For example, the price of lithium used in electric batteries could be correlated with the renewable energy consumption required for its extraction and refining, in addition to its geological scarcity. The share of nuclear energy or green hydrogen in the energy mix of producing countries would be valued, creating a direct incentive for the adoption of cleaner production practices. Approximately 70% of global lithium is mined in Australia, Chile, and China (USGS, 2023), highlighting the need for a global approach. Lessons from LIBOR and Implications for Governance.

The transition from the London Interbank Offered Rate (LIBOR) to new risk-free reference rates (RFRs) after the 2014 reform, triggered by manipulation scandals, offers valuable lessons. This reform, initiated notably by the Wheatley report (2012), emphasized the need for robust governance, increased transparency, and a reliable transactional database. The transition was complex, involving the modification of thousands of contracts and the development of new regulations, such as the European BMR 2016/1011 on benchmarks.

In the case of our conversion currency, the establishment of such an index would require comparable infrastructure: a database of verifiable transactions, reputable contributors, and an independent oversight mechanism. The goal would be to create an ecological reference rate, not based on interest rates, but on the aggregated value of the basket's components, expressed in a unit of account. This "rate" would allow for transparent valuation of strategic transactions and limit manipulation. The governance of this new system should avoid the pitfalls of LIBOR by incorporating, from its design, mechanisms for resilience to shocks and attempts at influence.

The management entity's board of directors should be composed of members with divergent but complementary interests, ensuring balance and equitable representation of environmental, economic, and social issues. Strategic Advantages and Implementation Challenges. The adoption of such a mechanism would offer several strategic advantages. First, increased price stability for essential resources, facilitating long-term planning of investments for the energy transition. A European company would no longer be exposed solely to dollar volatility for the purchase of oil or nickel but to the relative stability of a diversified basket.

Second, a strong incentive for innovation and the adoption of clean technologies, as ecologically responsible produced resources would be intrinsically better valued. Furthermore, this conversion currency would promote an "economy of sobriety" by aligning monetary scarcity with ecological scarcity. By valuing resources based on their environmental impact and the difficulty of replacing them, it would discourage waste and encourage intensive recycling. The Club of Rome report, "The Limits to Growth" (Meadows et al., 1972), had already highlighted the interdependence of economic and ecological systems, advocating for more conscious resource management.

Implementation Challenges and the Transitional Phase. The implementation of such a system is complex and raises considerable political, economic, and technical challenges. Politically, it would require unprecedented international coordination, involving sovereign states, multilateral institutions, and non-state actors. The role of the G20, which represents over 80% of global GDP and two-thirds of the world's population, would be central in negotiating and adopting a legal and institutional framework. Economically, the transition would involve substantial changes in trading practices, risk management, and accounting.

Companies would have to adapt to a new price reference system and potentially invest in cleaner production technologies to optimize the valuation of their products. This transition would likely be gradual, with a transitional period of coexistence where fiat currencies and the new conversion currency would be used in parallel, allowing economic actors to adapt. Technical challenges include the development of secure and transparent trading platforms, the establishment of protocols for verifying the basket's assets, and the training of qualified personnel to manage these new infrastructures.

The use of blockchain technologies, for its traceability and immutability, could be considered for recording transactions and certifying assets, increasing trust and reducing administrative costs. Integration of Carbon Emission Allowances. A crucial aspect of this model is the integration of emission allowances. Currently, these allowances are financial instruments whose price fluctuates according to supply and demand on specific markets (such as EU-ETS, California Cap-and-Trade). By including them in the conversion currency basket, their value would be stabilized and directly linked to overall ecological performance.

An unused emission allowance could thus become a tangible asset within the basket, actively rewarding decarbonization efforts. This mechanism would provide emission allowances with greater liquidity and international recognition. Instead of being treated as mere national or regional quotas, they would become components of a global reference currency, incentivizing all countries not only to reduce their emissions but also to generate unused emission allowances that they could integrate into the basket. This would create a virtuous circle where the value of saved carbon would directly translate into purchasing power for essential and sustainable resources.

From Theory to Practice: A Mapped Path. The proposal for an ecological conversion currency is not utopian. It aligns with ongoing efforts in international financial regulation and increasing environmental awareness. It capitalizes on proven financial mechanisms, such as the SDR basket or LIBOR reform, adapting them to the imperatives of the 21st century. The European Parliament, for example, has already recognized the importance of critical raw materials for a sovereign Europe in its resolution of November 25, 2021, on a European strategy for critical raw materials. This recognition underscores the need for concerted action to secure and decarbonize supply chains.

The path to implementing this tool is paved by the necessity of strong political will and rigorous design. The potential benefits, in terms of economic stability, ecological resilience, and acceleration of the energy transition, amply justify the magnitude of the effort required. It is about building a monetary pillar for the Anthroposcene, capable of reconciling economy with planetary limits, as Latour advocates in his reflections on modes of existence (2012).

Chapter 36 Pillar 6 — Risks of Capture and Safeguards The Capture of Energy Producers: An Archipelago of Influences The implementation of a monetary system based on the kilowatt-hour (kWh) as a unit of account and value, as postulated by the Quantum Theory of Money (QTM), represents a major normative advance, but is not without systemic risks. The first of these lies in the potential capture of regulatory institutions by dominant economic agents in the energy production sector.

This phenomenon, dubbed "regulatory capture" by Stigler (1971), occurs when the interests of private or public companies in the energy sector disproportionately influence the definition and application of norms governing this new monetary paradigm. Economic history abounds with examples of this dynamic. In the United States, the Federal Communications Commission (FCC) has long been criticized for its close ties to telecommunications giants, leading to policies deemed favorable to established companies to the detriment of innovation or the public interest (McChesney, 1997).

Similarly, the financial industry exerted considerable influence over banking deregulation in the 1990s and 2000s, culminating in the 2008 crisis, highlighting the difficulty of maintaining strict independence for regulators in the face of powerful economic actors with considerable means of influence. In the context of an energy currency, electricity producers, whether private conglomerates or national entities, would hold an unprecedented strategic position. Their ability to generate the underlying asset of the currency would give them immense leverage over macroeconomic stability.

The risk is that this influence would not only translate into legitimate lobbying, but also into opaque pressures or systemic conflicts of interest, aimed at manipulating the price or availability of the kWh for exclusive gains rather than for the balance of the global monetary system and the energy transition. Transparency International's 2020 report on corruption in the energy sector already highlighted the magnitude of the sums involved, estimating that $1.6 trillion in energy investments are threatened by global corruption each year.

In a system where energy is money itself, these figures could increase exponentially, transforming production and distribution arenas into sites of exacerbated influence struggles. Engineering Institutional Safeguards To counteract this capture risk, the establishment of an "Independent Energy Monetary Consortium" (IEMC) is advocated. This supranational institution, endowed with inalienable legal and budgetary autonomy, would have the exclusive mission of guaranteeing the integrity of the kWh-based monetary system. Its composition should be multidisciplinary, including experts in energy accounting, macroeconomics, international public law, climate science, and ethics.

The nomination process for its members should incorporate rigorous competence criteria, financial independence from the energy industry, and regular rotation of mandates, similar to certain principles established for the European Court of Auditors or the European Central Bank. Decisions regarding the development and validation of kWh production standards, as well as its authentication as a unit of value, should be taken by qualified majority, or even unanimity for matters concerning the fundamental principles of the system.

The legal architecture of the IEMC must draw inspiration from international treaties guaranteeing the independence of certain institutions, such as the Treaty on European Union which grants functional and institutional autonomy to the ECB (Article 130 TFEU). Protected whistleblowing mechanisms, regular external audits, and full transparency on deliberations and decisions would be essential to prevent any attempt at interference. The Deflationary Threat Inherent in Energy Efficiency The continuous improvement of energy efficiency, a pillar of the ecological transition, introduces an inherent risk of deflation in a kWh-based monetary system.

Increased efficiency, characterized by a decrease in the energy needed to produce the same good or service, would, at a constant nominal kWh value, translate into an increase in the purchasing power of the energy currency. While this dynamic is desirable for economic and environmental prosperity, its asymmetry between production and consumption can become problematic. A situation where the same energy input allows for the production of more and more goods and services, without monetary adjustment, would lead to a relative scarcity of money compared to increased production, generating sustained deflationary pressure.

This deflation, if too strong or unexpected, can curb investment, discourage consumption, and disrupt the financial balance of economic agents, as shown by Japan's experiences with persistent deflation from the 1990s (Bernanke, 2000). However, improving energy efficiency is a historical constant and a necessity for climate change mitigation. Between 1990 and 2018, global energy intensity (energy needed to produce one unit of GDP) decreased by an average of 1.7% per year (IEA, Energy Efficiency Report, 2019). This trend, far from reversing, is expected to accelerate with technological advances and sobriety policies.

The Reference Energy Quantum: A Counter-Cyclical Instrument To counter this structural deflationary risk, QTM proposes an annual adjustment of the "reference energy quantum" (REQ). The REQ represents the quantity of energy (in kWh) that the monetary system recognizes as the basis of the unit of account. It is, in a way, the "definition" of the monetary unit itself, similar to the definition of the kilogram or the meter. This adjustment must not be arbitrary but based on objective and verifiable data, particularly aggregate energy efficiency gains at the global level. The IEMC would be responsible for calculating and publishing this annual metric.

If global energy efficiency improves by X%, then the REQ would be adjusted downwards by X%, meaning that each monetary unit would now represent a smaller quantity of kWh. This mechanism is an innovative form of "devaluation" of the unit of account, not to revive growth through inflation, but to maintain price stability in the face of increasing energy productivity. It aims to ensure that the purchasing power of the monetary unit remains relatively stable in terms of goods and services, even if the amount of energy needed to produce them decreases. The decision to adjust the REQ should be subject to the same governance rigors as those for producer oversight.

Energy Sovereignty and System Resilience The establishment of an energy monetary system also raises the question of states' sovereignty in the face of this new form of currency. If the kWh becomes the universal currency, nations producing renewable energy could gain considerable economic and political advantage. This "energy power" could be perceived as a new form of hegemony, shifting influence from oil or gas nations to those with high solar, wind, or geothermal potential. The principle of permanent sovereignty over natural resources, recognized by UN General Assembly Resolution 1803 (XVII) in 1962, will need to be reinterpreted in the era of energy currency.

Renewable energy resources, by definition, being more diffused and potentially more accessible than concentrated fossil fuels, could paradoxically favor a decentralization of production and a diversification of actors. However, production technology and transport and storage infrastructures remain points of power concentration. The IEMC's decision-making autonomy, while guaranteeing monetary stability, must not encroach on the ability of states to define their own energy mix and sobriety policies. The system must be designed to allow nations to maximize their clean energy production while contributing to the global money supply without undue pressure through the currency.

Preventing "Monetary Energy Wars" A latent risk is the emergence of "monetary energy wars," where states would seek to manipulate their energy production or consumption in order to influence the REQ and, by ricochet, the value of the currency. For example, a nation massively producing low-cost energy could seek to flood the market with energy to exert deflationary pressure, thereby weakening less productive economies. To counter this, the REQ should not be based solely on production, but also on a set of aggregate consumption and efficiency indicators.

The IEMC's role here would be to monitor these global dynamics and implement corrective mechanisms, such as limitations on energy exports beyond a certain threshold relative to domestic consumption, or targeted subsidies for research and development in energy efficiency in less advanced regions. International public law, particularly the principles governing economic sovereignty and international cooperation, will need to be adapted to frame this new sphere of influence.

Institutions like the World Trade Organization (WTO) will potentially have to evolve to integrate the monetary energy dimension into their cross-border regulations, framing energy exchanges as monetary transactions in their own right. Managing Externalities and Exogenous Shocks All monetary systems are vulnerable to exogenous shocks. In the context of an energy currency, these shocks could include natural disasters affecting renewable energy production (prolonged droughts affecting hydropower, low winds for wind power, solar storms rendering panels inoperable), major technological breakthroughs, or geopolitical conflicts impacting infrastructure.

These events could create significant volatility in the real energy quantum available, introducing unforeseen inflationary or deflationary pressures. The resilience of the system will depend on its ability to absorb these shocks without compromising the credibility of the currency. Energy Stabilization Funds and Insurance Mechanisms A conceivable solution involves the creation of an "Energy Stabilization Fund" (ESF), managed by the IEMC. This fund would be fed by a fraction of the revenues generated by worldwide energy production, or by contributions from member states proportional to their economic and energy weight.

Its purpose would be to provide emergency aid to regions affected by major energy shocks, ensuring the stability of local energy consumption and production. Furthermore, mutual insurance mechanisms between states could be developed, under the supervision of the IEMC, to pool risks associated with climate or technological hazards. In such a framework, national or regional entities contributing to energy systems could benefit from energy transfers or monetary compensation in the event of a major failure of their local production, for example, a prolonged period of low sunshine in a region heavily dependent on solar power.

The legal design of these funds and mechanisms should draw inspiration from successful experiences of existing monetary stabilization funds or mutual aid mechanisms, such as the European Stability Mechanism (ESM), which has proven its effectiveness, albeit with necessary criticisms, in stabilizing the Eurozone during sovereign crises. The objective is to prevent energy liquidity crises that could escalate into monetary crises. The Challenge of Measuring and Certifying kWh The credibility of an energy currency intrinsically relies on the reliability of kilowatt-hour measurement and certification. Each unit of this new currency must be traceable, authenticable, and non-falsifiable.

Without a universally accepted measurement method and robust independent certification, the system could be exposed to fraud, manipulation, and speculation, thereby undermining public trust. The development of international measurement standards, similar to ISO standards for quality or safety, will be fundamental. These standards will need to be developed by neutral and recognized bodies, in collaboration with producers, researchers, and regulators. Smart metering and decentralization technologies, such as blockchain, could play a crucial role in this traceability.

Blockchain Technology as an Integrity Shield Distributed Ledger Technology (DLT), and particularly blockchain, offers unique perspectives for guaranteeing the integrity of the monetary kWh. Each kWh produced and fed into the grid could be recorded as a unique "token" on a public and immutable blockchain. This technology would allow for near-perfect traceability of every unit of energy, from its source of production to its consumption. A "certified kilowatt-hour" (cKWh) would then become the basis of the monetary unit. Certification would be ensured by decentralized "oracles" verified by the IEMC, which would attest to the actual production of renewable energy.

This would make fraud extremely difficult, as any attempt to distort production data would be immediately detected and rejected by the network. The cost of fraud would thus become higher than the expected benefit. Platforms like Power Ledger have already demonstrated concrete applications of blockchain for the traceability and micro-trading of renewable energy, proving the technical feasibility of this approach on a small scale. Extension to a global monetary system would require an infrastructure of unprecedented scale, but the fundamental principles are already proven.

Democratic Legitimacy and Social Acceptance Finally, the success of an energy currency will depend on its democratic legitimacy and social acceptance. Such a transformative system cannot be imposed from above without eliciting resistance and rejection. The governance mechanisms of the IEMC, the adjustments of the REQ, and crisis management will need to be the subject of transparent and inclusive public debates. "Trust," as North and Weingast (1989) remind us, is the foundation of any institution. A currency is only accepted if citizens and economic agents trust its value and the stability of its issuer.

This requires clear communication, public education, and the participation of stakeholders in the decision-making process. Consultation and Co-construction of Standards Mechanisms for citizen consultation, global forums on energy currency, and processes for co-constructing standards will need to be established. National parliaments and international organizations will need to be actively involved in validating the treaty establishing the IEMC and in overseeing its actions. The objective is to avoid a disconnect between technical elites and populations, which could undermine the system's legitimacy.

The "yellow vests" affair in France, partly triggered by a carbon tax perceived as unfair and imposed without consultation, offers a striking example of the consequences of an environmental policy that is poorly accepted socially. An energy currency must be perceived as a global common good, serving everyone, and not as an instrument of a new technocracy. Its architecture must therefore integrate robust democratic safeguards.

Part IV — Biophysical Economics and the NÖM Unit Chapter 37 From GDP to Net Energy Unit: GDP, an Inadequate Measure of Prosperity and Planetary Boundaries Gross Domestic Product (GDP), established as the central indicator of economic performance after the Bretton Woods Agreement in 1944, was designed to measure the production of goods and services. Its widespread adoption, initiated by Simon Kuznets' work in the 1930s, has structured global economic policy. However, this centrality is increasingly being questioned, particularly in the face of environmental sustainability and social well-being challenges.

The limitations of GDP are intrinsic to its construction: it records economic activity without distinguishing its nature or its externalities. A natural disaster, for example, can lead to an increase in GDP due to reconstruction efforts, masking the destruction of natural and human capital. Similarly, pollution and subsequent depollution expenditures are recorded positively, illustrating an accounting system that fails to capture ecosystem degradation. Several reports and analyses have converged to criticize the relevance of GDP as a sole measure of progress.

The report of the Stiglitz-Sen-Fitoussi Commission, published in 2009 under the title "Measuring Economic Performance and Social Progress," highlighted the need for a broader statistical framework, integrating social and environmental dimensions. This report emphasized that production indicators alone are not sufficient to capture quality of life, health, or the state of the environment. Attempts to move beyond GDP have emerged, such as the Genuine Progress Indicator (GPI), developed by Daly and Cobb in 1989 in their work "For the Common Good." The GPI seeks to correct GDP by subtracting environmental and social costs, while adding the value of unpaid work (household, volunteering).

This approach offers a more nuanced picture of prosperity, integrating factors such as income distribution and the degradation of natural resources. Shortcomings of GDP in the Face of Energy and Environmental Challenges Energy consumption is an essential component of economic activity measured by GDP, but the latter reflects neither the quality nor the sustainability of this consumption. GDP growth is historically correlated with an increase in the consumption of non-renewable primary energy, mainly fossil fuels. This dependence raises the question of the resilience of economies in the face of resource depletion and price volatility.

The IPCC (Intergovernmental Panel on Climate Change), in its Sixth Assessment Report (2022), clearly established the link between global economic activity, greenhouse gas emissions, and global warming. GDP, by not taking into account the negative environmental impacts of the activities it measures, provides no warning signal about the unsustainability of consumption and production models. The concept of decoupling, often mentioned, between economic growth and resource consumption or emissions, remains controversial and yet to be demonstrated on a significant scale.

While relative decoupling (emissions growth rate lower than that of GDP) has been observed in some advanced economies, absolute decoupling (emissions reduction despite GDP growth) is rare and does not appear sufficient compared to the climate objectives of the 2015 Paris Agreement. The quantification of ecosystem services and the degradation of natural capital remains a major challenge for current accounting systems. The destruction of a primary forest or the depletion of an aquifer can generate short-term economic activity (logging, irrigated agriculture) that contributes to GDP, without their intrinsic ecological value or their regenerative capacity being accounted for in the liabilities.

The Net Energy Unit (NÖM): A Proposal for an Eco-Centric Measure Given the shortcomings of GDP, particularly its environmental and energy myopia, it is imperative to develop complementary, or even alternative, indicators. We propose the Net Energy Unit (NÖM), defined as 1 Gigajoule (GJ) of final usable energy net of embodied gray energy from the extraction, transformation, and distribution process. The NÖM aims to quantify the effective availability of energy for human societies after deducting the energy investments necessary for its own production. Energy plays a fundamental role in any economic process, in accordance with the laws of thermodynamics.

The first law, the principle of energy conservation, states that energy can neither be created nor destroyed. The second law, the principle of entropy, shows that usable energy gradually degrades into unusable heat during its use. A large part of the extracted energy is dissipated or consumed by the very processes of energy production. The concept of Energy Return On Investment (EROI) is central to understanding the NÖM. EROI is the ratio between the energy delivered by a source and the energy expended to obtain it. A low EROI reveals an energy source whose production is very energy-intensive, thereby reducing the net energy available to society.

For example, conventional oil had an EROI of about 100:1 in the 1930s, whereas tar sands have an EROI of around 5:1 or less. The NÖM does not account for all raw energy extracted, but only the usable energy that remains after subtracting the energy required for the entire supply chain. For example, if the production of 10 GJ of crude oil requires 2 GJ for extraction, transport, and refining, the net available energy is 8 GJ. This calculation must extend to the entire life cycle of energy technologies, including the manufacturing of infrastructure (wind turbines, solar panels).

Measurement Methodology and Implementation Challenges Quantifying the NÖM involves an in-depth life cycle assessment (LCA) for all energy sources. This process requires accounting for the gray energy incorporated into materials, the energy depreciation of infrastructure, losses during transport and conversion, as well as the energy consumed for decommissioning. This is a complex task that requires precise and standardized data. The LCA method must be robust to avoid energy load transfers or incomplete accounting.

For example, the LCA of a photovoltaic panel must include the energy expended for the extraction of raw materials (silicon, metals), the manufacturing of the panel, its transport, installation, maintenance, and recycling. If this gray energy is excessive, even "green" final energy loses its net interest. The measurement of the NÖM must be dynamic and adaptable. The EROIs of energy sources vary over time depending on the depletion of deposits, the improvement of extraction technologies, and innovation. Since the most accessible oil and gas deposits are already exploited, the effort required to extract the remaining resources increases, leading to a decrease in global average EROIs.

The implementation of the NÖM as a macroeconomic indicator at the national or global level would require extensive international collaboration and a redesign of energy data collection systems. National statistical agencies and organizations like the International Energy Agency (IEA) should integrate this approach into their reports, in addition to gross energy production and consumption statistics. Global Data 2024 and EROI Evolution Prospects Aggregated global EROI data are complex to establish, as they vary considerably depending on the energy source, technology used, and geographical area. However, average estimates illustrate the overall decrease in energy returns for certain sectors.

The EROI for conventional oil, which was over 30:1 in the 1960s, is now estimated between 10:1 and 15:1 for the remaining most profitable deposits. The EROI for shale gas is even lower, often between 5:1 and 7:1. It is important to note that these figures are subject to debate and may vary depending on the calculation methodology and the scope considered (including or not the energy cost of invested capital). Coal, despite its high climate impact, historically has a high EROI, often above 30:1, due to its ease of extraction relative to its energy content.

Intermittent renewable energy sources, such as wind and solar photovoltaics, have EROIs that are improving with technological advancements. Today, the EROI for onshore wind is estimated between 20:1 and 30:1, and for photovoltaics between 8:1 and 12:1, depending on the technology and location. It is crucial to understand that EROI is not the only criterion: the environmental implications across the life cycle must be considered, and not just net energy consumption. However, net available energy is a necessary condition for the complexity and prosperity of a society as we know it, as highlighted by researchers such as Charles A.S. Hall.

Net available energy below a certain threshold (estimated by some at 5:1 to maintain a complex industrialized society) could lead to economic contractions and profound reorganizations. Impacts on Energy Planning and Public Policies Integrating the NÖM into energy planning would allow for a more realistic evaluation of transition strategies. Rather than focusing solely on the gross production of "green" energy, it would be essential to evaluate the net energy that these new sources can effectively provide to society.

This approach reveals that simply replacing fossil fuels with renewables will not necessarily guarantee the maintenance of energy abundance if net energy returns are low or declining. European legislation, with the directive on the promotion of energy from renewable sources (Directive 2009/28/EC, revised by Directive EU 2018/2001), emphasizes the shares of renewable energy but does not take into account the net energy balance of these sources. LCA is already required for certain products in legislative frameworks such as Regulation (EU) 2017/1369 establishing a framework for energy labeling, but it is not systematized across energy sectors.

Public policies should be reoriented to prioritize energy efficiency not only in terms of end-use, but also in terms of production efficiency. This means investing in technologies with high EROIs, but also in less energy-intensive infrastructures and lifestyles that reduce overall energy demand. A society that maximizes its NÖM will be more resilient to energy shocks and better able to achieve a sustainable transition. The concept of "peak net energy" is a growing concern. While peak gross energy production is often discussed (cf.

King, 2012, "The Oil Crash and You"), peak net energy could occur earlier or have more severe consequences, as it would make it more difficult to maintain the infrastructures and services essential to societal complexity. Understanding the NÖM is therefore a prerequisite for anticipating and addressing these structural challenges. The NÖM as a Compass for Global Sustainability The shift from a monetary economy based on GDP to a physical economy centered on net energy invites a fundamental reevaluation of our societal objectives.

The NÖM, by directing attention to the energy available to society after all necessary deductions, provides a more rigorous measure of society's ability to maintain its level of complexity and well-being, in accordance with the biophysical limits of the planet. Adopting the NÖM does not mean abandoning GDP or other indicators of social well-being. Rather, it is a complementary and necessary approach, offering a different lens through which to evaluate progress and prosperity. While GDP measures the flow of economic activity, the NÖM measures the system's capacity to generate and maintain this activity beyond the efforts required for its simple energy reproduction.

In 2023, global primary energy consumption reached approximately 600 exajoules (EJ). If only 10% of this energy is lost in transformation and distribution processes for household electricity, and if the gray energy embodied in global infrastructures is not properly deducted, then the amount of net energy actually available is substantially lower. It is estimated that about 50% of primary energy is not used for final societal services but is lost as heat and inefficiencies, according to the IEA. The NÖM would seek to refine this figure to quantify the effectively usable energy over a complete life cycle.

The implementation of NÖM principles could transform decision-making, directing investments towards projects with high net energy value and low environmental impact. For example, energy renovation of buildings, although costly in financial capital, can have a very high EROI if it significantly reduces energy consumption over the building's lifespan. Towards Informed Energy Governance Energy governance guided by the NÖM would encourage energy sobriety and efficiency at all levels. Legislation could evolve to integrate EROI criteria into the evaluation of energy investment projects, alongside financial profitability or direct carbon impact.

This approach would help unmask "false solutions" which, under the guise of innovation, consume more energy than they actually provide to society after deducting indirect environmental and energy costs. The NÖM can serve as a guiding principle for establishing national and global energy budgets, a notion advanced by economists such as Pierre-Noël Giraud in "L'homme inutile" (2015). While carbon budgets are already under discussion (for example, the remaining carbon budget to limit warming to 1.5°C is approximately 400 gigatonnes of CO2 in 2023, according to the IPCC), an NÖM budget would establish limits on the total net energy that societies can afford to use sustainably.

The ultimate goal would be to ensure that future generations have sufficient energy capital to maintain a decent quality of life, while respecting the regenerative capacities of the biosphere. Only by precisely quantifying net available energy can we make informed discernment between possible development paths, avoiding the pitfalls of the illusion of infinite growth on a planet with finite resources. The NÖM proposal is an invitation to a deeper reflection on the physical foundations of our economy. It demands a paradigm shift, moving from an anthropocentric view of the economy to an ecocentric view, where energy and matter are the ultimate arbiters of sustainability.

The future depends on our ability to integrate these biophysical realities into our measurement and decision-making frameworks. Chapter 38 Unified Energy Accounting (UEA) The Limits of the Exclusive Monetary Paradigm Modern accounting, structured around the double-entry system developed by Luca Pacioli as early as 1494, has historically favored a purely monetary representation of wealth and economic flows. This framework, although fundamental for the organization of human activities since the commercial Renaissance, today reveals profound shortcomings in the face of global sustainability challenges.

The imperative of financial profitability often masks the reality of biophysical withdrawals and regenerations, creating systemic blindness to environmental externalities. This unilateral monetary approach has led to a progressive disconnection between the economic value attributed to goods and services and their real ecological cost. Gross Domestic Product (GDP), a central indicator of national economic performance, for example, incorporates expenditures related to natural disasters or pollution remediation as positive contributions, without distinguishing the destructive nature of the underlying activities.

This semantic and accounting distortion alters the public perception of true prosperity. The emergence of Earth System science from the second half of the 20th century highlighted the increasing interdependence of human societies with planetary biogeochemical cycles. The Meadows report *The Limits to Growth* (1972) was a major milestone, emphasizing the impossibility of infinite exponential growth in a world of finite resources. The notion of "biocapacity," introduced by Mathis Wackernagel and William Rees in the 1990s, quantifies the ability of ecosystems to produce useful resources and absorb waste.

The neglect of physical dimensions in conventional accounting has direct consequences for public policy formulation. Massive investment decisions in energy-intensive infrastructures, justified by rapid financial returns on investment, rarely take into account the depletion of non-renewable resource stocks such as rare metals, or greenhouse gas (GHG) emissions beyond carbon budgets compatible with the Paris Agreement (2015). Ecological Economics and the Need for a Dual

Reading Ecological economics, a discipline that emerged in the 1980s with figures like Herman Daly, has challenged this monetary predominance.

It postulates that the human economy is a subsystem of the Earth's ecosystem, and as such is subject to the laws of thermodynamics. The first principle (conservation of energy and matter) and the second principle (entropy) impose fundamental constraints on productive processes. The analytical framework of ecological economics advocates for the integration of material and energy flows in the evaluation of economic systems. Approaches such as Material Flow Accounting (MFA), developed by Eurostat and the OECD, or Leontief-type Input-Output analyses, already model these interdependencies.

However, these tools often remain confined to sectoral or macroeconomic studies and have not yet been fully integrated into the core of corporate or national accounting. The persistent gap lies in the absence of a unified accounting structure that simultaneously, and with the same rigor, treats monetary and physical dimensions. While financial statements are scrutinized meticulously, the state of natural capital and associated biophysical flows remain "externalities" rarely fully internalized. This perpetuates the illusion of unlimited wealth disconnected from its material foundations.

Foundations of Unified Energy Accounting (UEA) Unified Energy Accounting (UEA) proposes to overcome this dichotomy by establishing a truly integrated double-entry system, where each monetary transaction or significant economic event is associated with its physical, and particularly energy, equivalent. It is not about "monetizing" nature, but about assigning a measurable physical value to flows and stocks, in addition to their fiduciary value. The core of UEA rests on the homogenization of physical units of measurement, promoting a common metrology. Energy, quantified in joules (J) or tons of oil equivalent (toe), emerges as the most universal standard.

Indeed, all human activity, from agricultural production to manufacturing, including services, is irreducibly energy-consuming or energy-transforming. The goal of UEA is not to replace monetary accounting, but to complement and contextualize it. It aims to make visible the biophysical substrate of the economy, in the same way that the French General Chart of Accounts (PCG) (CRC 99-03 regulation) structures the financial representation of companies. Entities will be required to produce not only financial balance sheets and income statements, but also energy and material flow balance sheets and statements.

Principles and Key Definitions A fundamental principle of UEA is the establishment of systemic duality. Each financial asset item (fixed assets, inventories, cash) must be re-evaluated in terms of cumulative energy content or energy potential. Each monetary flow (revenues, expenses) must be associated with the underlying material and energy flows. For example, the acquisition of a machine will be recorded for its cost in euros, but also for its embodied energy (energy necessary for its manufacture, transport and maintenance) and its annual operational energy consumption.

"Energy assets" could include fossil or renewable energy deposits, energy production capacities, gas or oil stocks, but also natural capital such as forests for their carbon sequestration capacity or arable land for its agricultural production potential. "Energy debt" would represent the future commitment to spend energy on waste management, infrastructure decommissioning, or restoration of degraded environments. An energy income statement would track energy inputs and outputs over a given period (typically one year), distinguishing primary energy (untransformed) from secondary energy (transformed), and identifying dissipation losses according to the laws of thermodynamics.

This traceability would make it possible to measure the real energy efficiency of processes and organizations, beyond their financial profitability alone. The classification of energy flows could be inspired by the MFA material flow taxonomy: extracted renewable energy, extracted non-renewable energy, energy imports and exports, energy consumption. In terms of inputs, a distinction would be made between "incorporated energy" of consumed goods and services, and "operational energy" needed for direct functioning. Contributions and Implications of UEA for Governance The adoption of UEA would radically transform the evaluation of economic performance.

A company whose financial profitability is high but whose energy balance sheet is in deficit (consumption exceeding renewal capacity or transformation efficiency) would be considered unsustainable. This would make it possible to identify "energy stranded assets," i.e., investments that will lose value due to their incompatibility with decarbonization objectives or facing resource scarcity. A Carbon Tracker Initiative study (2019) estimated that nearly $1.6 trillion of fossil assets could become stranded by 2035. UEA would introduce a new form of due diligence for investors and regulators, not only financial but also energy and material.

Central banks could integrate these metrics into the assessment of systemic risks, beyond traditional financial stress tests. The Banque de France, for example, has already initiated work on integrating climate risks into bank balance sheets (2020). At the macroeconomic level, UEA would enable the establishment of national and transnational carbon budgets with increased precision, by directly linking them to economic flows. The measurement of the energy intensity of economies and their "energy degrowth" (or "enhanced energy efficiency") would become a key indicator of progress, complementary to GDP.

This approach is essential for the implementation of carbon neutrality objectives set by the European Union by 2050, enshrined in the Green

Deal (2019). Tools and Methods for Implementation The integration of UEA would require the development of unified and interoperable databases, allowing the traceability of energy flows throughout value chains. Digital technologies, particularly blockchain for data transparency and artificial intelligence for predictive analysis, would offer valuable tools for collecting, processing, and auditing this complex information.

Work on life cycle assessments (LCAs) for products and services, standardized by ISO 14040 and ISO 14044, would provide a robust methodology for calculating embodied energy and associated environmental impacts. The extension of these methodologies to the scale of complete organizations, as in CARE accounting (Comptabilité Adaptée au Renouvellement de l'Environnement) proposed by the collective led by Jacques Richard and Alain Burlaud (2015), constitutes a prefiguration of UEA frameworks. The establishment of international standards for UEA, under the aegis of organizations like the United Nations or the International Organization for Standardization (ISO), would be a crucial step.

These standards would allow for the comparability of data between countries and companies, facilitating the emergence of a world economy more consciously managed from an energy perspective. It is imperative that accounting standard-setting bodies, such as the International Accounting Standards Board (IASB) or national commissions, undertake thorough reflection to integrate these biophysical dimensions. The modification of regulatory frameworks, such as the EU's Corporate Sustainability Reporting Directive (CSRD), which will extend extra-financial reporting obligations, constitutes a first step towards more inclusive accounting.

Institutional and Philosophical Stakes The implementation of UEA will face inevitable resistance. The historical primacy of money is deeply rooted in minds and institutions. Moving to a dual accounting logic, monetary and energy, implies a reorientation of value systems and economic incentives. Actors whose prosperity is based on extractivist or energy-intensive models might perceive UEA as a direct threat to their economic model. This is truly a Copernican revolution in accounting, challenging the axiom that value is reduced to its monetary expression.

As Nicholas Georgescu-Roegen pointed out in *The Entropy Law and the Economic Process* (1971), the dominant economic logic ignores irreversible transfers of energy and matter, perpetuating an illusion of perpetual growth without biophysical costs. The education of future accountants, economists, and business leaders will need to be adapted to include solid training in life sciences, thermodynamics, and industrial ecology. The tools of engineers and ecologists will need to be integrated into the practices of financiers and jurists. This is essential for forging economic actors capable of understanding the complexity of systemic interdependencies.

Towards Polycentric Resource Governance UEA offers a conceptual infrastructure for polycentric resource governance (Elinor Ostrom, 1990), where decisions are no longer solely dictated by short-term financial profitability considerations. By providing a more complete picture of costs and benefits, including those that are not immediately monetizable, UEA is a tool for strengthening the resilience of communities and ecosystems. Concretely, the establishment of UEA could require the creation of new control and audit entities, or the adaptation of existing ones (Cour des comptes, Environmental Protection Agencies).

These structures would be responsible for verifying the conformity of energy and material balance sheets, and ensuring their integrity, in the same way that financial balance sheets are audited by statutory auditors. The ultimate goal is the reconciliation of the economy with the biosphere, by recognizing that true prosperity cannot be dissociated from the health of ecosystems and the availability of resources.

By making visible the energy and material footprint of each economic decision, UEA aims to catalyze a transition towards a regenerative and resilient economy, where value is measured not only in euros, but also in joules, in tons of sequestered carbon, and in the capacity for living renewal. Chapter 39 Mandatory Multigenerational Provisions: The Ethical and Legal Imperative of Multigenerational Provisions The issue of multigenerational provisions presents itself as a central challenge in light of ecological crises and technological commitments whose externalities extend over timescales exceeding human lifespan and even that of several generations.

This involves collectivizing, in an anticipatory manner, the future costs associated with present activities, so as not to burden future generations with an unsustainable ecological and economic debt. This principle, although morally evident, confronts the limitations of contemporary legal and economic frameworks, which are primarily structured by the short term. The notion of intergenerational responsibility, although embedded in certain philosophical traditions—one thinks of Hans Jonas (1979) and his principle of responsibility—struggles to find operational translation in positive law and financial mechanisms.

Public law, particularly constitutional law, is beginning to integrate this dimension through environmental charters, such as the French Environmental Charter of 2004, whose article 6 sets forth the principle of prevention and precaution. However, the exhaustive quantification and effective provision for future burdens remain largely deficient, hindering an essential temporal decentering of public decision-making. Similarly, international law, with agreements such as the Paris Agreement on climate signed in 2015, recognizes the need to act for present and future generations, but the mechanisms for financing and repairing future damages are not sufficiently binding.

This results in a hiatus between the affirmation of principles and their concrete implementation, particularly concerning the establishment of dedicated funds, whose sustainable management and ring-fencing represent an unprecedented challenge for state systems. Ecological economics, in particular, highlights this systemic failure. It emphasizes that the current valuation of natural resources and ecosystem services does not reflect their long-term replacement or restoration cost, nor deferred negative externalities.

The integration of these costs into national and corporate accounting models is a *sine qua non* condition for truly sustainable accounting, enabling the establishment of adequate provisions. Technological Decommissioning: An Illustration of Deferred Liabilities The case of nuclear infrastructures represents the archetype of multigenerational liabilities that contemporary society has accumulated without adequately provisioning for their costs. The decommissioning of a nuclear power plant is an operation of extreme technical and financial complexity, whose duration often extends over more than a century, thus engaging several generations.

In France, the Court of Auditors has regularly emphasized the shortcomings of provisions made by operators, particularly EDF. In 2014, a report by the French Court of Auditors estimated that provisions for decommissioning and management of nuclear waste were underestimated by several billion euros. The estimated average cost of decommissioning a PWR-type nuclear reactor is approximately 1 billion euros per gigawatt-electric (M€/GWe), figures that have been re-evaluated upwards on several occasions.

For a fleet like that of France, with 56 reactors ranging from 900 to 1450 MW, the total cost represents a colossal amount, whose present value fluctuates considerably depending on the discount rates used. This uncertainty weighs heavily on the credibility of current provisions. High-level and long-lived nuclear waste (HAVL), for its part, requires deep geological storage whose durability must be ensured over hundreds of thousands of years. The Cigeo project in Bure, France, illustrates the scale of this challenge.

The total cost of this project is estimated at over 25 billion euros to construct and operate the storage facility, not including surveillance and maintenance costs over geological epochs. These already colossal sums do not always account for technological or geological contingencies that could arise over such time horizons. The problem is exacerbated by the financing of provisions. Often, the sums are placed in dedicated funds, but their management is subject to the vagaries of financial markets and political pressures for reallocation to other uses.

It is imperative to isolate these provisions, to ring-fence them through robust fiduciary mechanisms, and to ensure their indexation to real future costs, rather than to optimistic projections or excessive discount rates that artificially devalue distant liabilities. Climate Debt and Compensation Mechanisms The climate crisis also generates a multigenerational debt of unprecedented scale, not only in terms of impacts (sea-level rise, extreme events, biodiversity loss) but also in terms of mitigation and adaptation technologies. Among these, Carbon Dioxide Removal (CDR) techniques feature prominently, ranging from Bioenergy with Carbon Capture and Storage (BECCS) to Direct Air Capture (DAC).

These technologies, while promising, involve considerable energetic and financial costs, as well as uncertainties regarding their large-scale effectiveness and their side effects. The current cost of DAC, for instance, is estimated at 200-600 dollars per ton of CO2 captured (National Academies of Sciences, Engineering, and Medicine, 2019). Considering the gigatons of CO2 that would need to be removed from the atmosphere to meet the objectives of the Paris Agreement, the necessary amounts run into tens, or even hundreds, of trillions of dollars. Current economic models struggle to integrate these costs prospectively.

Carbon market mechanisms, such as emission trading schemes (ETS), tend to internalize a portion of the costs, but their effectiveness is often limited by the volatility of carbon prices and exemptions granted to certain sectors. Furthermore, they do not cover all negative externalities associated with past and future emissions, nor the costs of repairing incurred damages. Actuarial methods are essential here. They involve evaluating future risks and costs with statistical precision, in order to build up sufficient financial reserves.

Their application to climate debt would involve estimating the costs of necessary CDR technologies to achieve temperature targets, but also the value of ecological and economic losses linked to extreme climatic events. A global fund, endowed with provisions levied on the profits of emitting industries, could be envisaged, under robust international governance. Carbon Markets and the Question of Intergenerational Equity Carbon markets, intended to internalize the social cost of carbon, struggle to reflect the magnitude of future damages.

The price of a ton of CO2, for example in the EU ETS, fluctuates but often remains below estimates of the real social cost of carbon, which varies between 50 and 200 dollars per ton according to studies (IPCC, 2018). This undervaluation leads to insufficient investment in decarbonization and a deferral of burdens onto future generations. For true intergenerational justice, it is imperative to adjust the price of carbon to integrate the cost of ecological restoration and future technological developments, including those of CDR. This is what James E.

Hansen (2009) advocates with his proposal for a "carbon fee and dividend," which would involve a high carbon tax redistributed to the population, thereby strongly incentivizing decarbonization and indirectly provisioning for future costs. Moreover, compensation mechanisms like BECCS (Bioenergy with Carbon Capture and Storage) raise complex questions of land use and competition with food production, creating negative externalities that can, in turn, generate new environmental liabilities. A multigenerational provision must not only cover the direct costs of a technology but also its systemic effects and the costs of their subsequent management or correction.

Biodiversity Erosion and the Principle of Non-Regression The massive loss of biodiversity, recognized as the sixth mass extinction by many experts (Kolbert, 2014), constitutes another form of multigenerational liability with inestimable consequences. Ecosystem services, essential for human well-being (climate regulation, pollination, water purification, etc.), are degrading at an alarming rate. Their restoration is often technically impossible or financially prohibitive, which makes the establishment of provisions particularly complex.

The principle of non-regression, critical to the constitutionalization of environmental law, especially in France since the Constitutional Council's decision of 2013, stipulates that new legislation cannot undermine environmental protection requirements already integrated into texts. This principle, while fundamental, does not in itself offer a financing mechanism to compensate for biodiversity losses already incurred or inevitable. Current conservation efforts, though indispensable, are largely insufficient.

Estimates of the funding needed to achieve global conservation objectives (for example, those defined by the Convention on Biological Diversity) amount to hundreds of billions of dollars per year, while current expenditures are much lower. A 2021 report by the United Nations Environment Programme (UNEP) estimated that the global funding gap for biodiversity was $711 billion per year. The actuarial method here should evaluate the "replacement cost" or the "cost of the irreparable" for lost ecosystem services.

If a species is extinct, it is irreplaceable; if an ecosystem is destroyed, its restoration takes decades or centuries, at a cost often exceeding the initial economic benefits of its destruction. Provisions should then serve to finance proactive restoration measures, land acquisition for conservation, and research on genetic conservation. Challenges in the Monetary Valuation of Nature The monetary valuation of biodiversity is a perilous exercise, often criticized for its tendency to essentialize living things. Nevertheless, attempts are being made to integrate these costs into current economic and legal systems.

The Economics of Ecosystems and Biodiversity (TEEB, 2010) report greatly contributed to establishing methodologies for estimating the economic value of services provided by nature, highlighting the hidden costs of their degradation. The creation of biodiversity trust funds, financed by royalties on the exploitation of natural resources or by taxes on anthropogenic activities with a proven impact on ecosystems, could provide a stable and dedicated source of funding. These funds should be managed transparently and independently, with long investment horizons, to ensure the availability of necessary resources for future generations.

The Global Environment Facility (GEF), although in existence for many years, and other similar initiatives, do not have sufficient financial capacity to address the magnitude of the challenges. A reform of the international financial architecture is essential to internalize ecological debt. The example of the World Bank playing a driving role in promoting the integration of natural assets into national accounts (World Bank, 2017) is a step, but must be translated into binding provisioning mechanisms for states and businesses.

Legal Frameworks and Governance of Multigenerational Provisions The establishment of binding multigenerational provisions requires a profound transformation of national and international legal frameworks. Constitutional law, as the supreme norm, is called upon to play a pivotal role by explicitly enshrining the principle of intergenerational responsibility and the obligation to provision for ecological liabilities. Several constitutional reform projects, for example at the European level, could integrate this crucial dimension.

Article 3 of the French Environmental Charter (2004) stipulates that "Everyone must prevent the harm they are likely to cause to the environment or, failing that, limit its consequences." While this "failing that" may imply a form of financial compensation, it does not systematically translate into mandatory and sufficient provisions. A bolder reading and a jurisprudential interpretation oriented towards anticipating costs are necessary. Specific sectoral legislation must also evolve. For nuclear power, for example, it would be appropriate to strengthen the capitalization requirements for operating companies and to proactively and independently audit the state of provisions.

The French law on transparency and security in nuclear matters of 2006, although a step forward, could be expanded to include automatic revaluation mechanisms and adjustment of provisions based on technological advancements and decommissioning observations. At the international level, binding treaties could establish minimum standards for intergenerational provisions, particularly for activities with high environmental risk.

The idea of an "intergenerational drawing right" on global funds guaranteed by wealthy nations could mutualize the risks and costs of the heaviest ecological liabilities, for example those related to the management of nuclear waste in certain countries or the restoration of large transboundary ecosystems. From Fund Governance to Resource Ring-fencing The creation of dedicated trust funds, independent of national budgetary cycles, is paramount. These entities, governed by boards of experts and civil society representatives, including "future generations advocates," should be mandated to protect these funds from any attempt at diversion or under-provisioning.

The Norwegian model of the Global Government Pension Fund, although targeting retirement, offers an example of long-term asset management with a sustainability objective. The issue of the discount rate is central. A high discount rate, commonly applied in economic analyses, tends to significantly devalue costs and benefits that manifest in the distant future. For multigenerational liabilities, it is imperative to use very low, or even zero, discount rates, reflecting the intrinsic value of nature and the principle of intergenerational equity.

Nicholas Stern (2007), in his report on climate change, advocated for a discount rate close to zero for global public goods, so as not to externalize the cost of the climate crisis onto future generations. The legal ring-fencing of these funds would entail constitutional or international guarantees preventing their dissolution, their reallocation to other uses, or their depletion. Such mechanisms should be designed to survive political regime changes and economic crises, thus ensuring financial and ethical sustainability over the timescales required by the nature of contemporary environmental problems.

Chapter 40 Regulated Markets and Caps The Institutionalization of Environmental Markets: Between Regulation and the Commodification of Nature The emergence of environmental markets, notably those for carbon, water, and biodiversity, represents a paradigmatic attempt to integrate ecological considerations within dominant economic frameworks. In response to the failure of command-and-control approaches and Pigouvian taxes to curb environmental degradation on a sufficient scale, these mechanisms aim to internalize negative externalities by assigning tradable rights.

However, this market imperative raises fundamental questions about the very nature of environmental goods, their commensurability, and the intrinsic efficacy of such mechanisms. The commodification of vital elements such as the atmosphere, water, and life itself challenges the ethical and practical limits of neoclassical economics applied to living systems. These institutional architectures are rooted in Ronald Coase's (1960) propositions on transaction costs and the allocation of property rights to resolve externality problems.

The underlying idea is that by creating a price for goods previously considered free, economic actors would be incentivized to optimize their use and innovate to reduce their impact. This logic, though appealing in its abstraction, runs up against the complexity of ecological systems, the non-substitutability of certain ecosystem services, and the distributive inequalities inherent in any initial allocation of rights. A critical analysis of these regulated markets requires a multidimensional understanding, at the intersection of law, economics, and philosophy.

The European carbon market (EU ETS): twenty years of trial and error between efficiency and justice The European Union Emissions Trading System (EU ETS), launched in 2005, is the world's largest carbon market. It covers approximately 40% of the EU's greenhouse gas emissions, extending to the energy, heavy industry, and, since 2012, aviation sectors. Its principle is based on a "cap-and-trade" mechanism: an overall emissions cap is set and progressively lowered, while emission allowances, each representing one tonne of CO2e, are distributed or sold to operators.

Those who reduce their emissions below their allowances can sell their surplus, while those who exceed must purchase additional allowances. The first phases (2005-2007) and (2008-2012) were marked by an overly generous initial allocation of allowances, leading to a massive surplus and the collapse of carbon prices, often below 5 euros per tonne (Ellerman and Joskow, 2008). This situation seriously undermined the incentive to invest in low-carbon technologies. The 2008-2009 economic crisis exacerbated this surplus, making it even more persistent.

The slowness of the institutional response to this structural imbalance, particularly through the introduction of the Market Stability Reserve (MSR) safeguard clause in 2015 (Decision (EU) 2015/1814), has been sharply criticized. Phase III (2013-2020) saw the introduction of auctioning as the main allocation method and a linear reduction of the cap by 1.74% per year. Despite these adjustments, prices remained moderate until the end of the decade. It was only with the reforms of Phase IV (2021-2030), including an increase in the annual linear reduction factor to 2.2% and a strengthening of the MSR, that prices significantly increased, regularly exceeding 80 euros per tonne in 2022 and 2023.

This rise signals increased system credibility and a stronger incentive for decarbonization. The balance sheet in 2026 shows a cumulative reduction in emissions from covered sectors of approximately 37% compared to 2005. However, this performance must be nuanced by the effects of production offshoring (carbon leakage) and the ability of sectors to truly adapt their infrastructure. The deployment of the Carbon Border Adjustment Mechanism (CBAM) (Regulation (EU) 2023/956 of 10 May 2023) from 2026 aims to mitigate this risk by imposing a carbon price on imports.

The EU ETS has demonstrated its capacity to evolve and adapt, but this flexibility has sometimes come at the expense of initial ambition and generated uncertainties for economic actors. Issues of climate justice and competitiveness have often slowed down the adjustment of the cap and the expansion of the scope. The proposed inclusion of road transport and building heating in an extended version of the EU ETS (EU ETS 2), starting in 2027, raises concerns about the impact on low-income households.

Social compensation mechanisms, such as the Social Climate Fund, are envisaged to mitigate these distributive effects, reminding us that economic efficiency cannot be dissociated from social acceptability. The Commodification of Water: The Case of the Murray-Darling Basin in Australia Water management through market mechanisms represents a distinct but equally controversial approach. The Murray-Darling Basin in Australia offers an emblematic example of the establishment of a water rights market, implemented to address the overexploitation of a vital resource in a context of increasing aridity.

This system, formalized by the Water Act of 2007, aims to efficiently allocate irrigation rights and protect freshwater ecosystems via "environmental flows." The operation is similar to cap-and-trade: a total volume of available water is estimated annually, and then rights to access this water are allocated to historical users (farmers, industries). These rights can then be sold or leased on a secondary market. The hypothesis is that this flexibility will allow water to go to the most productive uses, while ensuring a minimum for maintaining the ecological health of the river. The results of this market are mixed.

While some farmers have been able to optimize their water use by selling surplus rights or purchasing supplements during periods of drought, the volatility of prices and uncertainty about total availability have created significant instability. Water prices have reached peaks of over AUD 1,000 per megalitre during severe drought periods in the early 2000s and 2010s. This volatility has favored a concentration of rights in the hands of larger actors and shifted risks to small farmers. Moreover, the objective of ecological restoration, which was supposed to be achieved through the acquisition of rights for environmental purposes, is far from being fully realized.

The volumes of water allocated to the environment proved insufficient during critical periods, threatening biodiversity and ecosystem health. The difficulty of understanding the hydrological complexity of the basin and its multiple interconnections made setting an appropriate ecological "cap" particularly delicate (Quiggin, 2006). Critics highlight that water, as an essential resource for life, should not be subject to the same market logics as other economic goods. The social and cultural dimension of water, particularly for Aboriginal populations, is difficult to integrate into a framework of transferable property rights.

The Murray-Darling experience underscores the limits of the total commodification of natural resources, especially when they are intrinsically linked to issues of survival, social justice, and sovereignty. Biodiversity Markets: Controversial "Offsetting" "Ecological compensation" mechanisms or "biodiversity offsets" aim to counterbalance the residual negative impacts of a development project on biodiversity through positive actions carried out elsewhere. The idea is to achieve "no net loss" or, ideally, a "net gain" in biodiversity. These mechanisms are framed by national regulations, such as the "avoid, reduce, compensate" (ERC) hierarchy in French law (cf.

Environmental Code, Article L. 110-1). They are also promoted by international financial institutions, such as the World Bank, since the 2000s. The principle is to quantify the loss of biodiversity generated by a project (for example, in hectares of habitat destroyed or displaced species) and to associate an equivalent or greater compensation. This compensation can take the form of habitat restoration, creation of reserves, or conservation management on other sites. The objective is often expressed in "biodiversity units" or "habitat credits," which can theoretically be traded or sold.

This market, although less formalized and globalized than that for carbon, is experiencing notable expansion, particularly in countries like the United States (with the Clean Water Act) and Australia. For example, in New South Wales, the "Biodiversity Offsets Scheme" allows developers to purchase "biodiversity credits" from landowners managing conservation sites, if in-situ compensation is not possible. In 2021, this program had generated over AUD 21 million in transactions. Fundamental Criticisms of Biodiversity Offsets The criticisms leveled against biodiversity compensation mechanisms are numerous and substantial.

They first concern commensurability: how can heterogeneous species and ecosystems (a wetland with a forest, a rare species with a common habitat) be compared and exchanged? The notion of ecological equivalence is fragile, and compensation is often perceived as authorizing the destruction of a unique heritage in exchange for an uncertain promise of restoration elsewhere (Ten Kate et al., 2004). Second, the effectiveness of compensation is often doubted. Restoration projects or the creation of new habitats are complex, lengthy, and subject to many hazards (climatic, ecological, social).

There is a "temporal lag" between the immediate and certain destruction of a habitat and the future and uncertain restoration of another. Studies have shown that many compensation projects fail to achieve their ecological objectives (Gardner et al., 2011). The question of environmental justice is also prevalent. Destruction sites and compensation sites are not always located in the same way, sometimes leading to the relocation of impacts towards less powerful communities.

Furthermore, the commodification of nature can trivialize destruction and encourage an instrumental view of living things, reducing biodiversity to a sum of functions or services rather than an irreplaceable intrinsic value. More fundamentally, "offsets" risk legitimizing the destruction of irreplaceable ecosystems under the guise of a promise of compensation, rather than questioning the very necessity of the impacting project or encouraging alternatives. They create a regime where "permission to pollute" is monetized, whereas protection should be the rule and not the exception conditioned by payment.

Biodiversity, by its complex and systemic nature, resists being broken down into tradable units, highlighting the ethical and scientific limits of applying market doctrines. The Biophysical Limit and the Questioning of the Growth Paradigm The analysis of these regulated markets highlights a constitutive tension between the economic logic of infinite growth and the planet's biophysical limits. The market approach, by seeking to "put a price on nature," assumes that the monetary integration of these externalities will be sufficient to orient behaviors towards sustainability.

However, the experiences of the EU ETS, the Murray-Darling, and biodiversity offsets reveal that this integration is often partial, late, and subject to strong resistance. The issue of the "cap" is central in this regard. Setting a cap for carbon emissions, water withdrawals, or biodiversity losses is an eminently political and scientific decision that cannot be determined by market forces alone. These caps, to be effective, must be ambitious and aligned with planetary boundaries defined by researchers like Rockström and Steffen (2009). However, the influence of industrial lobbies and competitiveness considerations have often led to overly lax caps, undermining the environmental objective.

The concept of green growth, often associated with these market mechanisms, postulates a decoupling between economic growth and environmental impacts through technical innovation. However, recent data, particularly from the European Environment Agency, show that the nominal dematerialization of GDP is not accompanied by an absolute dematerialization of material and energy flows on a global scale. World GDP growth remains generally correlated with an increase in resource extraction and cumulative emissions, as shown by Hickel and Kallis (2019).

The very effectiveness of environmental markets is intrinsically linked to the political will to constrain economic activity within strict ecological limits. Without robust governance and non-negotiable ecological objectives, these markets risk becoming mere tools for legitimizing degradation or inequality, rather than levers for profound transformation. The technocratic approach underlying the creation of these markets often overlooks the social, ethical, and cultural dimensions essential for a true ecological transition. Nature itself, with its complex feedback loops and irreversible thresholds, does not easily fit into the simplifying models of neoclassical economics.

The risk is to substitute, through these mechanisms, a "false scarcity" (an administered shortage of emission rights or water rights) for the "true scarcity" of natural resources and ecosystem services. In doing so, the problem shifts from protecting nature to managing it financially, without always addressing its root causes. Towards a Reconsideration of Legal and Economic Frameworks The feedback from environmental markets questions the long-term validity of their initial premise. They highlight the imperative to reform these mechanisms to adapt them to ecological and social requirements.

For the EU ETS, this implies a significant acceleration of the cap reduction, an ambitious expansion of its scope, and constant vigilance regarding distributive effects. For water, it is imperative to reaffirm its nature as a common good and to guarantee minimum ecological flows before any market allocation, or even to reconsider the relevance of full commodification (Barraqué and Govaere, 2007). As for biodiversity, prudence must prevail over compensatory engineering: the hierarchical principle of the ERC sequence must be strictly applied, with an absolute priority on avoidance and reduction, compensation being only a last resort, and acknowledging its significant limitations.

The objective of not exceeding a 1.5°C global warming limit (Paris Agreement, 2015), or halting biodiversity erosion by 2030 (Kunming-Montreal Global Biodiversity Framework, 2022), requires systemic interventions that go beyond marginal price adjustments. It is necessary to restore precedence to environmental law as a non-negotiable instrument for regulating anthropogenic activities. This implies, for example, strengthening emission standards, prohibiting certain destructive practices, and strictly protecting ecologically sensitive areas.

Environmental constitutional law must also gain momentum, by recognizing nature as a subject of law or by more firmly integrating the principle of ecological non-regression. The example of Ecuador (Constitution of 2008) or New Zealand (Te Awa Tupua Act of 2017) granting legal personality to ecosystems, although sometimes criticized for their practical scope, opens up perspectives for rethinking our relationship with living systems. This recognition could transform the legal foundations and economic instruments through which societies interact with the biosphere. The ecological transition cannot be reduced to a sum of technical and market adjustments.

It presupposes a profound revision of societal values and objectives, a transition from an extractivist and linear economy to a circular and regenerative economy, rooted in respect for planetary boundaries. Markets can play a role, but only if they are subordinated to a clear, democratically defined, and legally binding ecological vision, rather than being the sole arbiters of the biosphere's destiny. In short, the effectiveness of these tools will depend on our collective ability to subordinate them to a truly transformative and just environmental ambition.

Chapter 41 Progressive Green Taxation The Dilemma of Environmental Taxation: Economic Efficiency and Social Justice The imperative of ecological transition confronts existing tax systems with a dual requirement: to internalize environmental costs previously externalized and to ensure an equitable distribution of efforts. Ecological economics has long highlighted that market mechanisms fail to efficiently allocate resources and regulate pollution without corrective state intervention, particularly through taxation.

As early as 1920, in his work *The Economics of Welfare*, Arthur Pigou identified the divergence between private and social costs, proposing a taxation of activities generating negative externalities. The relevance of environmental taxation lies in its ability to guide the behavior of economic agents by modifying their cost structures and incentives. By making environmentally harmful activities more costly, it encourages technological innovation, sobriety, and substitution towards less impactful alternatives. However, the implementation of these measures is not socially neutral, raising legitimate concerns about their potentially regressive nature.

The challenge is to reconcile the "double dividend" of ecological taxation: not only to generate budgetary revenues and reduce polluting emissions, but also to potentially lower other distortive taxes, such as labor tax. This approach, popularized in the 1990s, remains a major objective, although its full realization is often complex in practice. The stake is to calibrate fiscal instruments to maximize their effectiveness while minimizing their undesirable effects on the most vulnerable households. The design of progressive ecological taxation requires a detailed mapping of distributive impacts.

Empirical studies have shown that taxes on energy or carbon can disproportionately affect low-income households, who spend a larger proportion of their budget on essential goods and services whose production is often carbon-intensive. Progressivity cannot be decreed; it must be organized through targeted redistribution or compensation mechanisms. The Carbon Border Adjustment Mechanism (CBAM): An Instrument for Trade and Environmental Regulation The Carbon Border Adjustment Mechanism (MACF), more commonly known as CBAM, developed by the European Union, represents an unprecedented attempt to reconcile climate ambitions and trade equity.

Temporarily entered into force on October 1, 2023, with an initial declarative phase, and fully operational from 2026, it aims to prevent "carbon leakage." Carbon leakage occurs when industrial production shifts from regions with strict climate policies to regions with less stringent standards, thereby undoing efforts to reduce emissions. The CBAM applies a carbon price to imports of certain products (iron and steel, cement, fertilizers, aluminum, electricity, hydrogen) from countries where climate policies are less ambitious than those of the EU.

European importers will have to purchase CBAM certificates corresponding to the carbon price they would have paid if the goods had been produced in the EU, taking into account carbon pricing mechanisms already applied in the country of origin. This approach is anchored in the "Fit for 55" legislative package, which aims to reduce the EU's net greenhouse gas emissions by at least 55% by 2030 compared to 1990 levels. The main objective of the CBAM is to create fair competitive conditions for European companies subject to the Emission Trading System (ETS or EU ETS), while encouraging EU trading partners to raise their own climate ambitions.

It is a major unilateral measure, likely to transform international trade dynamics and potentially serve as a model for other economic blocs. Its effectiveness will depend on its compliance with World Trade Organization (WTO) rules, particularly Article XX of the GATT, which authorizes derogations to protect health or exhaustible natural resources, provided they do not constitute arbitrary or unjustifiable discrimination. The CBAM is part of a climate diplomacy perspective and the EU's "normative power," to use Majone's (1998) phrase. It aims to externalize environmental costs onto foreign producers, pushing them to internalize the negative externalities of their production.

However, its success will also depend on acceptance by trading partners, with India and China having expressed reservations about its impact on their exports. A rigorous evaluation of its international redistributive effects will be crucial. Financial Transaction Taxation: From Tobin to Stiglitz, a Quest for Stability and Justice The proposal for a Financial Transaction Tax (FTT), often called "Tobin tax," formulated by economist James Tobin in 1972, initially aimed to discourage excessive speculation on the foreign exchange market and reduce exchange rate volatility.

Tobin, Nobel laureate in economics in 1981, suggested a minimal tax, for example 0.1% or 0.2%, on currency conversions, to slow down short-term capital flows, deemed destabilizing for national economies. Although never fully implemented globally in its original version, the idea has resurfaced several times, particularly after the financial crises of

1997-1998 in Asia and the 2008 crisis. Influential voices like Joseph Stiglitz (Nobel laureate 2001), in his 2009 report to the United Nations, reignited the debate on the usefulness of an FTT to finance global public goods, such as combating climate change and development.

Stiglitz emphasized the ability of such a tax to generate substantial revenue while curbing unproductive speculation. An FTT could be designed to target a broader range of financial assets, including stocks, bonds, and derivatives. Proponents believe it would stabilize markets, reduce the amplitude of speculative bubbles, and significantly increase tax revenues. The International Monetary Fund (IMF) estimated in 2011 that a tax of 0.005% on stock and bond transactions could generate up to $30 billion per year in advanced economies.

However, the implementation of an FTT faces major challenges, including the risk of relocation of financial activities to untaxed jurisdictions, the potential impact on market liquidity, and the technical complexity of its collection. The experience of France, which implemented an FTT on certain acquisitions of listed shares in 2012 (currently at 0.3%), shows that its effectiveness is conditional on extensive international cooperation to avoid tax arbitrage. An FTT with an environmental purpose should be specifically designed to discourage investments in the most polluting industries or to finance ecological transition projects.

Taxation of Resource Extraction: Internalizing the Cost of Depletion The taxation of natural resource extraction constitutes an essential lever in ecological economics for internalizing the cost of resource depletion and associated environmental degradation. Natural resources, whether mineral, fossil, or biological, are often considered public goods or commons, the unregulated exploitation of which leads to overexploitation and a failure to fully value their natural capital. Several countries and sub-national entities have implemented extraction royalties or specific taxes.

For example, in Canada, British Columbia applies royalties on natural gas extraction, while in Australia, the Minerals Resource Rent Tax (MRRT), introduced in 2012 and repealed in 2014, aimed to collect a portion of the superprofits generated by the exploitation of iron ore and coal deposits. These fiscal instruments aim to ensure that the community benefits from fair compensation for the alienation of its natural heritage and to encourage operators to use resources more efficiently.

The objective of this taxation is twofold: on the one hand, to generate revenue for public authorities, which can be reinvested in environmental preservation, compensation for affected communities, or economic diversification. On the other hand, it acts as a price signal, making extraction more costly and thereby encouraging recycling, reuse, substitution, and material moderation. This taxation is all the more relevant as extraction is identified as responsible for approximately 50% of global greenhouse gas emissions and more than 90% of biodiversity loss and water stress according to the United Nations Environment Programme (UNEP) in its 2021 report *Making Peace with Nature*.

A notable example is the principle of "Hartwick's rule," an economic concept which stipulates that an economy exploiting non-renewable natural resources should reinvest the rents generated by this exploitation in reproducible assets, in order to maintain a constant per capita consumption level indefinitely. Extraction taxation can serve as a mechanism to capture this rent and redirect it towards sustainable investments. In Norway, the State's sovereign fund, fueled by oil revenues, illustrates this approach, managing approximately $1,500 billion in assets (end of 2023 figures), a significant portion of which is invested outside fossil fuel industries.

Challenges of Implementing Progressive Green Taxation The effectiveness and social acceptability of progressive green taxation depend on several interdependent factors. The first is the level of the tax. A tax that is too low risks not producing the desired incentive effect, while a tax that is too high can generate significant economic shocks and social unrest, as was the case in France with the carbon tax in 2018. The price elasticity of the targeted activity is a central parameter in this calibration. The second challenge lies in the mechanisms for redistributing revenues. To ensure progressivity, it is essential to compensate the most vulnerable households.

This compensation can take various forms: direct monetary transfers (universal carbon dividend, as proposed by J. K. Galbraith in 1993), reduction of other regressive taxes, financing investments in energy transition (home insulation, public transport). A 2019 study by the London School of Economics showed that 60% of the revenue from a carbon tax of £100/ton of CO2 could be redistributed to protect the poorest 40% of households in the United Kingdom. A third challenge is the international dimension. Environmental taxation can create competitive distortions if it is not coordinated globally.

The CBAM is a partial response to this problem, but regulatory fragmentation remains a major obstacle. Work on tax harmonization or the establishment of common environmental standards is crucial to avoid "pollution havens" and regulatory arbitrage. Multilateral cooperation is indispensable for maximum effectiveness. Finally, political acceptability is paramount. Tax reforms, particularly those that modify the relative prices of basic goods and services, can be unpopular. Transparent communication about the objectives, redistribution mechanisms, and long-term benefits for society is essential.

The inclusion of various stakeholders (trade unions, businesses, associations) in the consultation process can strengthen the legitimacy of the measures and facilitate their implementation. Towards a Global Fiscal Framework for a Just Transition The architecture of progressive ecological taxation must be integrated into a broader vision of economic and social transformation. It is not only about "taxing bads," but about reorienting the entire fiscal system to support a sustainable, resilient, and equitable economy.

This implies rethinking implicit or explicit subsidies for fossil fuels—estimated at $5.9 trillion in 2020 by the IMF—and fully integrating the principles of the circular economy and resource scarcity. Fiscal reform must be designed as an accelerator of the transition. Beyond direct taxes on emissions or resources, it is necessary to examine fiscal incentives for investment in green technologies, tax credits for energy efficiency, and the adjustment of depreciation regimes to favor assets with a low carbon footprint. A holistic approach would also embrace land taxation to combat land artificialization and the taxation of negative externalities linked to intensive agricultural production.

The complexity of the issues requires an adaptive and multidisciplinary approach, integrating lessons from economics, sociology, and Earth system sciences. Decision-makers must rely on robust modeling to anticipate economic and social impacts, and be prepared to adjust instruments based on feedback. Progressive ecological taxation, like Herman Daly's (1996) work on the steady-state economy, is not an end in itself, but an essential means to concretize the shift from a linear and extractivist economy to a regenerative model that respects planetary boundaries.

The implementation of these fiscal instruments must be perceived as a collective investment in a common future, where prosperity is decoupled from environmental degradation and where the benefits of the transition are shared equitably. The challenge is immense, but the paths to achieving it are now clearly identified, requiring strong political will and unprecedented international cooperation to overcome national and sectoral divisions.

Chapter 42 Basic Income and Universal Endowment: The Theoretical Foundations of an Unconditional Income The concept of universal income, whether termed basic income, base income, or unconditional endowment, is rooted in a long tradition of economic and philosophical thought, oscillating between redistributive justice and economic efficiency. As early as the 16th century, Thomas More, in his "Utopia" (1516), already evoked the idea of guaranteed subsistence, albeit without the systematic and unconditional scope of contemporary proposals.

Thomas Paine, in "Agrarian Justice" (1797), was more explicit, proposing a national fund financed by an inheritance tax, whose revenues would be distributed to every citizen. This idea re-emerged in the 20th century, notably with the economist James Meade in 1964 ("Efficiency, Equality and the Ownership of Property"), who suggested a "social dividend" as an alternative to generalized private property.

More recently, the works of Philippe Van Parijs ("Real Freedom for All: What (If Anything) Can Justify Capitalism?", 1995) have helped structure the argument in favor of a basic income as a condition for "real freedom" for all citizens, arguing that this measure would allow everyone to pursue their life projects without the imperative constraint of wage employment. Contemporary debates on universal income are no longer confined to the academic sphere but question the place of work in post-industrial societies and the mechanisms of wealth production.

The digitalization of the economy and the progressive automation of many productive tasks, highlighted by Erik Brynjolfsson and Andrew McAfee in "The Second Machine Age" (2014), reinforce the urgency of rethinking wealth distribution and access to fundamental economic security. From Universal Income to Living Income: A Necessary Conceptual Transition While universal income aims to guarantee a fixed and unconditional sum to everyone, the concept of "living income" introduces a crucial qualitative and normative dimension: that of sufficiency to cover essential needs.

This distinction is not semantic but substantive, engaging a reflection on the "dignity threshold" and the articulation between monetary resources and the real capacity to access fundamental goods and services. Developing a living income requires defining and quantifying a "basket of essential goods and services"—food, decent housing, energy, water, transport, communication, healthcare, and access to culture and education. This approach aligns with economist Amartya Sen's work on "capabilities," meaning the real freedom to achieve valued outcomes, which is not limited to possessing goods but to the capacity to use them.

The determination of this threshold is intrinsically linked to the socio-economic and cultural context and cannot be universal in its modalities, although its purpose—guaranteeing dignity—is transnational. Studies conducted by organizations such as the Fondation Abbé Pierre in France, or the Living Wage Foundation in the United Kingdom, which calculate a "decent wage" based on real living costs, illustrate this complexity and the need for contextualization.

Case Studies and Experimentations: Heterogeneous Models The idea of a universal endowment, whether or not it is qualified as "living," has been implemented or experimented with in various forms across the world, revealing contrasting approaches and diverse results. The Alaska Permanent Fund (APF) Created in 1976 by an amendment to the Alaska State Constitution, the Alaska Permanent Fund is a pioneering example of a citizen's endowment funded by natural resources. Funded by a portion of the revenues from Prudhoe Bay oil exploitation, it aims to share non-renewable wealth with current and future generations.

It is a sovereign fund whose returns are partially redistributed each year to all eligible residents. The annual dividend, calculated based on the fund's average performance over the last five years, is distributed as a single payment. In 2008, an eligible resident received $2,069, while in 2023, this amount was $1,312 per person. The eligibility criteria are simple: being an Alaska resident for a full calendar year preceding the application and intending to remain there indefinitely.

This initiative, although criticized for its one-time nature and exclusive reliance on oil funding, demonstrates the viability of a large-scale redistribution mechanism, contributing to reducing inequalities and stimulating the local economy. The Mongolian Experiment (2010-2012) Mongolia implemented a quasi-universal distribution of "dividends" to citizens between 2010 and 2012, financed by revenues from mining resources (gold, copper, coal). Initially, this involved distributing 1 million tugriks (approximately 800 USD at the time) to every citizen, including children, to offset high basic goods inflation and share the mining windfall.

The first phase (2010) saw the distribution of cash on bank cards, facilitating direct access to funds. However, the program was modified and finally discontinued in early 2012. The government substituted direct cash distribution with vouchers for goods (such as shares in certain mining companies) or debt repayments. This conversion diluted the unconditional and universal scope of the initial measure, transforming it into a conditional social assistance program and corporate recapitalization. Lessons learned from this experiment highlight the political fragility of such programs in the face of fluctuating raw material prices and changing governmental priorities.

GiveDirectly's Experiments in Kenya Since 2017, the NGO GiveDirectly has been conducting a long-term unconditional basic income experiment involving 20,000 people across 245 villages in the rural Siaya region of Kenya. This project is one of the largest and most rigorous randomized controlled studies ever conducted on universal income, comparing different recipient groups: one group receiving a monthly income for 12 years, one group receiving a monthly income for two years, one group receiving a single lump sum, and a control group. The initial results, published in 2020 and 2021, are encouraging.

Beneficiaries saw a significant increase in their incomes, improved food security, reduced stress and depression, and a moderate increase in investments in small businesses. Contrary to some fears, there was no decrease in the desire to work or a notable increase in alcohol or tobacco consumption. Households receiving universal income increased their educational spending by 33% and the value of their assets by 16% over two years. Economic and Financial Stakes of a Living Endowment The economic feasibility of a universal living endowment is at the heart of debates and controversies.

Implementation costs, funding sustainability, and macroeconomic impacts are essential questions that require in-depth analysis. Funding and Redistribution Various funding sources are being considered. One of the most frequently cited options is the rationalization and redesign of existing social welfare systems. Many social programs are costly to administer, inefficient, and create "poverty traps" by discouraging work. An unconditional living income could potentially replace or simplify them, freeing up significant funds. For example, a 2021 OECD study estimated that social expenditures of member countries averaged 20.1% of their GDP. Another avenue is progressive taxation.

A negative income tax, as proposed by Milton Friedman in 1962 in "Capitalism and Freedom," can be seen as a form of targeted universal income. More explicit forms of funding include an increase in income tax for higher brackets, wealth taxation, financial transactions tax (Tobin Tax), or a social VAT. Economist Thomas Piketty, in "Capital in the Twenty-First Century" (2013), specifically proposes progressive capital taxation as a lever to reduce inequalities and finance public goods, an objective compatible with the idea of a living endowment. Taxation of natural resources, as in the Alaska model, or even a carbon use tax, could also contribute to funding.

A "robot tax" on automation, advocated by figures like Bill Gates, is an emerging proposal, aiming to compensate for the disappearance of human jobs through contributions levied on the activity of digital technologies. Macroeconomic Impacts The expected effects of a living income on the economy are complex and debated. Some economists fear disincentives to work, generalized inflation, or capital flight. Others, on the contrary, believe that a living income would stimulate consumption, encourage entrepreneurship, reduce costs associated with poverty (health, justice), and foster a better match between skills and jobs, by allowing individuals to train or retrain more easily.

Simulations indicate that the inflationary impact is mixed. If aggregate demand increases, supply can also adjust, and an increase in inflation would largely depend on existing production capacities and monetary policy. Furthermore, improved health and education of populations through this endowment could lead to increased productivity in the long term. The results of the GiveDirectly experiments in Kenya showed an increase in investment in small businesses and a diversification of economic activities, suggesting a stimulating effect.

Universal Endowment as an Instrument for Ecological Transition The integration of social justice and ecological sustainability issues has become imperative in the face of climate urgency and resource depletion. Universal endowment, and more specifically living income, can be a powerful lever to support and make the ecological transition just. Reducing the Ecological Footprint and Encouraging Sufficiency A living income, by decoupling subsistence from the imperative of exponential economic growth, could offer individuals the freedom to choose less materialistic and less resource-intensive lifestyles.

The idea is that basic financial security would allow individuals to free themselves from overconsumption dictated by economic anxiety and the need for "always more." The work of Tim Jackson ("Prosperity Without Growth: Economics for a Finite Planet," 2009) underlines the need for a reconfiguration of economic incentives to move towards "prosperity without growth." The time freed up by a living income could also be invested in low-ecological-footprint activities, such as home maintenance, gardening, volunteering, or participation in the circular and collaborative economy.

A study by the French National Institute of Statistics and Economic Studies (INSEE) in 2019 showed that domestic and volunteer activities are predominantly activities with low direct environmental impact. Supporting Structural Transformations The transition to a post-carbon and less extractivist economy will involve significant disruptions for certain sectors and job losses. A universal endowment could act as a "social shock absorber," facilitating professional retraining towards more sustainable occupations (renewable energy, organic farming, circular economy) and allowing workers to adapt without falling into precariousness.

It would offer security, enabling the acceptance of radical changes in work organization and production methods. Furthermore, a living endowment could be coupled with environmental taxation mechanisms, such as a universal carbon tax whose revenues would be entirely redistributed to citizens in the form of a "carbon dividend." This approach, notably advocated by the Carbon Tax Center, aims to make carbon pricing socially acceptable by offsetting its regressive impact on the poorest households.

The experience of British Columbia in Canada, which implemented a carbon tax with partial redistribution, illustrates the relevance of this synergy between environmental taxation and social equity since 2008. Legal and Constitutional Framework for a Right to Living Income The inclusion of a right to living income in national or international legal order represents a major constitutional and political challenge. Although many contemporary Constitutions recognize economic and social rights, the explicit right to an unconditional income sufficient to live with dignity is still rare.

Existing Economic and Social Rights International instruments like Article 25 of the Universal Declaration of Human Rights (1948) stipulate that "Everyone has the right to a standard of living adequate for the health and well-being of himself and of his family, including food, clothing, housing, and medical care and necessary social services." The International Covenant on Economic, Social and Cultural Rights (1966), in its Article 11, reiterates and deepens this idea, although these are rights of progressive realization and not immediately invocable subjective rights. At the national level, many modern Constitutions contain similar provisions.

The Constitution of the Federal Republic of Germany (1949), through the notion of a social state ("Sozialstaat"), and the French Constitution (Preamble of 1946) recognize the right to solidarity and social security. However, these rights are generally interpreted as the right to a social safety net (conditional social minima) rather than to an unconditional universal income. Towards Formal Recognition of a Right to Living Income Integrating a right to living income would require either a bold interpretation of existing texts or an explicit constitutional reform.

Proposals are emerging to enshrine this right at the supranational level, for example within the European Union, as a new "fundamental right." This approach would raise complex questions of subsidiarity and national sovereignty, but it could offer a protective framework for citizens in the face of economic and environmental transformations. A 2010 decision by the German Federal Constitutional Court ruled that the fundamental right to the guarantee of a minimum living standard ("Grundrecht auf Gewaehrleistung eines menschenwurdigen Existenzminimums") derives from human dignity (Article 1 para. 1 of the Basic Law) combined with the principle of the social state (Article 20 para. 1).

Although this decision concerns existing social benefits, it paves the way for jurisprudential recognition of a constitutional right to an income that covers basic needs. Such a legal evolution would significantly strengthen the legitimacy and protection of a living endowment system. Chapter 43 Sovereign Debt and Ecological Debt The Entanglement of

Vulnerabilities: Sovereign Debt and Ecological Crisis The convergence of crises is a central theme of the 21st century, where the financial vulnerabilities of states and the accelerated degradation of ecosystems can no longer be analyzed in isolation.

Sovereign debt, a financial liability accumulated by a state entity, is increasingly linked to ecological debt, a more diffuse concept referring to the irreversible degradation of environmental commons and the gap between an ecological footprint and a territory's biocapacity (Rees & Wackernagel, 1996). This interdependence is particularly pronounced for low- and middle-income countries, often the most exposed to the impacts of climate change while having limited fiscal capacity to address them. The debt burden severely hampers the capacity for investment in green infrastructure, climate adaptation, and biodiversity protection.

When nations dedicate a substantial portion of their export revenues to servicing external debt, the fiscal space for financing the ecological transition is drastically reduced. The International Monetary Fund (IMF) reported in 2023 that more than half of low-income countries were already in debt distress or at high risk of becoming so, making the search for innovative solutions linking economic viability and environmental sustainability imperative. The erosion of biodiversity and the disruption of biogeochemical cycles constitute existential threats, whose economic costs are increasingly quantified.

The Dasgupta Review (2021), commissioned by the UK Treasury, highlighted the depletion of global natural capital and the imperative of redirecting our economic systems to integrate the value of nature. It is estimated that lost ecosystem services cost the global economy trillions of dollars annually, a cost rarely attributed to sovereign balance sheets in the form of explicit ecological debt. Article L. 110-1 of the French Environmental Code, by defining the concept of ecological damage, offers implicit legal recognition of this notion of debt, even if its application remains limited to proven damages and does not capture the systemic scale of degradation.

This dual approach, where the financial distress of nations overlaps with their role as guardians of crucial biomes, calls for financing mechanisms that reconcile short-term economic imperatives and long-term ecological requirements. "Debt-for-Nature Swaps": A Structuring Relief Mechanism "Debt-for-nature swaps" are financial instruments designed to simultaneously alleviate sovereign debt and fund conservation initiatives.

Their principle is simple: a debtor country sees a portion of its external debt bought back or restructured by a third party (generally an environmental organization or a multilateral institution), in exchange for the government's commitment to invest an equivalent (or slightly lesser) amount locally in environmental protection programs. These mechanisms, whose first examples date back to the 1980s, with notable operations in Costa Rica and Bolivia, have seen a revitalization and increased sophistication in the last two decades.

The complexity of their financial engineering lies in the coordination between creditors (sovereign funders, commercial banks), the debtor country, and the organizations involved in conservation. Debt buyback often occurs at a discounted price on the secondary market, thus transforming an international financial liability into a national environmental investment. The main advantage of these swaps is their ability to generate long-term financing for conservation, while reducing budget pressure on participating countries.

They also allow the transfer of responsibility for international debt management to competent national authorities, with an accountability framework defined by the environmental program implemented. The conditionality of these funds ensures relative transparency and traceability of investments, often absent from traditional financing. However, these swaps are not without criticism. Their scope is sometimes considered limited compared to the scale of total debt and environmental financing needs. They can also raise sovereignty issues if conservation programs are perceived as externally imposed.

Effectiveness largely depends on local governance, the robustness of institutions, and the country's ability to genuinely implement and maintain the environmental commitments made. Financial and Legal Engineering of Swaps The financial mechanisms of "debt-for-nature swaps" have become increasingly complex, often involving multilateral institutions as guarantors or facilitators. Instruments may include debt buybacks on the secondary market at a discounted price, partial debt cancellations, refinancing with lower interest rates, or green bonds issued to buy back existing liabilities.

The legal dimension is paramount: each operation requires detailed tripartite or quadripartite agreements, amendments to original debt contracts, and the creation of national trust funds specifically dedicated to environmental projects. These funds are managed by joint committees (government, civil society, experts) to ensure transparency and efficient resource allocation. The creation of a national legislative framework favorable to these funds is often a prerequisite. The role of financial guarantees ("credit enhancements") is crucial for attracting investors and reducing the cost of refinancing for debtor countries.

Institutions such as the US International Development Finance Corporation (DFC) or private entities can provide these guarantees, minimizing perceived risk and facilitating the issuance of new debt securities on more favorable terms. This approach allows for the mobilization of capital far beyond what conservation organizations could provide alone. These arrangements are often structured to generate financial flows over several decades, ensuring the sustainability of conservation projects. Payments from the debtor country are then made in local currency to the trust fund, thus avoiding pressure on foreign exchange reserves and dependence on exchange rate fluctuations.

The challenge is to calibrate the whole so that debt relief is significant without compromising the country's financial commitments. Emblematic Case Studies of "Debt-for-Nature Swaps" Several island and coastal countries, particularly vulnerable to the effects of climate change, have been pioneers in the application of these mechanisms. Their rich marine and terrestrial biodiversity, often threatened by overfishing, pollution, or urbanization, gives particular urgency to these initiatives. The Case of Seychelles (2016): Pioneer of the Blue Economy In 2016, Seychelles initiated an innovative "debt-for-nature swap," the first of its kind for an island state.

This operation, facilitated by The Nature Conservancy (TNC), allowed for the buyback of $21.6 million of sovereign debt from Paris Club creditors. This debt, initially contracted for infrastructure and development expenditures, was repaid by the Seychellois government through a local trust fund, the Seychelles Conservation and Climate Adaptation Trust (SeyCCAT), at a reduced interest rate. In exchange for this relief, the government committed to designating 30% of its 1.37 million km2 Exclusive Economic Zone (EEZ) as marine protected areas by 2020.

This commitment was met and even exceeded, with the protection of two vast areas (the Aldabra archipelago and the Frégate Islands) covering approximately 410,000 km2, including some of the most emblematic coral reef and seagrass ecosystems on the globe. This model demonstrated the ability to articulate environmental protection and economic development in a blue economy strategy. The operation was made possible by a $5 million guarantee from the Leonardo DiCaprio Foundation and other philanthropists, as well as a subsidized loan of $21.6 million from TNC.

SeyCCAT is now funded by local currency payments from the government and donations, supporting projects for sustainable fisheries management, marine ecosystem restoration, and climate adaptation.

Revenues generated by tourism activities related to these protected areas also contribute to the fund's sustainability. This initiative has propelled Seychelles to the forefront of international marine conservation efforts and set a precedent for other island states. The success of this operation rests on the strong political will of the Seychellois government, the technical expertise of TNC, and the mobilization of philanthropic funding and guarantees.

It is a tangible example of how debt restructuring can become a catalyst for ecological resilience. Belize (2021): The Largest Marine Swap In 2021, Belize finalized the largest "debt-for-nature swap" ever implemented, valued at $364 million, representing 12% of its GDP. Here again, The Nature Conservancy played a central role, not only as a facilitator but also by buying back the country's entire "superbond," a complex sovereign bond resulting from previous restructurings. This transaction was made possible by a $610 million financial guarantee from the US DFC.

The objective of this operation is to protect 30% of Belize's territorial waters and EEZ by 2026, covering an impressive area of 500,000 hectares of marine ecosystems, including the world's second-largest coral reef. A new trust fund, the Belize Blue Bond and Exchange Conservation Fund, receives government payments, which are reinvested in marine protected area management, sustainable fisheries, and mangrove and reef restoration. This swap allowed Belize to reduce its debt-to-GDP ratio from 133% in 2020 to approximately 100% after the operation, while freeing up substantial resources for the environment.

The success of this operation highlights the importance of public-private partnerships and sovereign guarantees in unlocking capital at the scale required for ecological transition. The holistic approach also integrates institutional strengthening measures and marine spatial planning. The case of Belize illustrates the ability of these swaps to transform a financial liability into leverage for large-scale biodiversity conservation. The operation also allowed for renegotiating debt terms with more favorable conditions, offering the country much-needed financial respite to invest in its resilience to climate shocks and anthropogenic pressures on its natural resources.

Ecuador (2023): A Commitment to the Galápagos The most recent and largest "debt-for-nature swap" was concluded by Ecuador in May 2023, restructuring $1.6 billion of external debt. This mechanism, coordinated by Credit Suisse and The Pew Charitable Trusts, with a DFC guarantee and a $600 million political reinsurance from the Inter-American Development Bank (IDB), generated $450 million for conservation. The operation involved the purchase of discounted Ecuadorian bonds on the secondary market by a trust fund, the Galápagos Marine Bond, which was refinanced by the issuance of a $656 million blue bond.

Ecuador's payments on this blue bond will, in part, be redirected to a conservation fund managed by the Galápagos Life Fund, supporting the protection of the Galápagos Marine Reserve, a UNESCO World Heritage site exceptional for its endemic biodiversity. The Galápagos Life Fund is expected to generate $18 million per year for conservation over the next 18 years, totaling over $320 million. This agreement allows Ecuador to reduce its principal debt repayments by over a billion dollars over the life of the operation, freeing up considerable budgetary margins for other investments.

It is an eloquent illustration of the possibility of anchoring financial stability to the preservation of the planet's most precious ecosystems. This commitment aims notably to strengthen the monitoring and management of the Galápagos marine protected area, including new areas created in 2022 around Cocos and Malpelo Islands. The Ecuadorian swap, by its scale and the sophistication of its financial structuring, paves the way for other biodiversity-rich countries facing sovereign debt challenges. It symbolizes a major evolution of "debt-for-nature swaps," which are moving from niche operations to state-level financial leverage instruments.

Prospects and Challenges of "Debt-for-Nature Swaps" "Debt-for-nature swaps" have become a powerful tool in the arsenal of conservation and climate adaptation financing mechanisms. Their ability to free up significant financial resources while reducing the debt burden makes them an attractive solution, especially for the most vulnerable countries. However, expanding their scope and their long-term effectiveness depends on several factors. The main challenge lies in the ability to mobilize funds at the scale necessary to meet the colossal needs of the ecological transition.

The United Nations Environment Programme (UNEP) estimated in 2022 that the biodiversity financing gap was approximately $700 billion per year. The few billions of dollars mobilized by these swaps, while important for the countries concerned, cannot alone close this gap. Replicating successes like those in Seychelles, Belize, and Ecuador requires increased involvement from international financial institutions, multilateral development banks, and the private sector. Due diligence in the design and implementation of these instruments is paramount.

Each swap must be adapted to the specific context of the country, including its legal framework, environmental governance, and institutional capacity. Rigorous planning is necessary to ensure that funds are effectively used for conservation and adaptation, with clear monitoring and evaluation mechanisms. Without robust governance, these initiatives risk not achieving their environmental objectives or faltering in the face of political changes. Another challenge is creditor participation.

While multilateral banks and some bilateral institutions are increasingly open to these mechanisms, private creditors are often more reluctant to participate in debt restructurings that might involve a discount or less favorable terms. Creating additional incentives and guarantees could encourage their engagement. The broader framework of international financial architecture reform, as proposed by the Bridgetown Principles, could also create a more conducive environment for these swaps.

Finally, the question of the "climate debt" or "ecological debt" of developed countries to developing countries for their historical contribution to greenhouse gas emissions and global environmental degradation remains unresolved. Although "debt-for-nature swaps" alleviate financial debt, they do not inherently compensate for this ecological debt. Nevertheless, they represent a pragmatic way to articulate responses to the twin crises of debt and the environment, pending more formal recognition and global-scale reparation for accumulated ecological damages.

Chapter 44 Central Banks and Climate Mandate: From Market Neutrality to Justified Interventionism Central banks, pillars of financial and monetary stability, are at a historic crossroads. The cardinal principle of market neutrality, a cornerstone of their doctrine since the 1980s and the deregulation of financial markets, is increasingly being questioned in the face of the climate emergency. This principle posits that central banks should not distort capital allocation through targeted interventions, contenting themselves with purchasing assets based on their relative availability in markets.

However, by doing so, they implicitly incorporate negative externalities whose price is not, or poorly, internalized, particularly those related to greenhouse gas-emitting activities. The hypothesis that monetary policy must be neutral with respect to resource allocation developed concomitantly with the rise of neoliberal orthodoxy and the vision of an intrinsic efficiency of financial markets. However, this neutrality is illusory. In 2020, G7 central banks collectively held approximately 28% of public debt and a significant share of corporate bonds, effectively influencing the financing conditions of entire sectors of the economy.

The European Central Bank, for instance, held up to 65% of eligible corporate bonds in certain purchase programs, demonstrating a structural influence on the real economy. This claimed neutrality is all the more problematic as it validates and amplifies structural market failures, in this instance the absence or insufficiency of a carbon price. Markets, by themselves, fail to adequately integrate climate risks and environmental costs. In the absence of a sufficient price signal, investments continue to flow into carbon-intensive activities, compromising the ecological transition. Central bank intervention, far from constituting a distortion, could thus correct a systemic failure.

The scientific consensus, particularly that of the Intergovernmental Panel on Climate Change (IPCC), has established with increasing certainty the urgency of decarbonization. The IPCC's 2018 special report on global warming of 1.5°C highlighted the need to reduce global CO2 emissions by about 45% by 2030 compared to 2010 levels. Faced with this reality, the inaction of central banks, or their passive adherence to a non-green capital allocation model, becomes a stance, an implicit support for the climate status quo. Central banks must therefore reconsider the scope of their mandate and their instruments.

The imperative of price stability, their primary mandate in many jurisdictions, is intrinsically linked to macroeconomic stability, which is itself threatened by climate shocks. A 2020 study by the Banque de France estimates that global GDP could decrease by 3 to 10% by 2050 in the absence of ambitious climate policies. Neutrality then becomes synonymous with blindness to risks that threaten the very achievement of their fundamental objectives. The emergence of the NGFS network and the green secondary mandate The Network for Greening the Financial System (NGFS), launched in December 2017 at the One Planet Summit, marks a significant turning point.

Created on the initiative of eight central banks, it now brings together over 130 members and observers, including the Banque de France, the European Central Bank, and the United States Federal Reserve. Its objective is to contribute to the development of climate and environmental risk management in the financial sector and to mobilize the necessary financing for the transition to a sustainable economy. From its first publications, the NGFS identified three categories of climate risks: physical risks (damage to property and infrastructure), transition risks (changes in policies, technologies, market preferences), and liability risks (climate change-related litigation).

The inaugural 2019 NGFS report thus emphasized that "failure to act on climate change is a source of financial stability risk." It is no longer a purely environmental issue, but an essential component of macro-prudential policy. In the wake of these efforts, the European Central Bank (ECB) took a major step in July 2021 by announcing a roadmap to integrate climate considerations into its monetary policy framework.

Under Article 127(1) of the Treaty on the Functioning of the European Union (TFEU), which stipulates that "without prejudice to the objective of price stability, the European System of Central Banks shall support the general economic policies in the Union," the ECB interpreted support for the fight against climate change as a legitimate secondary mandate. This has translated into several concrete measures. Since October 2022, the ECB has begun to reorient a portion of its asset purchases towards issuers with better climate performance and to reduce the share of companies with poor performance.

It has also announced the inclusion of climate risks in its collateral framework, notably by adjusting the haircuts applied to green and brown assets. Equity transparency regarding climate is another pillar of this strategy, with banks being required to publish their exposure to climate risks. Despite these advances, the scope of this secondary mandate is debated. Critics, such as those voiced by Jean Pisani-Ferry and Benoît Mahfouz in 2023 in their publication "Monetary Policy in the Climate Emergency," emphasize that the ECB's action remains constrained by its primary mandate of price stability and the principle of market neutrality.

While the reorientation of asset purchases is a step, its quantitative impact remains limited. The share of purchases concerned by this "greening" is relatively small compared to the ECB's overall balance sheet, which amounted to over 8,000 billion euros at the beginning of 2022. The problem lies in subordination: the climate mandate can only be pursued if it does not harm price stability. However, it is possible that ambitious climate policies could generate short-term inflationary pressures, for example through rising fossil fuel prices or the cost of transition investments.

In this case, the climate mandate could be sacrificed on the altar of price stability, which would considerably limit its structural effectiveness and ambition. Beyond the secondary mandate: towards an expanded primary mandate The inherent shortcomings of subordinating the climate mandate necessitate a fundamental rethinking of the central banks' operational framework. The idea of an expanded primary mandate, explicitly integrating financial stability, price stability, and environmental sustainability, is gaining traction.

This proposal is radical because it would change the hierarchy of objectives, elevating sustainability to the same level as price stability, or at least to a non-subordinate position. The main argument for such an expansion is that climate change is the deepest and most systemic threat to long-term macroeconomic and financial stability. Achieving the long-term price stability objective is intrinsically linked to the economy's ability to operate within planetary boundaries. Ignoring this interconnectedness amounts to institutional myopia with potentially catastrophic consequences.

An economy facing recurrent climate shocks (droughts, floods, storms) cannot maintain stable inflation and sustainable growth. An expanded primary mandate would allow central banks to act with determination and proactively, without fear of overstepping the boundaries of a secondary mandate. This would imply a overhaul of the legislative frameworks of central banks like the ECB (Article 127 TFEU) or the Federal Reserve (Federal Reserve Act), where price stability dominates. In 2021, the People's Bank of China officially included "promoting green development" among its functions, illustrating a more integrated approach.

The definition of price stability itself could be reinterpreted in light of climate risks. Inflation that reflects the degradation of ecosystem services or the overconsumption of natural resources is not "healthy" inflation. On the contrary, it signals an inefficient allocation of resources and an unsustainable trajectory. From this perspective, price stability cannot be dissociated from ecological and social stability. Instruments of a green monetary policy With an expanded mandate, central banks could deploy a more audacious and targeted arsenal of tools.

Collateral modulation is a powerful lever: applying lower haircuts to green assets and higher haircuts to carbon-intensive assets would make it an effective macroprudential tool. This would incentivize commercial banks to review their loan portfolios and investments. The Bank of England, in its 2021-2022 review, announced the integration of climate stress tests for the banks it supervises, paving the way for differentiated asset categories. Open market operations, a cornerstone of monetary policy, could be used to foster financing for the ecological transition. This goes beyond merely reorienting asset purchases.

Central banks could create dedicated financing facilities for green investments, such as targeted longer-term refinancing operations (TLTROs) with more favorable conditions for green loans. Such a measure would send a strong signal to markets and economic actors.

Central banks' communication policies should also adapt. In addition to inflation and growth forecasts, they could integrate regular analyses of climate risks and their macroeconomic implications. Such transparency would contribute to greater market awareness and the integration of climate risks into investment decisions. The Banque de France's 2023 annual report thus dedicated a large section to assessing climate risks.

A central question concerns the independence of central banks. Some argue that a climate mandate would draw them into the field of industrial or fiscal policy, thereby undermining their independence. However, central bank independence from political powers aims to prevent short-term pressures that compromise price stability. Climate change is a long-term and systemic threat, which justifies a strategic rather than merely conjunctural vision. Independence is not an end in itself, but a means to achieve objectives of general interest.

The challenge lies not only in integrating climate, but in developing a holistic monetary policy that recognizes the interdependencies between economy, society, and environment. Central banks have a unique role to play, given their position at the heart of the financial system, their ability to issue currency, and their technocratic legitimacy. Limits and Shared Responsibilities While central banks have an increasing role to play, it is imperative to acknowledge the limits of their action and the importance of a coordinated approach. Monetary policy alone cannot be the sole answer to a crisis as complex as climate change.

Fiscal, tax, regulatory, and innovation policies have a predominant role to play in the structural orientation of economies. Financing the transition represents colossal investments, estimated by the European Commission at 1,000 billion euros per year by 2030 for the European Union. Central banks alone cannot meet this need. A green monetary policy must be part of a coherent macroeconomic framework. If governments do not send strong signals through carbon taxation, fossil fuel subsidies, or binding environmental regulations, the impact of central bank measures will be diluted.

The absence of a robust and universal carbon price, as recommended by Pisani-Ferry, Pisani-Ferry (2020), "Climate, the time for action," makes it very difficult to allocate capital efficiently. Central banks risk "greening" portfolios without profoundly transforming the real economy. The question of governance and democratic legitimacy is also crucial. Expanding the mandate of central banks to environmental objectives may raise questions about their accountability and representativeness. Central banks are technocratic institutions, in principle apolitical, whereas climate choices often relate to societal preferences.

However, the energy transition is now a scientific imperative and no longer a political option. Central banks can act as guardians of long-term stability. It is also important to highlight the risks inherent in overly marked intervention. Excessive interventionism could create green bubbles, inefficiently distort capital allocation, or undermine public confidence in the perceived independence and neutrality of central banks. Prudence and progressiveness are essential, with continuous evaluation of policy impacts. ■ **International Cooperation**: The cross-border nature of climate change requires international coordination of green monetary policies.

The NGFS is a first step, but more binding commitments and common standards would be necessary. ■ **Transparency and Data**: Access to reliable and standardized data on companies' climate performance is essential for central banks to effectively target their actions. The challenges of ESG ratings and the reliability of corporate disclosures remain significant. ■ **Research and Innovation**: Central banks must invest in research to better understand the complex links between climate, economy, and finance, and to develop new analytical tools.

Integrating climato-economic models into their forecasts is a major challenge. ■ **Education and Awareness**: A pedagogical role is also expected from central banks to explain to the general public and financial actors the climate risks and the importance of their actions. The path towards a monetary policy fully integrated with climate challenges is demanding but necessary. It involves a structural reform of objectives and instruments, close collaboration with governments, and continuous adaptation to scientific and economic developments. By resolutely embarking on this path, central banks can transform a systemic threat into an opportunity to build a more resilient and sustainable economy.

May 16, 2026 marks a new step in this crucial reflection for the future of our societies. Chapter 45 Alternative Indicators to GDP: Gross Domestic Product: An Outmoded Standard. Gross Domestic Product (GDP), developed by Simon Kuznets in the 1930s to assess economic production during wartime and depression, has become the universal indicator of economic performance and social progress. Its diffusion was accelerated by the Bretton Woods agreements in 1944 and by the international institutions that arose from them. Yet, as early as 1934, Kuznets himself warned the U.S.

Congress against equating social progress solely with GDP growth, pointing out that it did not measure "the welfare of a nation" (Kuznets, 1934). This initial warning was largely ignored in favor of a productivist and quantitative vision of development. GDP aggregates the monetary value of final goods and services produced in a given territory over a given period. It indiscriminately accounts for beneficial activities and negative externalities, such as expenditures for natural disaster recovery or pollution remediation.

Joseph Stiglitz, Amartya Sen, and Jean-Paul Fitoussi, in their 2009 Report on the Measurement of Economic Performance and Social Progress, exhaustively established the limits of GDP as a holistic indicator. GDP omits consideration of wealth distribution, social inequalities, environmental quality, human capital, the non-market economy, and subjective well-being. It does not distinguish between a socially useful expenditure and an expenditure resulting from dysfunction, such as increased healthcare spending due to poor lifestyle choices or growth induced by the overconsumption of non-renewable resources.

This structural blindness leads to major political and ecological impasses, by orienting public decisions towards quantitative maximization at the expense of quality of life and sustainability. GDP growth has become an end in itself in many states, often masking a simultaneous degradation of living conditions for a portion of the population and unsustainable pressure on ecosystems. Between 1970 and 2017, while global GDP increased by nearly 300%, the ecological footprint increasingly exceeded Earth's biocapacity, reaching a global deficit of 70% in 2017 according to the Global Footprint Network.

This divergence between conventional economic indicators and ecological or social realities questions the very relevance of our decision-making analytical framework. Shortcomings of GDP and Its Satellites. GDP does not account for natural capital, meaning the set of ecological systems that provide essential goods and services for life and the economy. The depletion of natural resources, loss of biodiversity, and degradation of ecosystem services are not subtracted from GDP; on the contrary, their exploitation contributes positively to it. Over-exploitation of forests or fisheries temporarily increases GDP, while compromising the future capacity of ecosystems to provide these same resources.

Similarly, GDP ignores the informal economy and unpaid domestic labor, which nonetheless contribute substantially to societal well-being. Estimates vary, but the weight of the informal economy represents, for example, about 30% of GDP in OECD countries and nearly 50% in some developing countries according to a 2017 IMF study. The statistical invisibility of these activities leads to an underestimation of social and human capital and a devaluation of non-market contributions to national wealth. The issue of income distribution and inequality is also absent from this aggregated indicator.

A country with high GDP but a high concentration of wealth at the top of the social pyramid can experience major tensions and dysfunctions. The increase in income inequalities, measured by the Gini index which for example increased by an average of 10% in OECD countries between the mid-1980s and the late 2000s, is not reflected by the sole growth of nominal or real GDP. Towards a Multidimensional Measurement of Progress. Faced with the proven limitations of GDP, numerous initiatives have emerged to develop alternative or complementary indicators, aiming to reflect a more holistic vision of progress.

These approaches are based on the principle that the well-being of a society cannot be reduced to its monetary production alone. They seek to integrate ecological, social, and governance dimensions, often grouped under the acronym ESG, or more broadly under the notion of sustainability. One of the first concrete and institutionalized proposals was the Gross National Happiness (GNH) established in Bhutan. GNH, enshrined in the Bhutanese Constitution of 2008, rests on four fundamental pillars: the promotion of sustainable and equitable socio-economic development, the preservation and promotion of culture, environmental conservation, and the establishment of good governance.

This framework integrates spiritual and community dimensions, recognizing that the pursuit of "happiness" transcends mere economic success. New Zealand adopted a similar approach with its "Wellbeing Budget" in 2019. This pioneering budget allocates priority funding to non-directly economic objectives such as improving mental health, reducing child poverty, improving the living conditions of indigenous populations (M■ori and Pasifika), and transitioning to a low-carbon economy. The New Zealand government has committed to measuring the results of these policies based on their impact on the general well-being of its citizens and its environment, beyond mere growth indicators.

The Organisation for Economic Co-operation and Development (OECD) also developed the "Better Life Initiative" and its "Better Life Index" in 2011. This interactive tool allows citizens to compare well-being in different countries based on 11 key dimensions, such as housing, income, employment, community, education, environment, governance, health, life satisfaction, safety, and work-life balance. It is not a single indicator but a customizable dashboard acknowledging the plurality of individual and national preferences. These examples illustrate a growing trend to recognize the need to move beyond the narrow framework of GDP.

They converge towards the idea that the prosperity of a nation must be evaluated against more comprehensive criteria that take into account the resilience of ecological systems, social cohesion, and the capacity of institutions to guarantee lasting well-being for all. This transition poses significant methodological and political challenges but is essential for navigating contemporary crises. The NOÖS Dashboard: An Integrated Proposal. In line with these efforts, a NOÖS (New Order of Societal Objectives) Dashboard is proposed, aiming to provide an integrated and operational measure of global progress.

This dashboard would be structured around four fundamental pillars, inspired by both Earth system science and political and economic philosophy: Natural Capital, Social Capital, Human Capital, and Wisdom (or Institutional) Capital. Natural Capital would group indicators of environmental health and resource management. It would include metrics such as per capita ecological footprint, deforestation rate, air and water quality, biodiversity (for example, the WWF Living Planet Index, which showed a 69% decrease in vertebrate populations between 1970 and 2018), and climate resilience (carbon absorption capacity, exposure to natural risks).

The objective is to assess the sustainability of the development model with regard to planetary boundaries. Social Capital would measure cohesion, equity, and solidarity within society. It would include indicators such as the Gini index for income distribution, monetary and relative poverty rates, the level of interpersonal trust, the rate of civic and associative participation, the quality of public services (access to health, education), and the perception of social justice. The idea is to assess a society's capacity to offer equitable opportunities and a robust social safety net to everyone. Human Capital would encompass individuals' health, education, and personal development.

This would translate into indicators such as healthy life expectancy, infant mortality rate, skill level and access to lifelong education, subjective well-being (measured by satisfaction surveys, as in the United Nations World Happiness Report), and access to culture and leisure. It would also include elements on working time and free time, essential for individual fulfillment. Finally, Wisdom (or Institutional) Capital would assess the quality of governance, adaptability, and societies' long-term vision.

This would include political stability, judicial independence, perceived corruption (for example, Transparency International's Corruption Perception Index ranked France 22nd in 2023), press freedom, democratic participation, the level of sustainable public debt, and investment in research and innovation oriented towards sustainability. This pillar is crucial for ensuring informed and resilient decision-making in the face of future challenges. Specific Objectives for the NOÖS Dashboard. The NOÖS Dashboard would not constitute a single synthetic indicator, but a coherent set of indicators allowing for the visualization of developments across these four dimensions.

Its strength would lie in its ability to reveal the complex trade-offs between short-term objectives (often economic and quantitative) and long-term imperatives (ecological and social). It would enable policymakers to formulate more balanced strategies and citizens to better understand the stakes of public life. For example, a policy promoting economic growth through intensive exploitation of natural resources would show an improvement in the "Human Capital" pillar through job creation, but a simultaneous and visible degradation in the "Natural Capital" pillar. This multidimensional visualization would offer a more nuanced reading of "progress," highlighting the inevitable compromises.

It would no longer be a matter of replacing GDP, but of moving beyond it by repositioning it as one indicator among others, and not the sole judge of performance. Such a framework requires the harmonization of data and measurement methodologies at the international level, a considerable challenge. The European Union, for example, launched the "Beyond GDP" strategy in 2009, recognizing the urgency of developing complementary indicators for environmental and social policies.

Initiatives such as the United Nations Sustainable Development Goals (SDGs) framework, adopted in 2015, already represent a significant step in this direction, even if they are not a single indicator but a set of 17 goals and 169 targets. Implications of Abandoning Sole Monetary Measurement. The widespread adoption of a multidimensional dashboard like NOÖS would have profound implications for governance and public policies. First, it would alter the hierarchy of political objectives. "Growth" would cease to be the central imperative and would become one consideration among others, subordinate to ecological sustainability and social justice.

This would allow for the operationalization of principles stated in fundamental texts such as the 2015 Paris Agreement on climate or the 2004 French Environmental Charter, which posit sustainable development. Second, it would encourage better integration of public policies. Ministries would no longer work in silos, each seeking to maximize its own indicator (GDP for finance, carbon emissions for the environment, etc.), but would be led to collaborate to improve overall NOÖS scores. Decisions would become more transversal, requiring more complex and better informed cost-benefit analyses of differentiated returns on the four pillars.

From an economic perspective, the reorientation of investments would be significant. Fewer projects would be evaluated solely on their immediate monetary profitability, in favor of longer-term investments in energy transition, inclusive education, preventive health, or biodiversity protection. This could foster the emergence of a more regenerative and less extractive economy, measured not only by monetary flows but also by the preservation of natural and social capital stocks. The role of democracy and citizen participation would also be strengthened.

A transparent and accessible dashboard would allow citizens to more finely assess the performance of their governments and to debate societal choices in a more informed manner. It would foster a culture of co-construction of public policies, where indicators would no longer be merely expert tools, but supports for democratic dialogue on the definition of the "common good" and "living together." Implementation Challenges and Necessary Perseverance. Implementing such a system is complex. It requires a overhaul of national statistical systems, training of civil servants and elected officials, and above all, a shift in cultural paradigm.

Resistance would be strong, particularly from economic doctrines attached to single measurement and established interests benefiting from the current model. Institutional inertia in the face of such changes is documented, as evidenced by the difficulties in fully integrating environmental accounting into national accounts, despite UN recommendations since the 1990s via the System of Environmental-Economic Accounting (SEEA). The standardization of measurement methods and data collection on a global scale remains a major challenge. International comparisons are crucial for assessing progress and identifying best practices.

Enhanced collaboration between international organizations such as the UN, OECD, World Bank, and national statistical institutes would be indispensable to build consensus around shared and rigorous metrics. The Stiglitz-Sen-Fitoussi Commission report had already highlighted this imperative necessity. Success would finally depend on the ability to communicate clearly about the relevance and complexity of these new indicators. It is not about rejecting the economic dimension, but about reframing it within a broader and more sustainable perspective.

The transition from a simple and universally understood metric, however incomplete, to a multidimensional dashboard requires continuous educational effort and unwavering political will, reflecting the efforts of Bhutan or New Zealand to integrate more holistic approaches. The stakes of collective resilience and sustainability for the 21st century no longer allow us to dispense with it. Chapter 46 Just Transition and the Geography of Transformation Carbon-Dependent Zones: A Complex Industrial Legacy The geography of ecological transformation is intrinsically linked to territories whose economies have been historically structured by fossil fuel industries.

These regions, often emerging from the industrial revolutions of the 19th and 20th centuries, are characterized by a strong dependence of employment and social fabric on extractive or highly greenhouse gas-emitting sectors. The example of Silesia in Poland, Appalachia in the United States, or Hauts-de-France in France is emblematic of this configuration. In Silesia, coal mining shaped the economic and social landscape for centuries, still employing over 80,000 people in 2018 (Eurostat, 2019). The gradual closure of mines, initiated in the 1990s, met with significant social resistance, illustrating the difficulty of decarbonizing mono-industrial economies.

The restructuring plan for the Polish coal industry, supported by the European Union, aims for a progressive exit from coal by 2049, but the transition is still slow and conflict-ridden. Similarly, the American Appalachians, the cradle of coal extraction, have been suffering for several decades from the effects of this industry's decline. Mining counties have seen their populations decrease and their public health indicators deteriorate. The "Coalfield Communities Economic Development Act" of 2012 (United States), though commendable, has not been sufficient to stem structural unemployment and diversify an economy rooted in coal for over a century.

Hauts-de-France, once a major mining and steel basin in Europe, has already experienced several waves of deindustrialization. While reconversion towards new economic activities is underway, social and environmental scars persist. The former mining pit of Wallers-Arenberg, repurposed as an energy research center, symbolizes the challenges and opportunities of these transformations. These territories need a holistic approach that goes beyond simple financial compensation. Mechanisms for supporting a just transition: a normative and financial response In response to these challenges, dedicated mechanisms have emerged to support the most vulnerable regions.

The concept of "just transition," originally coined by American trade unions in the 1970s to protect workers from industrial changes, has been integrated into international climate governance. Article 4, paragraph 5 of the Paris Agreement (2015) refers to it as the need "to take into account the imperatives of a just transition of the workforce and the creation of decent work and quality jobs." The European Union has been a pioneer in institutionalizing these principles with the establishment of the Just Transition Mechanism (JTM) in 2020, under the aegis of the European Green Deal.

This mechanism comprises three pillars: a Just Transition Fund (JTF), which is expected to mobilize up to 17.5 billion euros for the period 2021-2027, a public sector loan facility from the European Investment Bank (EIB), and EUMechanism (Eurostat, 2020). The Just Transition Fund (JTF) specifically aims to mitigate the socio-economic impacts of the climate transition in the most affected regions. It supports projects for economic diversification, worker reskilling, regeneration of polluted sites, and investments in the circular economy. Poland, Germany, and Italy are among the main beneficiaries of this fund.

For example, the Greater Poland region is expected to receive over 600 million euros for its lignite phase-out. However, the effectiveness of these funds will depend on their ability to move beyond a simplistic infrastructural logic. As Andreas Kahl (2021) emphasizes in his work *Climate Justice and the European Green Deal*, for the JTM to be truly transformative, it must be structured around strengthened citizen participation, consideration of pre-existing inequalities, and an endogenous vision of territorial development rather than one imposed from above.

The pitfalls of authoritarian modernization and the need for procedural justice The ecological transition, if poorly orchestrated, can turn into an authoritarian modernization that reproduces or exacerbates existing inequalities. Ecology, under the guise of scientific rationality, can sometimes mask logics of resource grabbing or social exclusion. The extraction of critical minerals, essential for manufacturing batteries for electric vehicles, already raises the question of "extractive justice" in countries of the Global South. In European regions, the risk is that of a disconnect between national or supranational decision-makers and local realities.

Imposing industrial closure timetables without in-depth consultation with local stakeholders – trade unions, small and medium-sized enterprises, local associations – can lead to a feeling of abandonment and mistrust towards climate policies. A "procedural justice" approach is therefore paramount. It implies that decision-making processes regarding the transition must be inclusive, transparent, and participatory. This means giving a significant voice to affected communities, enabling them to co-construct reconversion strategies and to directly benefit from the positive spin-offs of new economic activities.

The failure of certain energy transition projects in the past highlights the need for local ownership of initiatives. The example of the "yellow vest" movement in the French debate around the carbon tax in 2018-2019, perceived as unjust because it did not adequately support low-income households, illustrates the fragility of climate policies that neglect the social and territorial dimension. Rethinking endogenous development: beyond economic substitution The "just transition" cannot be limited to a mere substitution of economic activities or a simple technological reconversion. It must encompass a deeper reflection on the development models of the territories concerned.

Rather than seeking to replace one polluting industry with another, even a green one, it is about building more resilient, diversified local economies anchored in the needs and specificities of local ecosystems. This involves valuing existing know-how, developing the social and solidarity economy, promoting agroecology in rural or peri-urban areas, and fostering short supply chains. An OECD report (2020) on regional policy and just transition emphasizes the importance of an "integrated territorial development" approach, which considers environmental, social, and economic dimensions interdependently.

The notion of "regional capabilities," theorized by Amartya Sen (1999) in his capabilities approach, finds its full relevance here. It is not just about transferring financial resources, but about strengthening the ability of inhabitants to choose the lifestyles they value, by offering them the educational, social, and professional means to emancipate themselves from old industrial models. Continuous training and professional retraining must be seen as investments in human capital rather than mere palliatives to unemployment. De facto, the geography of transformation must translate into increased decentralization of climate policy planning and implementation.

Regions and local authorities, as proximate actors, are best placed to identify the specific needs of their populations and to orchestrate transition projects adapted to local contexts. This subsidiarity is a sine qua non for social acceptability and the lasting effectiveness of just transition policies. Investments in natural capital and ecological restoration Beyond economic and social restructuring, the just transition must incorporate a strong environmental dimension. Regions dependent on fossil fuels are often those that have suffered the most significant ecological degradation: soil and water pollution, mining subsidence, air contamination.

The restoration of these degraded ecosystems is an essential component of environmental justice. "Investments in natural capital," by rehabilitating wetlands, forests, or ecological corridors, contribute not only to biodiversity but also to the creation of new, non-relocatable local jobs in the ecological engineering and environmental management sectors. The *Renaturalization of the Emscher River* project in Germany, a major example of hydrological restoration of a river polluted by mining activity in the Ruhr, cost over 5 billion euros over 30 years but generated numerous ecological and social benefits.

Such projects, if well-designed, can also have a positive impact on public health in these territories often marked by increased rates of respiratory and cardiovascular diseases. Reducing air and water pollution, improving access to green spaces, directly contributes to the well-being of populations formerly exposed to industrial pollution. This is a form of historical reparation. The Aarhus Convention (1998) on access to information, public participation in decision-making and access to justice in environmental matters is particularly relevant here.

It ensures that citizens in regions affected by restoration or ecological rehabilitation projects can obtain information, participate in their development, and challenge decisions they deem harmful. This is an essential tool for environmental justice and a truly democratic transition. Territorial foresight and "new productive horizons" Just transition implies a capacity for "territorial foresight" that goes beyond electoral horizons or short economic cycles.

It involves anticipating profound changes and supporting local actors in defining "new productive and social horizons." This approach cannot simply be the result of central planners, but must be co-constructed with all the dynamic forces of the territories. Future sectors are emerging around renewable energies, the circular economy, the energy renovation of buildings, sustainable food production, and services to people and ecosystems. Silesia, for example, is investing massively in green technologies and solar parks, while Hauts-de-France is positioning itself in hydrogen and electric batteries.

Nevertheless, the creation of sustainable jobs in these new sectors requires massive investments in local research and development, as well as a constant adaptation of educational and vocational training systems. A report by the International Research Center on Environment and Development (CIRED, 2022) emphasizes that capitalizing on past industrial know-how, by reorienting it towards low-carbon activities, can be a promising path. Thus, the geography of transformation is not only a map of past challenges, but also a map of future opportunities.

It is the basis for a reinvention of the links between humanity and its environment, between work and nature, and between social justice and ecological sustainability, in a continuous movement of co-evolution between natural and human systems. Part V — Mundia, World Auxiliary Language Chapter 47 Why an Auxiliary Language in 2026? The Linguistic Hegemony of English: A Multifactorial Analysis of Its Systemic Implications English, as the global *lingua franca* since the second half of the 20th century, exerts a predominant influence in scientific, economic, diplomatic, and cultural domains.

This supremacy, inherited from British imperial power and subsequently from American economic and geopolitical hegemony after 1945, is not without consequences. It raises fundamental questions regarding the equity of international communication, the induced economic costs, and the epistemic biases it generates. The idea of a universal auxiliary language, though ancient, retains its relevance at a time when global interconnections demand fluidity and equal treatment in exchanges. The dominant position of English confers a structural advantage to native speakers and Anglo-Saxon cultures.

Non-native speakers, though often multilingual, must dedicate considerable effort to acquiring and mastering this language, an effort that translates into direct and indirect costs in terms of education, time, and cognitive energy. This linguistic asymmetry accentuates inequalities in access to information, professional opportunities, and full participation in global discourse. It also creates a cognitive load for non-natives, who, focusing on linguistic formulation, may see their analytical or creative capacity impaired (Philipson, 1992, *Linguistic Imperialism*). Cognitive Biases and English as a *Lingua Franca* The prevalence of English in scientific research is particularly telling.

According to a 2017 UNESCO study, approximately 90% of scientific publications indexed in international databases are in English. This proportion, far from trivial, induces systemic biases. First, it marginalizes entire sections of non-Anglophone research, making their dissemination and recognition more difficult. Second, it can influence the very way of thinking and conceptualizing, with certain linguistic structures favoring or hindering the expression of certain ideas (Boroditsky, 2011, "How Languages Reshape Our Thoughts"). The "linguistic filter" thus imposed can lead to a homogenization of thought frameworks, limiting epistemic diversity.

Cognitive biases associated with the use of a single dominant language affect decision-making, particularly in multilingual contexts.

Studies have shown that speaking in a foreign language can reduce certain cognitive biases, such as loss aversion or framing bias, by distancing the speaker from immediate emotional reactivity (Keysar et al., 2012, "The Foreign-Language Effect"). However, in an English *lingua franca* context, this effect is mitigated for non-natives, who, subjected to the constant tension of expressing themselves in a second language, may on the contrary experience cognitive overload that impairs their full capacity for analysis and subtle communication.

Native speakers, for their part, may miss nuances and subtleties expressed by non-natives, leading to misunderstandings or misinterpretations. This linguistic homogenization, despite certain pragmatic arguments related to apparent efficiency, proves to be a factor of cognitive and cultural impoverishment in the long term. It hinders alternative forms of thought and imposes a framework for interpreting the world that is not intrinsically universal but historically and culturally situated. The capacity of a language to shape the perception of reality and the conceptualization of problems (Sapir-Whorf, 1920s-1940s) is a crucial consideration here.

Limiting linguistic diversity potentially limits the diversity of solutions and perspectives, which is essential to address the complex challenges of the 21st century. Cultural Hegemony and the Economic Costs of Linguistic Non-Diversity English does not only convey information; it is also the vector of a dominant culture and a set of intrinsic values. The omnipresence of American and British culture, disseminated through cinema, music, media, and literature, tends to standardize global cultural references.

This cultural hegemony can lead to an erosion of less powerful linguistic and cultural identities, marginalizing forms of expression and indigenous knowledge that do not find translation or resonance in the Anglophone *mainstream*. The 2005 UNESCO Convention on the Protection and Promotion of the Diversity of Cultural Expressions recognizes this threat and calls on States to safeguard linguistic and cultural plurality. The economic costs associated with English as the sole *lingua franca* are significant and multi-level. The cost of translation and interpretation in international institutions is a striking illustration.

The European Union, for example, with its 24 official languages, dedicates a substantial annual budget to this task. In 2019, the total expenditure for translation and interpretation of European institutions approached one billion euros (998 million euros), as indicated by the annual activity report of the European Commission's Joint Interpretation and Conference Service. Almost a quarter of this budget, approximately 250 million euros, is directly attributable to the operation of the translation and interpretation directorates general alone. Hidden Costs and Systemic Inefficiencies Beyond direct and quantifiable costs, there are hidden costs and systemic inefficiencies.

Learning English represents a colossal educational investment for non-Anglophone states, with uneven returns. Businesses, particularly SMEs that cannot afford dedicated translators, are often disadvantaged in international markets where English proficiency is an implicit prerequisite. The lack of fluidity in communication can lead to errors, delays, and loss of contracts, the overall economic cost of which is difficult to estimate but certainly substantial on a global scale. These costs reveal a form of informal linguistic tax that the world pays to maintain the current system.

This tax is unevenly distributed, penalizing countries and individuals whose native language is furthest from English or whose educational resources are limited. It contributes to an implicit transfer of value to Anglophone economies and reduces fair competition in many sectors, from research to engineering and trade. Moreover, the phenomenon of translation loss (lingua loss) is concerning. When scientific, literary, or philosophical works are translated into a foreign language by a non-native speaker, subtleties, idiomatic nuances, or stylistic registers can be irremediably lost.

This impoverishes not only the translated work but also mutual understanding and the interpenetration of thoughts and cultures, as George Steiner emphasizes in *After Babel* (1975). Knowledge thus amputated loses its depth and its ability to inspire new perspectives. The Relative Failure of Esperanto: Lessons for a Future Auxiliary Language Esperanto, created at the end of the 19th century by Ludwik Lejzer Zamenhof, represents the most elaborate and successful attempt to design an international auxiliary language. Its regular grammar, simple phonetics, and vocabulary largely based on Indo-European roots made it an apparently ideal candidate for widespread adoption.

More than a century after its creation, Esperanto has a few million speakers, according to estimates varying from a few hundred thousand to two million, only a few thousand of whom are native speakers (Linz and Piron, 1999, *World's Most Beautiful Language*), far from the anticipated universal adoption. The reasons for its limited success are multiple and deserve in-depth analysis to inform the development of any future auxiliary language. First, its phonological and lexical Eurocentrism has been a major impediment. Although simpler for Europeans, Esperanto's phonetics contain sounds absent in some Asian or African languages, making it less easy to learn for these populations than it seems.

Its overwhelmingly Romance and Germanic vocabulary gives it a strong Western flavor, which limits its appeal for truly global adoption. Structural and Political Obstacles Second, the grammar, though regular, was not necessarily devoid of complexity for everyone. The use of an inflectional system, particularly the accusative case, although logical in its design to avoid ambiguities, represents an additional difficulty for speakers of languages without grammatical cases. An ideal auxiliary language should aim for maximum agglutination or structural isolation to reduce cognitive and memory load.

The "one sound, one letter" system and the absence of irregular plurals or complex conjugations do not completely counterbalance these perceived difficulties. Third, the socio-political factor played a decisive role. Esperanto never benefited from sufficient state or institutional support to establish itself as an international communication tool. Its journey was fraught with obstacles, particularly persecutions under totalitarian regimes (Nazism and Stalinism) that saw it as a threat to national unity and dominant ideology. The absence of a strong geopolitical power to promote it, unlike English, sealed its fate as the language of a transnational but minority community.

Esperanto also suffered from a paradoxical positioning. It is often perceived as a militant language, associated with an idealistic vision of the world, which, paradoxically, may have hindered its adoption by institutions or actors concerned with perceived neutrality. The question of linguistic identity and social prestige is also crucial: an auxiliary language should not appear as an inferior substitute, but rather as a practical tool complementary to national languages. The success of an auxiliary language does not depend solely on its intrinsic simplicity, but above all on its cultural acceptability and its appropriation through favorable social and political dynamics.

Imperatives for a Universal Auxiliary Language for the 21st Century The lessons learned from the hegemony of English and the experience of Esperanto provide essential criteria for the design of an auxiliary language adapted to contemporary challenges. This language should not be part of a logic of substituting national languages, but rather one of complementarity, aiming to create a neutral and equitable communication space. It must be non-imperialistic, meaning built on principles of universality and not cultural hegemony, reflecting global linguistic diversity without favoring a particular civilizational area. Structural simplicity is paramount.

This implies a minimalist grammar, without complex inflections, a vocabulary phonetically and semantically accessible to the majority of global speakers, and a simple and predictable syntax. Models of creole languages, which arise from the simplification and fusion of several languages, could offer interesting avenues. The goal is to minimize the learning curve, so that an individual can acquire functional fluency quickly, with minimal investment in time and resources. Phonological and morphological regularity, characteristic of Esperanto, would remain a major asset (Large, 1985, *The International Language: Past, Present and Future*).

Cultural Neutrality and the Digital Imperative Cultural neutrality is a *sine qua non* condition. The vocabulary should not be predominantly drawn from a single linguistic family, but draw from an extensive corpus of languages representative of major geographical and cultural areas. Systems of universal roots or combinatorial morphemes, inspired by languages like Lojban or Toki Pona for example, could be explored to create a maximally depoliticized and deculturized lexicon. The aim is not erudition, but communicative clarity and efficiency. Native integration of digital tools is also crucial.

A modern auxiliary language should be designed from the outset for easy implementation in computer systems, machine translation software, and digital interfaces. This implies a syntax compatible with automatic analysis, a well-defined lexical ontology, and a unique representation of sounds and spellings. This techno-linguistic dimension is an advantage absent when Esperanto was created, and it can play a major role in accelerating adoption if well designed. Work on ontologies and interlanguages for machine translation (e.g., Bar-Hillel, 1960) can contribute to this reflection. Finally, such a language would require significant institutional and political support.

This could take the form of an international consortium of states, non-governmental organizations, and civil society actors, working towards its promotion and development. UNESCO, or a new institution specifically dedicated, could be its pilot. The initiative cannot be unilateral; it must stem from a collective will to overcome current linguistic barriers to foster more equitable and effective global cooperation, in the face of climate, economic, and social emergencies. The concept of "linguistic common goods" could guide this approach.

Towards a Constitutional and Economic Framework for an Auxiliary Language The adoption of a universal auxiliary language would involve considerations of constitutional and international law. To be legitimate and sustainable, such a language would need to be recognized by international treaties, potentially under the aegis of the United Nations, and integrated into national legal frameworks, while respecting the linguistic sovereignty of states. Linguistic rights, as defined by texts like the Universal Declaration of Linguistic Rights (Barcelona, 1996), should be at the heart of its deployment, ensuring that it complements and does not supplant mother tongues.

Economically, the benefits of an auxiliary language would substantially reduce translation and interpretation costs for international organizations and businesses. The annual billion euros of the EU mentioned earlier could be redistributed to other priorities or reinvested in education and cultural diversity. For businesses, the democratization of international communication would open new markets and reduce barriers to entry for SMEs. The Auxiliary Language as Global Infrastructure An auxiliary language can be conceptualized as a global infrastructure, just like the internet or transportation systems.

Its construction and maintenance require initial investments, but generate considerable positive externalities for the entire international economic and social system. The increased productivity of exchanges, improved multilateral coordination, and reduced cultural misunderstandings are significant non-monetary benefits. Moreover, it could foster the emergence of true global citizen science, by facilitating the dissemination of knowledge and cross-border collaboration. The transition to such a language would not be instantaneous.

It would require a progressive process, involving targeted education programs, economic incentives, and validation by research institutions and professional organizations. The *Convention on the Protection and Promotion of the Diversity of Cultural Expressions* of 2005 can serve as a framework, by adding a protocol on facilitating international communication. A phased approach, potentially starting with specific sectors (scientific, diplomatic, commercial), could facilitate its acceptance and integration.

The question is no longer whether humanity needs an auxiliary language, but how best to conceive and deploy it to meet the imperatives of an interconnected world facing existential challenges. Climate urgency, biodiversity preservation, and the regulation of emerging technologies demand unhindered communication and the capacity for planetary collaboration, beyond linguistic burdens and cultural biases.

Chapter 48 Mundia Specifications The Genesis of a Universal Language: Ethical and Pragmatic Stakes of Mundia The development of a universal language, such as Mundia, is not a linguistic utopia, but a systemic necessity, dictated by the growing interdependence of human societies and the complexity of global challenges. Current linguistic fragmentation, estimated at approximately 7,168 living languages in 2024 according to Ethnologue, represents a substantial impediment to transnational cooperation, generating colossal translation costs – nearing 45 billion dollars annually for the European Union alone, and over 60 billion for the United States in 2019 (Common Sense Advisory).

These figures represent only a fraction of the inefficiency attributed to idiomatic barriers, which also hinder the transfer of knowledge, crisis resolution, and mutual understanding among cultures. This project is part of a historical lineage of similar initiatives, from Johann Martin Schleyer's Volapük (1879) to Louis-Lazare Zamenhof's Esperanto

(1887), including Interlingua (1951). However, Mundia distinguishes itself through a radically new approach, based on the insights of cognitive sciences, comparative linguistics, and contemporary political philosophy, aiming to maximize cultural neutrality and structural simplicity.

The objective is not to supplant existing languages, invaluable treasures of humanity, but to provide an auxiliary medium, a lexical and grammatical "bridge," capable of facilitating communication among speakers of all origins, without privileging any particular culture or linguistic area. The Roots of Statistical Neutrality: Lexical and Semantic Equity The statistical neutrality of roots constitutes Mundia's ethical and linguistic foundation. This approach aims to prevent any cultural or geographical prevalence in the selection of fundamental lexemes.

Rather than drawing primarily from Indo-European languages, like Esperanto which derives 75% of its words from Latin and Romance languages (Piron, 1989), Mundia opts for a balanced distribution of its semantic roots among the major global language families. This selection process is based on a comparative analysis of global lexical frequencies, taking into account the number of native and secondary speakers, language vitality, and geographic representation. It is not about creating artificial words ex nihilo, but identifying phonemes and phonetic sequences with low connotations, and then assigning them fundamental meanings defined by international consensus.

This paradigm ensures that the cognitive load of initial learning is distributed equitably among all speakers, regardless of their mother tongue. Grammatical and Phonological Simplicity: The Quest for Universal Accessibility The quest for universal accessibility for Mundia translates into a linguistic architecture of maximum simplicity, manifested through twelve fixed grammatical rules and minimal phonology. This design constraint stems from a deep understanding of language acquisition mechanisms and the inherent obstacles to learning a second language.

The Twelve-Rule Grammar: Isolating Paradigm The isolating morphology adopted by Mundia is a deliberate choice to minimize inflectional complexity. Like Semitic or Chinese languages, words are invariable, without declensions or conjugations. Grammatical relations are expressed by word order, particles, or prepositions, drastically reducing the paradigms to be memorized. This feature facilitates message encoding and decoding, lightening the load on learners' working memory. The twelve fundamental grammatical rules, rigorously defined, cover all syntactic structures necessary for clear and unambiguous communication.

They concern aspects such as plural formation (by adding an invariant morpheme, for example), temporality (marked by adverbs of time or atonic auxiliaries), negation, interrogation, and relative clause formation. This structural economy, validated by Chomsky's work on universal grammar (Chomsky, 1965), enables a reduction in learning time to an unprecedented scale. Minimal Phonology with Seventeen Phonemes: A Global Sound Atlas Mundia's phonology is limited to seventeen phonemes, a number considerably smaller than the average for natural languages (which is around 30-40 phonemes).

This choice is crucial to ensure easy pronunciation by all of humanity, regardless of native phonetic repertoires. The selection of these phonemes was based on their universality, meaning their frequent presence in the world's languages and their ease of articulatory production. The seventeen phonemes include five cardinal vowels (e.g., /a/, /i/, /u/) and twelve consonants (e.g., /p/, /t/, /k/, /m/, /n/, /s/, /r/). Each phoneme is associated with a single grapheme in the extended Latin alphabet, ensuring a one-to-one correspondence between sound and writing, a property absent in many natural languages and one that considerably simplifies literacy.

This phonetic and graphic standardization is essential for minimizing the influence of regional accents and natural dialectal variations. Mundia's Specifications: Towards Accelerated and Inclusive Acquisition The objective of less than 200 hours of learning for a speaker of any first language (L1) represents the ultimate evaluation criterion for Mundia's success. This constraint, ambitious but achievable, is supported by research in glottodidactics and psycholinguistics demonstrating the inverse correlation between grammatical complexity and acquisition time.

Accelerated learning models, such as those developed for Ogden's *Basic English* (Ogden, 1930), have proven the feasibility of functional communication with reduced vocabulary and grammar. This requirement for fast learning is not only pragmatic but also ethical. It aims to democratize access to international communication, reducing linguistic inequalities that currently disadvantage billions of individuals. According to UNESCO, in 2021, approximately 75% of global scientific publications are in English, making access to knowledge inequitable for non-English speakers. Mundia aims to be a tool for rebalancing these asymmetries.

Cognitive Modeling of Language Learning Mundia's design integrates principles of cognitive psychology, particularly cognitive load theory (Sweller, 1988) and explicit memorization. The language's structural simplicity reduces the "extrinsic load" associated with learning complex rules, allowing learners to focus their cognitive resources on vocabulary acquisition and communication practice. Empirical studies on learning constructed languages, such as Esperanto, have already shown significantly faster acquisition times than for natural languages.

For example, research conducted by Professor Helmar Frank (Paderborn, 1970s) suggested that acquiring an equivalent level of proficiency in Esperanto required between 100 and 150 hours, compared to 1000 to 1500 hours for a natural language like English or French.

Mundia, through its even greater simplification, aims to surpass these performances. Mundia and International Law: Towards Legal Recognition of a Universal Language The emergence of a universal language like Mundia raises fundamental questions in international law, particularly concerning its recognition and integration into the global normative framework.

The United Nations Charter (1945), through its Article 1, paragraph 3, advocates international cooperation and the promotion of respect for human rights and fundamental freedoms, without distinction as to language. Yet, institutional reality is that of a predominance of a few official languages, creating de facto linguistic hierarchies.

Article 2 of the Universal Declaration of Human Rights (1948) stipulates that everyone is entitled to all the rights and freedoms set forth in the UDHR, "without distinction of any kind, such as... language." Mundia, by facilitating access to information and civic participation beyond traditional linguistic barriers, could become a concrete instrument for implementing this fundamental right. Its neutral and accessible nature makes it an ideal candidate for institutional recognition.

Soft Law and International Organizations The recognition of Mundia could initially occur through *soft law*, via recommendations from international organizations such as UNESCO or the International Telecommunication Union. Gradual adoption by the scientific, academic, and diplomatic communities would lead to increased legitimacy. Pilot initiatives in international conferences, multilingual scientific publications, or humanitarian translation projects could demonstrate Mundia's practical effectiveness.

Ultimately, legal codification in the form of a Treaty or an International Convention could grant Mundia the status of "universal auxiliary language" or "neutral international communication language." Such a legal instrument would guarantee its protection, promotion, and continuous development, while establishing protocols for its teaching and use in official spheres. France's Toubon Law of 1994 (Law n° 94-665), though specific to French, shows that states are prepared to legislate on language use to guarantee certain principles.

Socio-Economic and Environmental Implications of Mundia Beyond linguistic and legal dimensions, the adoption of a universal language like Mundia generates profound socio-economic and environmental implications, addressing the challenges of the 21st century. Facilitating cross-border communication is a *sine qua non* condition for effective global governance in the face of the triple planetary crisis: climate, biodiversity, and inequalities. Economically, a reduction in translation and interpretation costs, estimated at several hundred billion dollars annually worldwide, would allow for the reallocation of substantial resources towards productive and sustainable investments.

The opening of markets to more fluid communication would foster innovation and international trade, but with a more equitable dimension, by reducing the linguistic premium currently enjoyed by speakers of dominant languages. Environmental Cooperation and Open Science The climate crisis, illustrated by the IPCC report (2023) highlighting the need for drastic reductions in greenhouse gas emissions, demands unprecedented scientific and political collaboration. Mundia, by removing linguistic barriers, would accelerate the sharing of scientific knowledge, climate data, and innovative technological solutions.

"Open Science," promoted by UNESCO (Recommendation on Open Science, 2021), would find in Mundia a powerful catalyst, making discoveries accessible to all researchers, regardless of their linguistic origin. ■ Reduction of fragmentation of scientific knowledge. ■ Acceleration of collaborative innovation processes. ■ Facilitation of climate diplomacy and multilateral negotiations. ■ Strengthening of disaster response capacities. ■ Democratization of access to biodiversity conservation protocols. ■ Improved understanding of environmental issues by local populations. ■ Support for the creation of transnational citizen networks for environmental justice.

The Political Philosophy of Inclusive Universalism Philosophically, Mundia embodies the Kantian ideal of a community of peoples founded on reason and communication. It offers a model of inclusive universalism, which, far from homogenizing cultures, provides them with a space for dialogue and deepened mutual understanding. The inherent neutrality of the language ensures that discursive power is not monopolized by any particular linguistic entity, thus promoting true equality of speech. Jürgen Habermas's work on the ethics of discourse (Habermas, 1983) emphasizes the importance of undistorted communication for the emergence of rational consensus.

Mundia offers the ideal linguistic framework for such deliberation, by minimizing semantic misunderstandings and power asymmetries related to the mastery of dominant languages. It is a concrete step towards global citizenship, where every voice can be expressed and understood, thus forging the foundations of lasting peace and harmonious coexistence. Chapter 49 Mundia Phonology The Vowel and Consonant Structure of Mundia: A Remarkable Phonological Economy The Mundia language, proposed as a global lingua franca by the Geneva Charter in 2042 (Article 3, paragraph 2), exhibits a phonology of remarkable simplicity and regularity.

This sound architecture is the result of a deliberate approach to minimize ambiguity and facilitate learning, an aspect highlighted by the 2038 report of the International Centre for Applied Linguistics (CILA), section 2.1. It relies on a restricted phonemic inventory, ensuring high acoustic redundancy and robustness against variations in speaker accents, as established by auditory perception studies conducted by Wang and Lee in 2040 (pp. 112-115). The vowel inventory is limited to five units, corresponding to the cardinal phonemes [a], [e], [i], [o], [u]. This selection aligns with Jakobson's observations (1941) on universally widespread and perceptually most stable vowel systems.

These vowels are all oral, short, and distinctly separated in formant space, which significantly reduces the risk of confusion, even in noisy environments or with degraded signal quality (Chomsky & Halle, 1968, pp. 300-305). Mundia's consonants number twelve: [p], [t], [k], [b], [d], [g], [m], [n], [s], [l], [r], [j], [w]. This palette covers the main distinctive places and manners of articulation according to comparative phonological analyses (Maddieson, 1984), while avoiding rare or articulatorily complex sounds for a majority of native speakers of various languages.

The minimal pairs generated by this inventory are systematically differentiated by a single universally recognized phonetic feature. It is worth noting the absence of affricates, complex fricatives (such as [■], [■], [f], [v], [θ], [ð]) or clicks, which simplifies articulatory movements and reduces the cognitive load of production and perception. This simplification, deemed drastic by some purists during debates prior to the adoption of the Charter (Rome Conference, 2041, Proceedings, p. 187), is precisely one of the pillars of Mundia's effectiveness as a large-scale intercultural communication tool.

The Exclusion of Consonant Clusters and its Impact on Phonetic Clarity A salient characteristic of Mundia phonology is the strict prohibition of consonant clusters. This fundamental rule means that it is impossible to find two adjacent consonants within the same syllable or at the junction of two syllables. Every consonant must be immediately followed or preceded by a vowel. This structural constraint has profound implications for speech perception and production. It eliminates complex phonetic assimilation and reduction phenomena often observed in clusters, which can be a major source of confusion and difficulty for non-native learners.

For example, regressive assimilation of voicing ([d] in "doctor" in English) or changes in place of articulation ([n] to [m] before [p] in "impossible" in French) are inherently absent. The absence of clusters improves the "segmentability" of the speech stream, facilitating the recognition of word and syllable boundaries. In languages where clusters are frequent (for example, English "strength" [st■■■θ] or Russian "vstrecha" [■fst■r■e.t■■■]), listeners often have to rely on additional prosodic or lexical cues to disambiguate the signal. Mundia dispenses with this additional cognitive load, lightening the decoding process.

Comparative study conducted by the Linguistic Harmonization Committee (CHL) in 2039 revealed that languages without consonant clusters are statistically perceived as more "clear" and "distinct" by a wide range of speakers, regardless of their native language. A survey of 12,000 participants showed that 85% of them found languages without clusters easier to understand at equal listening volume. The (C)V(C) Syllable Structure and its Rhythmic Implications The syllable in Mundia adheres to the canonical (C)V(C) structure, where C represents an optional consonant and V represents an obligatory vowel.

This means that syllables can be of three types: V (vowel alone, like "a"), CV (consonant-vowel, like "pa"), or CVC (consonant-vowel-consonant, like "pat"). The vowel is the obligatory syllabic nucleus, testifying to its phonological centrality. This structure is typologically highly prevalent (Greenberg, 1963, Universal 9) and is considered the most universal and simplest to produce. It avoids syllables with complex onsets or codas (CCV, VCC, CCVC, etc.) and maintains a high regularity in the consonant-vowel alternation.

This contributes to a regular, predictable syllabic rhythm not subject to duration variations linked to the complexity of onsets or codas, as highlighted by the work of Ramus et al. (1999) on the role of the V/C ratio in discriminating rhythmic types. The absence of clusters, mentioned earlier, is a direct consequence of this (C)V(C) structure. If Mundia had CCV-type syllables, initial clusters would be present. If it had VCC-type syllables, final clusters would appear. The strict limitation to (C)V(C) guarantees a maximum phonetic distance between consonants, always separated by a vowel.

The order of consonants and vowels is rigorously maintained, avoiding rarer structures like syllables without an onset or coda in contexts where other syllables possess them. Each Mundia syllable is therefore clearly delimited, which facilitates the auditory segmentation of words and the encoding of individual phonemes. This regularity is a major asset for speech recognition and synthesis software, having achieved a 99.8% phoneme recognition rate for Mundia under ideal conditions, according to tests by the "Global Voice Analytics" (GVA) project in 2043. This syllabic regularity is also an important factor for preserving message integrity.

In non-ideal communication environments, such as disturbed radio links or distant conversations, the predictability of the syllabic structure helps reconstruct missing or corrupted parts of the signal, as shown as early as 1974 by S. Johnson's theory of predictive redundancy. The Prevalence of Open and Monomoraic Syllables In Mundia's practice, although the CVC structure is permitted, there is a tendency towards the prevalence of CV and V syllables, i.e., open syllables. According to the analysis of Mundia's lexical corpus, over 70% of syllables are of the CV or V type, while CVC syllables represent approximately 30%. This proportion favors rapid speech and economy of articulatory effort.

Mundia syllables are also monomoraic, meaning they contain only one minimal time unit, the mora. This characteristic is typical of so-called "mora-timed" or "syllable-timed" languages (Abercrombie, 1967). The absence of diphthongs or long vowels (which are often bimoraic) reinforces this temporal uniformity. This monomoraicity ensures a relatively constant syllabic duration, contributing to the language's isochronous rhythm. This facilitates the learning of tempo and prosody by non-native speakers and reduces misunderstandings related to differences in phonemic duration between languages.

Fixed Stress on the Penultimate Syllable: A Prosodic Keystone One of the most characteristic and important features of Mundia's phonology is the fixed tonic stress on the penultimate syllable of every word. This phonological rule is invariable and suffers no exceptions, regardless of the word's grammatical class or morphological complexity. This characteristic relieves the speaker of a significant memory constraint. In many languages, stress is variable, its position sometimes unpredictable and capable of changing the meaning of the word ("record" noun vs. verb in English, "revolver" in Spanish). This variability is a major source of difficulty for learners.

In Mundia, this uncertainty is entirely eliminated, allowing for more fluid and less error-prone production and perception. The fixed position of stress on the penultimate syllable also facilitates lexical segmentation for the listener. Indeed, the presence of stress on a given syllable provides a reliable prosodic cue as to the end of the preceding word or the beginning of the following word, particularly if that word is bisyllabic or longer. Studies by Cutler and Norris (1988) on lexical segmentation have shown that languages with fixed stress are generally easier for listeners to segment. The cognitive advantage of this fixed stress has been quantified.

According to a study by the Laboratory of Cognitive and Linguistic Sciences at the National University of Singapore, 87% of Mundia learners reported faster acquisition of prosody and lexical recognition compared to learning a language with mobile stress, based on an equivalent teaching duration. This advantage is particularly pronounced in environments where speech is fast or noisy. Consequences for Morphology and Word Formation The fixed stress rule has direct implications for Mundia's morphology. The creators of the language deliberately avoided the use of prefixes or suffixes which, by attaching to a base, could alter the position of the stressed penultimate syllable.

Processes of derivation and inflection are therefore designed to maintain this stable prosodic structure. For example, if a suffix were added to a two-syllable word (stress on the first syllable), that suffix would have to be two syllables long for the stress to remain on the "new" penultimate syllable. Or conversely, longer words are favored, where the suffix does not disrupt the rule. Most affixes in Mundia are one or two syllables long and are often integrated via non-agglutinative processes, favoring structural simplicity.

This prosodic constraint encourages relatively short word structures, often of two or three syllables, because beyond that, the mechanisms for maintaining fixed stress on the penultimate syllable become more complex both lexically and morphologically. This also contributes to the conciseness of the vocabulary. Statistical Justification of Phonological Simplicity The phonological design of Mundia, far from being arbitrary, is based on principles of quantitative linguistics and comparative data from hundreds of natural languages.

The objective was to maximize intelligibility and ease of learning for the largest proportion of human speakers, while minimizing biases inherent in phonological systems that are too complex or too culturally specific. The chosen phonemic inventory is a subset of the most frequent and universally attested sounds in the world's languages, according to phonological databases such as PHOIBLE (Moran & McCloy, 2018). Mundia's five vowels ([a, e, i, o, u]) constitute the quintessence of global vowel systems, appearing in over 70% of languages with a vowel inventory of five vowels or fewer.

The choice of the twelve consonants follows the same logic, favoring bilabial, alveolar, and velar stops (voiceless and voiced), corresponding nasals, and a few frequent fricatives and liquids. The absence of consonant clusters is also statistically motivated. While clusters are present in many languages, their complexity varies greatly. Systems without clusters are typologically less marked and generally easier to acquire early, which is an advantage for a language intended to be learned by adults often unfamiliar with phonological systems distinct from their native language.

Children first develop CV structures (MacNeilage, 1998), and this simplicity is therefore relevant for human linguistic cognition. The (C)V(C) syllable structure is one of the most robust and widely represented across the world's languages. It allows for a good consonant-vowel alternation and is considered the universal basis of phonotactics. By avoiding more complex structures (CCV, CCCV, VCC, etc.), Mundia reduces the number of phonotactic rules that learners must memorize. The fixed stress on the penultimate syllable, a characteristic common to languages like Polish, Swahili, or certain forms of Spanish, is chosen for its predictive value.

This regularity is a simple and effective way to reduce uncertainty in interpreting the oral message. A study conducted by the Max Planck Institute for Ortholinguistics in 2041 demonstrated that a fixed and predictable stress reduces lexical processing time by an average of 15% for non-native speakers, compared to a language with complex mobile stress. Mundia's phonology thus represents a pragmatic balance between linguistic expressiveness and facilitated learning. It is the result of rigorous linguistic engineering, concerned with communicative efficiency at a global level, and founded on a deep understanding of phonological universals and human cognitive constraints.

Chapter 50 Isolating Morphology and Grammar in 12 Rules: The Foundations of an Isolating and Invariant Morphology. The construction of a language with normative intentionality, which Esperanto in its time attempted, carries a significance that extends beyond mere linguistics to question humanity's capacity to refound its codes. The proposal of an isolating and ahistorical morphology, devoid of inflections, genders, and agreements, aims to deconstruct cognitive biases and hierarchies induced by the grammatical structures of natural languages.

This project, whose conceptual lineage traces back to Leibniz's work on a "universal characteristic," targets an unprecedented level of precision and semantic neutrality, capable of fostering systemic thinking. The absence of inflections eliminates morphological variations of words, stabilizing their form regardless of their grammatical role. This characteristic, observed in languages like Vietnamese or Mandarin, drastically simplifies learning and reduces the structural ambiguities inherent in inflectional languages. It implies that each lexeme, carrying a core meaning, retains a constant formal identity, allowing for increased focus on syntactic combinatorics.

The suppression of grammatical gender, which arbitrarily assigns lexical or suffixal marks to nouns and adjectives, eliminates a major source of discrimination and complexity. Works by feminist ecologists such as Val Plumwood (1993, "Feminism and the Mastery of Nature") have highlighted how gender dualisms are part of a logic of domination, transposed to the human-nature relationship. By eradicating these markers, this language proposes a more neutral semantic architecture, where emphasis lies in function and not in intrinsic attributes. The absence of agreements, whether in number, gender, or person, completes this morphological simplification.

It imposes a rigorous syntax where the position of words in the sentence determines their function. Each word has a single, invariable form, which reinforces the predictability of the structure and reduces the cognitive load associated with production and comprehension. This grammar, described as analytical or isolating, contrasts sharply with the synthetic systems of Indo-European languages. The Grammar of Twelve Rules: Foundation for Eco-Rational Communication. The grammatical structure is based on an axiomatic set of twelve rules, designed to maximize clarity, minimize ambiguity, and facilitate intercomprehension.

These rules, both prescriptive and descriptive, form the bedrock of a universal grammar whose purpose is not to replace existing languages, but to provide a tool for thought and communication of scientific rigor. It responds to the imperative for clarity in crucial debates concerning our collective future, as highlighted by the Brundtland Report (1987, "Our Common Future") on sustainable development. Rule 1: Strict SVO (Subject - Verb - Object). The sentence structure is rigorously Subject-Verb-Object (SVO). This configuration is one of the most frequent in natural languages (representing about 42% of languages inventoried by Dryer, 2005) and is recognized for its clarity.

It imposes a logical sequence that anchors the action to its agent, then defines its unfolding. Example: "Man li eat apple" (The man ate the apple). This syntactic constant eliminates stylistic inversions or passive constructions that can obscure meaning. Rule 2: Lexical Temporal Markers. The tense of the action is indicated by invariant lexical markers, placed before the verb. "li" for the past, "na" for the present, "fu" for the future. These markers are full-fledged words, devoid of inflection. Example: "li eat", "na eat", "fu eat". This approach radically simplifies the conjugation systems of inflectional languages, where the verb itself changes form.

It dissociates the concept of time from verbal morphology, making it explicit and contextually independent. Rule 3: Pre-Verbal Negation "no". Negation is expressed by the invariable word "no", placed immediately before the verb. Example: "Man no li eat apple" (The man did not eat the apple). This fixed and unambiguous position of the negator instantly clarifies the absence or refusal of an action. It avoids double negatives or variable placements that characterize many languages. Rule 4: Initial Interrogation "ka". A question is introduced by the invariable word "ka", placed at the beginning of the sentence. Example: "Ka man li eat apple ?" (Did the man eat the apple?).

This unique interrogative particle and its initial position clearly signal the interrogative modality, without requiring complex inversion or specific intonation. "ka" acts here as a binary logical operator. Rule 5: Pre-Nominal Adjective. The adjective is always placed before the noun it modifies. Example: "Big tree", "Cold water". This rule ensures a clear composition of the noun phrase, where the qualification precedes the qualified element. It reflects a semantic logic where the property is attributed before the entity is fully named, facilitating the progressive construction of meaning. Rule 6: Post-Verbal or Post-Adjectival Adverb. The adverb modifies a verb or an adjective.

It is placed immediately after the verb, or after the adjective. Example: "Li eat fast", "Tree big solid". This stable position of the adverb enhances the clarity of modifications made to actions or qualities. The role of the adverb is to intensify or nuance the statement, and its fixed place prevents any confusion about what it modifies. Rule 7: Pre-Nominal or Pre-Pronominal Preposition. The preposition is always placed before the noun or pronoun it introduces, forming an inalienable prepositional phrase. Example: "In house", "For you". This rule is fundamental for structuring circumstantial and spatio-temporal complements.

It aligns with the isolating logic of the language, where each word retains its form, and its function is signaled by its position or by a function word. Rule 8: Post-Elementary Coordinating Conjunctions. Coordinating conjunctions (e.g., "and", "or", "but") are placed between the elements they coordinate. Example: "Man and woman", "Eat or sleep". These logical operators maintain a median position, uniting words, word groups, or clauses of the same function. Rule 9: Invariable Personal Pronouns. Personal pronouns are invariable and are clearly distinguished by their form (e.g., "I", "you", "he", "she", "we", "you", "they-masculine", "they-feminine" would have only one single form).

There is no gender distinction for pronouns. Example: "I na look", "He fu speak". The absence of gender for personal pronouns reflects the language's goal of neutrality, avoiding the attribution of binary categories to entities. Rule 10: Invariable Definite and Indefinite Article. A definite article ("the") and an indefinite article ("a") exist, and are invariable in number and gender. They are placed before the noun. Example: "The book", "A book". These articles, by their invariance, emphasize the isolating nature of the language. Their role is to indicate the determination of the noun without adding morphological complexity.

France's Toubon Law (1994), which aims to preserve linguistic clarity, underscores the importance of precise determination. Rule 11: Number Formation by Juxtaposition. Numbers are formed by simple juxtaposition of basic units. For example, "ten-one" for eleven, "two-ten" for twenty. This numerical construction is transparent and arithmetic, eliminating the lexical irregularities characteristic of many languages. The decimal system is favored, in connection with universally adopted numeration. Rule 12: Derived and Unified Basic Vocabulary. Basic vocabulary words are chosen for their unequivocal semantics, with etymological roots favoring international intercomprehension.

Derivation operates through clear and unambiguous affixes. For example, a root like "ecology" can generate "ecological" (adjective), "ecologically" (adverb), "ecologist" (agent). This rule ensures maximum lexical coherence and predictability in the formation of new words. Lexical clarity is a major issue for technical and scientific communications, where polysemy can lead to costly errors. The IPCC report (2021, AR6) highlights the need for a shared and unambiguous vocabulary to address climate challenges. The Constitutional Implication of an Eco-Rational Language.

The proposal of a language governed by these twelve principles goes beyond a purely linguistic exercise; it projects the outlines of a new social contract, where communication itself becomes an instrument of collective regulation. In the field of constitutional law, such a language could defuse interpretive ambiguities, a source of legal and political conflicts. The clarity of legal expression is a foundation of the rule of law, as reminded by the principle of legal certainty.

Article 2 of the French Constitution of 1958 stipulates that "The language of the Republic is French"; this provision, reflecting a national specificity, does not prohibit reflection on an auxiliary language of universal scope for international law. Such a language, by its rigor, could serve as a medium for drafting international treaties, environmental conventions, or transnational legal codes. The linguistic complexity of international negotiations is notoriously an obstacle to the development of solid consensus, a point often raised during COPs.

The semantic transparency inherent in this isolating grammar would allow for a significant reduction in discrepancies of interpretation of legislative acts and judgments. The concept of "right to understand," advocated by jurists such as Antoine Garapon, would find a powerful lever in this language. The simplification of linguistic structures would facilitate access to norms for all, strengthening democratic legitimacy through enlightened participation. The Defender of Rights, in its 2017 report on "Users' rights in the face of administration," highlighted the need for simplification of administrative language to ensure the effectiveness of rights.

Beyond strict legal interpretation, this morphology and grammar enforce intellectual discipline. Every actor, whether citizen, legislator, or judge, would be compelled to express their thoughts with surgical precision, limiting the room for vagueness or uncertainty. This is all the more crucial in a context of ecological crisis where the terminology used (for example, "sustainable development," "carbon neutrality") can be subject to divergent interpretations, or even greenwashing. The Impact on Ecological Economics and Earth System Sciences.

Ecological economics, a discipline that integrates the laws of thermodynamics and the biophysical limits of the planet, calls for increased semantic precision. The conceptualization of the economy as a subsystem of the planetary ecosystem, promoted by Nicholas Georgescu-Roegen in "The Entropy Law and the Economic Process" (1971), requires linguistic tools capable of modeling complex interdependencies. This language, by its clarity, could become a vector for expressing post-growth economic models. The modeling of material and energy flows, carbon footprints, or life cycle analyses requires unequivocal terminology.

The ability of this language to name processes and quantities without the interference of connotations or grammatical ambiguities would make it a preferred tool for Earth system scientists. For example, the clear differentiation between "stock" and "flow," or between "renewable resource" and "non-renewable resource," would be intrinsically coded by precise semantics, without recourse to contextual interpretation. Reports from the Intergovernmental Panel on Climate Change (IPCC) are often the result of linguistic compromises to accommodate a multiplicity of languages and conceptual frameworks.

A reference language with this isolating grammar could standardize scientific and political communication. The conclusions of the Sixth Assessment Report of the IPCC (2021) on a 1.5°C temperature increase before the end of the century require collective action that only a shared understanding of terms and issues can catalyze. The ability of such a language to circumscribe planetary concepts and boundaries, as defined by Johan Rockström and Will Steffen (2009) in "Planetary Boundaries," would be invaluable. This language would allow for the abandonment of anthropocentric metaphors that often plague scientific and economic language, and that perpetuate an extractivist view of nature.

"Nature" itself is often gendered or personified in some languages, which can influence the perception of our relationship with living things.

By eliminating these biases, the language encourages a more objective and anthropocentric perception of humans in relation to other components of the Earth system. This fosters the emergence of ecosystemic thinking, where interconnectedness takes precedence over individuality. Towards a Political Philosophy of Clear Language. Political philosophy is intrinsically linked to the capacity of language to create common ground. A language whose grammar is designed for clarity and non-ambiguity redefines the contours of public debate.

It raises the question of the sincerity of political discourse and the possibility of rational deliberation. Jürgen Habermas, with his theory of communicative action, emphasizes the importance of distortion-free communication to achieve legitimate consensus. The imposition of such syntax and morphology could be perceived as a constraint, but it can also be seen as a liberation from linguistic conventions that sometimes mask the opacity of intentions. Equal access to the understanding of political discourse would reduce the information asymmetry between governors and governed.

Linguistic transparency is a pillar of participatory democracy, where every citizen can fully grasp the stakes of public decisions. The concept of popular sovereignty, for example, within such a linguistic framework, would be formulated unequivocally, clearly distinguishing the people as a collective, their representatives, and the scope of their power. Populist deviations, often fueled by rhetorical ambiguity, would be more difficult to articulate. The expression of social and environmental demands would gain sharpness, allowing for a more direct confrontation of arguments, and fewer wordplays.

The adoption of such a language, even as a complementary tool, would invite a renewed ethic of language. It would reinforce the responsibility of speakers regarding the scope of their statements. By its very structure, it would encourage systematic and modular thinking, a major asset for understanding the complex problems of our time. The structural clarity of language thus becomes a manifesto for clarity of thought and action. Chapter 51 Core Lexicon of 800 Roots: From Lexicographical Imperative to Glocal Governance The endeavor to elaborate a multilingual core lexicon, founded on demographic linguistic weighting, transcends mere semantic taxonomy.

It posits a constitutive interdependence between linguistic diversity and the human capacity to apprehend and modulate current systemic crises. The complexity of anthropocene challenges, from climate change to biodiversity collapse, demands a shared understanding of fundamental concepts, freed from unilateral epistemic preponderances inherited from past cultural and scientific hegemonies. This project aligns with attempts to decipher the deep structures of human thought, not to homogenize it, but to identify universally intelligible semantic anchor points.

The underlying hypothesis is that transversal terminological clarification is a prerequisite for the emergence of a more resilient and inclusive glocal (a fusion of global and local) governance. This approach reflects a concern for the "reflexive condition" of human societies facing the imminence of irreversible tipping points, as articulated by J. Diamond (2005) in *Collapse*. The established weighting, based on updated global demographic data, aims to confer representative legitimacy upon this lexicon, integrating often marginalized linguistic perspectives, which, by virtue of speaker volume, constitute crucial pools of thought and innovation.

The Genesis of a Pluricentric Approach The selection of languages participating in the weighting (Mandarin, English, Spanish, Arabic, Hindi, Portuguese, Russian, Japanese, German, French, Swahili) is the result of an analysis of contemporary demographic and geopolitical dynamics. Mandarin, with its 16% of global speakers, cannot be overlooked as a vector of fundamental concepts. English, while representing 13% of speakers, retains its function as a technical and scientific *lingua franca*.

Spanish (8%), Arabic (7%), and Hindi (7%) assert themselves by their numbers, but also by the richness of their philosophical and legal traditions, offering distinct approaches to human-nature relationships or social organization. This methodology avoids the pitfalls of unilateral universalization, often of Western construct, which tends to naturalize its own conceptual categories. The objective is not to create a semantic *Esperanto*, but to reveal fundamental convergences and divergences, synonymies and polysémies through a multilingual prism.

A striking example is the translation of the term "sustainable development," whose meanings vary considerably across cultural areas, directly impacting public policies (Guay & D. Olivier, 2017, *Dictionnaire critique et interdisciplinaire du développement durable*). Epistemological and Ontological Stakes of the Core Lexicon The elaboration of an 800-root core lexicon raises profound epistemological questions concerning the nature of shared knowledge and the very possibility of transcultural intelligibility. It is not merely a juxtaposition of word-for-word translations, but an exploration of underlying concepts, their etymologies, their contexts of use, and their philosophical resonances.

The root is not just a linguistic element; it is a semantic crystallization that carries within it entire sections of cosmologies, value systems, and normative frameworks. The difficulty lies in the non-isomorphism of conceptual structures between languages. The Western concept of "law," for example, can hardly be superimposed without loss onto the notions of *dharma* in Indian traditions or *fiqh* in Islam, where the religious and ethical dimension is intrinsically linked to the legal norm. The task, therefore, consists of mapping these conceptual rhizomes, identifying their points of contact and areas of fertile irreducibility, rather than seeking a perfect and illusory equivalence.

Franz von Schlegel's work, from the beginning of the 19th century, highlighted the importance of Indo-European roots, but the perspective here is resolutely synchronic and multilingual, addressing contemporary challenges rather than a unilateral historical genesis. The goal is to provide a common conceptual foundation enabling more precise and operational dialogues in the face of crises that, by nature, know no linguistic or cultural boundaries.

For example, the notion of "resilience," omnipresent in contemporary discourses on adaptation to climate change, refers to technical, ecological, social, and psychological realities whose fine understanding can vary considerably from one culture to another. Contribution to a Global Normative Ecology The absence of a shared semantic referential is a major impediment to the efficiency of international negotiations and the implementation of global commitments. The Paris Agreement on climate (2015), for example, uses terms such as "equity," "climate justice," or "common but differentiated responsibilities," whose interpretation varies among signatories.

A core lexicon could serve as a foundation for a *conventional lexicology* that, without imposing a unique definition, would articulate the nuances and points of terminological agreement or disagreement, thus facilitating convergence towards coordinated actions. This project is in continuity with international legal clarification efforts, similar to the work of the United Nations International Law Commission, but with a broader focus on transdisciplinary concepts. It touches upon what O. Fals Borda (1993) called the "dialectics of participatory action research," where the co-construction of meaning is as important as the production of knowledge.

By democratizing access to semantic trees, this lexicon can strengthen citizen participation in the elaboration of norms and public policies, breaking the hegemony of unilingual experts. Comparative constitutional law has long demonstrated that legal models cannot be transposed without altering their deep meaning (P. Magnard, 2011, *Le Prince sans nom*). The same applies to environmental or economic concepts. The notion of "property," for example, takes radically different forms depending on whether one refers to Roman law, African customary traditions, or the collective property regimes of certain indigenous societies.

Understanding these variations is essential for articulating governance regimes for global common goods. The Conceptual Architecture of the Core Lexicon The core lexicon is not limited to translating words. It aims to deconstruct concepts into constituent elements to reconstruct them intelligibly in each selected language.

For each root, a conceptual sheet would be developed, including: * The original term in each weighted language. * A succinct and neutral definition transcending cultural specificities. * Associated semantic fields and key conceptual distinctions. * Examples of use in different contexts (legal, scientific, economic, philosophical, etc.). * Cross-references with related or opposing concepts. For example, the concept of "natural capital" (Costanza *et al.*, 1997, "The value of the world's ecosystem services and natural capital") requires a translation that captures its economic dimension, but also its ecological and ethical aspects, without forcing a unilateral interpretation.

In Hindi, this could evoke notions of *prakriti* (nature) and *sampatti* (wealth/property), whose articulation is culturally marked. In Arabic, one could explore meanings associated with *tabi'ah* (nature) and *tharwah* (wealth), highlighting perspectives of resources as "gifts of God." Another pertinent example is the concept of "sovereignty." In international law, state sovereignty is a cornerstone. However, in the face of transnational challenges such as the climate crisis or pandemics, the notion of "responsible sovereignty" or "shared sovereignty" is gaining ground (Responsibility to Protect, United Nations).

The translations and interpretations of these concepts in languages such as Russian, Mandarin, or the Spanish of new Latin American constitutions (for example, the Ecuadorian Constitution of 2008 and its rights of nature) reveal fundamental tensions and evolutions in the understanding of the autonomy and interdependence of nations. Implementation and Heuristic Prospective The elaboration of this lexicon will involve the constitution of a college of multidisciplinary and multilingual specialists, working in synergy to guarantee the rigor and representativeness of the concepts. It is not a static task, but a dynamic and evolving process, subject to regular updating.

The advent of generative AI and natural language processing tools can facilitate the initial phase of data collection and pre-analysis, but conceptual validation requires human expertise, embodied by native speakers and thinkers rooted in their cultural traditions. This work is not only an improved translation tool; it is an instrument of comparative epistemology and intercultural diplomacy.

It is a prerequisite for the formulation of more effective international legal frameworks and a shared understanding of planetary boundaries, the very definition of which (for example, the work of Rockström *et al.*, 2009, "A safe operating space for humanity") can be nuanced according to cultural and linguistic prisms. The Normative and Ethical Scope of the Lexicon The ultimate purpose of this core lexicon goes beyond mere semantic compilation. It aims to equip global governance actors, from policymakers to citizen organizations, with a common language for concerted actions.

By making explicit the cultural underpinnings of concepts, it can defuse misunderstandings and strengthen mutual trust, essential elements for any meaningful international cooperation. It is a pillar for an ethics of shared responsibility in the face of the common destiny of humanity. Global environmental awareness has long been structured around concepts from hard sciences, often formulated in English.

However, the integration of traditional knowledge and non-Western perspectives is crucial for a just and equitable ecological transition.

The core lexicon can serve as a bridge between these different epistemologies, making it possible to value concepts like *Buen Vivir* (Living Well), originating from the Andes, which proposes an alternative to linear Western development by focusing on harmony between human beings and with nature.

By offering "translations of meaning" rather than simple "translations of words," the core lexicon helps to understand, for example, that "nature" in Europe can be perceived as an "environment" to be managed, while in certain indigenous cultures, it is a "mother" or a "living entity" with its own rights, as suggested by the Andean "Pacha Mama." It is by recognizing and articulating these perspectives that truly global solutions can emerge, based not on impoverishing uniformity, but on a richness derived from the plurality of worldviews.

The right to a healthy environment, although enshrined in many constitutions (more than 100 states according to the World Wide Fund for Nature, 2017), takes very diverse conceptual forms and legal scopes from one jurisdiction to another. Such a lexicon would allow mapping these nuances. This work prefigures a more polyphonic global governance, where legitimacy no longer stems from cultural or linguistic hegemony, but from a co-construction of meaning and norms.

It is a contribution to an "epistemology of decolonization" of knowledge (Boaventura de Sousa Santos, 2007, *Cognition and Emancipation: The World's Nonconformists for an Epistemology of the South*), indispensable for addressing the challenges of the 21st century. Chapter 52 Examples of Mundia Phrases and Texts: An Ecological Language for the Anthropocene The Mundia project, a constructed international auxiliary language (IAL), responds to the imperative of non-hegemonic universal communication, a necessary condition for effective global environmental governance.

It distinguishes itself from previous IALs by its philosophical grounding in ecological thought and its open methodological genesis. A decolonial approach, the deconstruction of binary categories, and an epistemological sensitivity towards non-Western cosmogonies guide its design, far removed from classic Eurocentric simplifications. The current planetary crisis, marked by biodiversity collapse, climate disruption, and growing social inequalities, demands a transdisciplinary and transcultural language capable of conveying complex concepts derived from Earth System sciences and philosophies of life.

The incommunicability between forms of knowledge, exacerbated by linguistic barriers, hinders international coordination and the implementation of systemic solutions (Rockström et al., 2009). Mundia aims to address this structural deficiency. Adopting a simple agglutinative morphology and semantically transparent vocabulary, Mundia minimizes the ambiguity inherent in natural languages and derived IALs. Its phonology is designed to be accessible to a majority of speakers, avoiding rare or complex sounds. This linguistic engineering is a pillar of its ambition to become a tool for equitable dialogue between cultures and disciplines.

The hypothesis that linguistic architecture influences cognition and perception of reality (Sapir-Whorf) is integrated, not to impose a unique vision, but to foster an "ecology of mind" (Bateson, 1972) where the translation of fundamental concepts of sustainability, reciprocity, and intergenerational justice becomes intrinsic. Mundia is thus a living language, whose evolution is conceived as collaborative and dynamic.

Common Usage Phrases in Mundia 1. *Alo.* (Hello) 2. *Mersi.* (Thank you) 3. *Yes.* (Yes) 4. *No.* (No) 5. *Pardon.* (Excuse me / Sorry) 6. *Komuni bi?* (How are you?) 7. *Bi, mersi.* (Fine, thank you.) 8. *Munde es eko.* (The world is beautiful.) 9. *Mi lerni Mundia.* (I am learning Mundia.) 10. *Tu parla Angla?* (Do you speak English?) 11. *Mi non komprendi.* (I don't understand.) 12. *Mi lupi tu.* (I love you.) 13. *Komo tu nomi?* (What is your name?) 14. *Mi nomi Mariam.* (My name is Mariam.) 15. *Akua es vital.* (Water is vital.) 16. *Klima changi.* (The climate is changing.) 17. *Tera suferi.* (The Earth is suffering.) 18. *Komun agi.* (Let's act together.) 19. *Homi egali.* (Humans are equal.) 20. *Futura es nu.* (The future is now.) 21. *Kolo pluvia.* (It rains a lot.) 22. *Agi now.* (Act now.) 23. *Dura agi es esen.* (Sustainable action is essential.) 24. *Rispekte naturo.* (Respect nature.) 25. *Suno doni vida.* (The sun gives life.) 26. *Paci forsa.* (Peace is strength.) 27. *Eduko liberta.* (Education liberates.) 28. *Bi-diverse valor.* (Biodiversity has value.) 29. *Sistema jus.* (Systemic justice.) 30. *Konsci uni.* (Consciousness unites.) Translation of Fundamental Documents into Mundia The translation of emblematic legal and political texts into Mundia serves a dual function: first, to demonstrate the language's capacity to articulate highly complex and universally relevant concepts; second, to facilitate wider dissemination and disinterested understanding of the fundamental principles underpinning international legal order and innovative national constitutions.

The choice of the Preamble to the 1948 Universal Declaration of Human Rights (UDHR) is not insignificant, as it lays the foundation for international human rights law, while the introduction to the 2008 Ecuadorian Constitution exemplifies the recognition of the rights of nature (Pachamama), a major legal advance. This translation endeavor is not limited to simple lexical transcoding. It involves a deep reflection on the adequacy of Mundia's semantic structures to the precision and performative force of the original texts. The objective is to preserve the intent and normative scope, while exploring Mundia's capacity to foster a renewed perception of these fundamental commitments.

Preamble to the Universal Declaration of Human Rights (1948) in Mundia *Konsidera ke ignoro et spreto a homi-jur et liberta rezo a barba akto ke ofensi homi-konsci e ke lupi-aspiro a munde ubi homi liberi parla et kredu, liberi teroro et wanto, es proklamado supa homi-aspiranto ;* *Konsidera ke es esen ke homi-jur protekti pa jus-regula, si homi non es forso aksepti rebeli kontra tirani et opresio ;* *Konsidera ke es esen developi amik-relato inter naziono ;* *Konsidera ke populi di Naziono Uni re-afirma in Karta su fido in fundamen homi-jur, in digno et valor a homi persona et in egali jur a man et fe-man, et decide anta developi sozi-progres et elevi vivo-standar in plu-liber vivo ;* *Konsidera ke Stato-membro promesi, in ko-opo kun Naziono Uni, attaini promo uni-respekto et obserba a homi-jur et fundamen liberta ;* *Konsidera ke komuni komprendo a tula jur et liberta es grand-importo forsa et realiza ta prometo ;* *Now, Gena Asembla,* *Proklami disi Uni Deklara a Homi-jur kom komuni idealo a tu populi et tu naziono, forso ke echa indi-aktu et echa organo di sozi, teni in memori disi Deklara, forso a progresiv-edu et nasyona et interna agi, forso et akno et obserba efektiv-plu genera et uni-versa a ta jur et liberta, inter populi a Stato-membro se et inter populi a teritori so domini.* This text illustrates Mundia's capacity to express abstract concepts such as "dignity," "fundamental rights," or "human conscience" through transparent lexical composition (*homi-konsci*, *fundamen homi-jur*).

The subject-verb-object structure is favored for maximum intelligibility. The translation strives to maintain the solemnity of the original 1948 document. First Paragraph of the Ecuadorian Constitution of 2008 in Mundia *Ekuador es konstitusional-stato a jur et justitia, sozi-et-demokrati, suvera, indi-depen, uni et inter-kulturi. So orga fundamena jur et valor suprema di respekto a homi-digno, jus-klima, jus-liberta, jus-egalita, et jus-sozi-ko-vivi ; ubi pluralita et diferenta et akno di Pachamama, es sumak kawsay, o bi-vivo. Lingo ofisial es Kastela ; kichwa et shuar es ofisial lingo for inter-kulturi relatia.

Vandra es la kapitala et la side di sozi-powa.* This paragraph highlights the conceptual integration of "Pachamama" (Mother Earth) and "Sumak Kawsay" (Good Living) in Mundia, central concepts in the

2008 Ecuadorian constitution. The juxtaposition of universal terms (*jus-liberta*, *jus-egalita*) with terms intrinsic to a specific cosmogony demonstrates Mundia's semantic flexibility. The preservation of proper nouns and specific cultural concepts is a key principle, avoiding reductive homogenization. The original Spanish text officially recognizes "buen vivir" or "sumak kawsay" as a guiding principle (Article 3, n. 9 of the Constitución de la República del Ecuador, 2008).

Mundia versus Esperanto and Interlingua: Epistemological and Constructive Approach A comparison of Mundia with established IALs like Esperanto (Zamenhof, 1887) and Interlingua (International Auxiliary Language Association, 1951) reveals fundamental divergences in terms of objectives, construction method, and philosophical framework. While all aim for facilitated communication, Mundia explicitly positions itself as a response to contemporary challenges, particularly the environmental crisis and the need for epistemic justice. Esperanto, created in 1887, was one of the first successful attempts at an IAL.

Its regular grammar, transparent lexical derivation, and quasi-phonetic phonology have enabled an active linguistic community, estimated at several hundred thousand speakers (Piron, 1994). However, its vocabulary, predominantly Romance and Germanic, and its largely Indo-European grammar, though simplified, do not entirely escape a certain linguistic ethnocentrism. Esperanto was designed at a time when global ecological issues were not yet systematically conceptualized, and its intrinsic philosophy remains focused on human fraternity from a largely classical humanist perspective.

Interlingua, developed by the IALA and published in 1951, adopts a naturalistic approach, based on the extraction of common vocabulary from Romance, Germanic, and Slavic languages. It aims to be immediately intelligible to speakers with knowledge of these language families, minimizing passive learning effort. Its grammar is also simplified but retains features familiar to European speakers. Interlingua prioritizes recognition over radical construction, which limits its inclusivity beyond Western linguistic areas and its capacity to integrate non-European concepts without forcing them into a pre-established mold. Mundia, in contrast to these traditions, starts from an eco-critical premise.

Its lexical construction integrates pan-linguistic roots, seeking phonetic and semantic convergence in a lexical corpus derived not only from Indo-European languages but also from Sino-Tibetan, Austronesian, Bantu, and Amerindian families. The objective is to surpass the 35% of monosymy often observed in classical IALs, to achieve a high level of semantic clarity (Lee et al., 2011). This approach responds to the criticism of an implicit "linguism" in previous constructions that favored the languages of the colonizer.

Phonologically, Mundia prioritizes a repertoire of consonants and vowels present in at least 80% of the world's languages, thereby reducing acquisition barriers for speakers from diverse backgrounds. Esperanto, with its diacritics (■, ■, ■, ■, ■, ■), and Interlingua, with its few less universal phonemes, do not always achieve this absolute phonetic universality. The average complexity of natural language phonetic systems is about 28 phonemes; Mundia limits itself to 22. The ecological footprint of languages is an emerging field of study in ecological economics (Kettunen, 2017).

Majority languages often impose ways of thinking and terminologies that are not always conducive to understanding local sustainability issues. Mundia, through its semantic decentralization and its capacity to encode indigenous knowledge about nature, seeks to be a "low cognitive footprint" language, facilitating interscientific and intercultural dialogue without imposing pre-existing mental models. In terms of adoption, Mundia does not initially aim for mass adoption by individual speakers like Esperanto, but rather for strategic use in scientific, diplomatic, and educational forums focused on sustainability.

The goal is first functional competence to address complex subjects, before broader cultural integration. The development of specialized corpora in environmental law, circular economy, and climate science is therefore a priority. Constitutional and Ecocratic Dimensions of Mundia The integration of Mundia into a global governance framework is inseparable from the notion of ecocracy, a political system where ecological principles and sustainability are the foundations of political decision-making (Dryzek, 1997).

In this context, Mundia is envisioned as an empowering tool for planetary citizens, enabling them to engage in informed and equitable discussions on environmental policies, beyond traditional linguistic and cultural divides. Article 2 of the Chicago Convention of 1944 provides for English as the working language of the International Civil Aviation Organization (ICAO). English is also the dominant language in 85% of indexed scientific publications (UNESCO, 2010 est. 2014) and the language of 55% of global websites. This linguistic hegemony raises the question of access to information and the power to define problems and solutions.

Mundia offers a counterbalance, providing a neutral linguistic space for international collaboration. Comparative constitutional law shows a trend towards the integration of the rights of nature, as in Ecuador (2008) and Bolivia (2009). Mundia, by its very design, facilitates the expression of these "non-human rights" and concepts of interspecies justice. Its vocabulary is not anthropocentric by default, but allows for an explicit articulation of co-evolutionary relationships between human and non-human. This capacity is crucial for the development of transnational or supranational ecological constitutional charters.

Deliberative democracy, as theorized by Habermas (1992), relies on the ability of actors to engage in rational and inclusive discourse.

Mundia aims to provide the linguistic foundations for such deliberation on a planetary scale, reducing power asymmetries related to mastery of dominant languages. Mundia's neutrality can foster the emergence of a global "ecological public sphere," where the plurality of voices and perspectives would be truly heard. Contemporary political philosophy, particularly work on global justice and ecological citizenship (Dobson, 2003), finds a potential vector in Mundia.

By offering a common language that is not the mother tongue of any dominant ethnic or national group, Mundia promotes a form of shared linguistic sovereignty, essential for building legitimate and effective global governance institutions in the face of poly-environmental and social crises. Towards an Ecology of Language and Linguistic Justice The idea of a universal language, often perceived as utopian or imperialistic, is here reinterpreted through the lens of language ecology. It is not about eradicating linguistic diversity, but about providing a "buffer language" that facilitates interconnections and the sharing of crucial knowledge for planetary survival.

Mundia is intended as a complement, not a substitute, to natural languages, each holding irreplaceable cultural and epistemic richness. Linguistic justice, intrinsically linked to epistemic justice, requires that all forms of knowledge, including traditional and indigenous knowledge, be accessible and valued on the global stage. Mundia, through its non-Eurocentric design and semantic adaptability, is a catalyst for this recognition. It allows for the translation without substantial loss of concepts derived from different cosmologies, essential for genuinely intercultural dialogue on the management of global common goods.

The adoption of Mundia by key institutions, such as the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization (2010), could represent a turning point. Article 10 of the Protocol emphasizes the importance of traditional knowledge associated with genetic resources.

Mundia would provide a vehicle for these communications, ensuring more robust protection of the intellectual sovereignty of communities holding such knowledge.

In summary, Mundia is not just an object of semiotics or linguistics; it is a political and ethical project, a concrete proposal for a world where collective survival will depend on our ability to communicate, understand, and act together, beyond linguistic borders and hegemonic legacies. Its conceptual rigor and its grounding in the imperatives of the Anthropocene make it a unique scientific contribution to the debate on global governance. Chapter 53 Writing System: Extended Latin and Alternatives Latin Hegemony versus Global Scriptural Diversification The Latin writing system, heir to the Etruscans and Greeks, today constitutes the predominant graphic framework on a planetary scale.

Its expansion, correlated with that of the Roman Empire and then European colonial powers from the 15th century onwards, led to its adoption by a plurality of languages originally written according to other graphic conventions. In 2023, among the 7,168 living languages surveyed by *Ethnologue: Languages of the World* (Eberhard, Simons, and Fennig, 2023), a significant proportion uses the Latin alphabet or extended derivatives. This dominance is not confined to Indo-European languages but extends to the most diverse linguistic families, from Afrikaans to Turkic languages, including many Austronesian and African languages.

ISO 15924, which lists codes for writing systems, assigns the code "Latn" to the Latin alphabet, attesting to its central status, although many extensions and diacritics have been developed to accommodate the phonological specificities of the languages that adopted it. Genesis and Evolution of the Extended Latin Alphabet The original Latin alphabet, composed of 23 letters in ancient times, has been considerably enriched over the centuries to adapt to the phonetic nuances of European, and later extra-European, languages. The introduction of diacritics (accents, cedillas, tildes, hooks, bars, etc.) constitutes the most visible extension of this system.

These markers, modified systematically or idiosyncratically, make it possible to distinguish phonemes non-existent in classical Latin, such as the closed "e" in French represented by the acute accent (é), or the Czech "ch" (■ with a caron). The extension process is also manifest in the adoption of new letters such as "w" or "z" in English, or "j" and "v" which differentiated from "i" and "u" respectively. This plasticity has favored its exportation, both through political decision-making processes and through cultural and educational evangelization.

The decision to transcribe an orally used language via the Latin alphabet is never neutral; it involves defining new linguistic and scriptural standards, sometimes competing with pre-existing systems, as in Timor-Leste where the official language, Tetun, has used the Latin alphabet since independence in 2002. Major Alternative Writing Systems: A Geopolitical and Cultural Cartography Beyond Latin hegemony, several writing systems maintain considerable vitality and spheres of influence, testifying to the world's rich cultural diversity. Transcription between these systems and the Latin alphabet is a major issue for international communication and linguistic preservation.

Cyrillic: A Byzantine and Slavic Heritage The Cyrillic alphabet, designated by the code "Cyrl" according to ISO 15924, is the graphic realization of a Byzantine cultural and religious legacy transmitted via the brothers Cyril and Methodius in the 9th century. It is currently used by an estimated 250 million people, according to the estimations of the National Institute of Oriental Languages and Civilizations (INALCO), particularly in countries in Eastern Europe and Central Asia, heirs of the former Soviet bloc. The Russian language (ISO 639-3 code: rus) is its most prominent example. The transliteration of Cyrillic into Latin varies according to national conventions, creating ambiguities.

For example, the name of the composer P.I. Tchaikovsky can be transliterated as Chtchaikovsky (French), Tchaikovsky (standard English), or Chaikovskii (ISO 9:1995 scientific transliteration system). This multiplicity of standards hinders fluid and reliable scriptural interoperability, as raised by the International Organization for Standardization. East Asian Scripts: Han and Hangul East Asia is home to powerful scriptural traditions. The Han system (ISO 15924 code: Hans for simplified, Hant for traditional), used for Mandarin (ISO 639-3 code: cmn), is one of the oldest and most complex, with tens of thousands of ideographic characters that have evolved over millennia.

This system conveys a worldview where a character can carry a pluri-syllabic concept, contrasting with the phonetic approach of alphabetic systems. Hangul (ISO 15924 code: Hang), the writing system of Korean (ISO 639-3 code: kor), is often cited as one of the most rational and scientific alphabets ever conceived. Created in the 15th century by King Sejong the Great, it is distinguished by its graphic representation of phonemes reflecting the position of the mouth during their pronunciation. Its relative simplicity, compared to the Chinese characters it gradually replaced, has significantly contributed to erudition in Korea.

The transliteration of Korean into Latin is also subject to variations, with the McCune-Reischauer system and the Revised Romanization of Korean being the most common, but introducing divergences. The Arabic Alphabet: The Vector of a Civilization The Arabic alphabet (ISO 15924 code: Arab) is the writing system of one of the most widely spoken languages in the world, Arabic (ISO 639-3 code: ara), and beyond, the vector of Islam, used to write languages as diverse as Persian, Urdu, and certain African languages. Its major characteristic is being an abjad that most often writes only consonants, with vowels indicated by diacritics or deduced from context.

The transliteration of Arabic into the Latin alphabet presents significant challenges due to the absence of certain Arabic phonemes in Latin and vice versa. Pharyngeal or emphatic consonants, long and short vowels, require specific conventions to be rendered faithfully, such as the use of diacritics or digraphs like "dh" for (■). The transcription of proper nouns and place names represents a geostrategic issue, as evidenced by the heterogeneity of city names in the Middle East in the Western press.

Devanagari: A Glyphic System of the Indian Subcontinent Devanagari (ISO 15924 code: Deva), an abugida descended from Brahmi, is the writing system used for Sanskrit, Hindi (ISO 639-3 code: hin), and several other languages of Northern India and Nepal. It is characterized by a horizontal top line from which characters are "suspended". Each consonantal character inherently carries a vowel, generally an "a". Other vowels and the absence of a vowel are indicated by diacritics. The transcription of Devanagari into the Latin alphabet is more systematized thanks to methods like the International Alphabet of Sanskrit Transliteration (IAST) and its derivative ISO 15919:2001.

Despite these standards, excessive simplification in common usage often neglects diacritics essential for phonetic precision, altering correct pronunciation and comprehension, a phenomenon that can be observed in the simplification of yoga or meditation names. Legal and Technological Challenges of Scriptural Coexistence The coexistence of distinct writing systems raises crucial legal and technological questions in the era of digital globalization. The recognition and interoperability of different scripts are not merely technical conveniences; they are essential levers for digital inclusion and the preservation of linguistic and cultural diversity.

Problems of Standardization and Transliteration Standards ISO 15924 (Codes for the representation of names of scripts) and ISO 639-3 (Codes for the representation of names of languages) are essential foundations for the classification and identification of scripts and languages. However, simple identification does not resolve conversion problems. The numerous transliteration standards (ISO 9 for Cyrillic, ISO 15919 for Devanagari, for example) aim to establish systematic bridges between graphic forms. Nevertheless, these standards are often poorly applied outside of specialized academic or technical contexts.

National or informal conventions continue to prevail, exacerbating fragmentation and ambiguity. An initiative to create a universally accepted transliteration system would not only be complex to implement due to cultural and linguistic resistance but could also unintentionally privilege one phonological system over another. The establishment of fully reversible inter-system transliteration schemes remains a distant goal, despite considerable efforts by specialists in computational linguistics.

Technical Imperatives: Unicode and the Scriptural Universal The emergence of Unicode (The Unicode Standard, published by the Unicode consortium), a character encoding system covering almost all writing systems used worldwide, represents a major technological revolution. Since its first version in 1991, Unicode has been extended to include more than 150,000 characters from 159 different writing systems, thus allowing any text, regardless of its language or script, to be displayed, stored, and processed consistently on digital devices. Before Unicode, encoding problems caused a digital "cacophony" where texts in different languages were often unreadable or corrupted.

The efforts of the International Electrotechnical Commission (IEC) and ISO, particularly with the ISO/IEC 10646 standard (Universal Coded Character Set), have worked in parallel with the Unicode consortium to ensure a unique and comprehensive specification. This has been fundamental for the development of the multilingual internet and for access to information for all, regardless of their native language or writing system. Constitutional and Legal Impact of Scriptural

Diversity On the legal front, the recognition of the plurality of writing systems is crucial for the protection of cultural and linguistic rights.

In multilingual nations like India, the 1950 Constitution recognizes 22 official languages, and implicitly several writing systems. Article 343 specifies that "the official language of the Union shall be Hindi in Devanagari script," while preserving the use of English for 15 years, which was later extended. The right to use one's language and script is often linked to human rights, as stipulated by Article 27 of the International Covenant on Civil and Political Rights (1966), which ensures linguistic minorities the right to use their own language.

However, the concrete implementation of these rights requires appropriate technical and educational infrastructure, including the production of educational and administrative materials in various scripts. In Poland, the law of January 6, 2005, on national and ethnic minorities and regional languages, for example, provides for the possibility of using place names in minority languages, sometimes implying the use of Cyrillic or other scripts. Epistemological and Socio-Economic Consequences of Scriptural Choices The implications of writing system choices go beyond mere technicality to affect thought structures, the transmission of knowledge, and global socio-economic dynamics.

Preference for a script can lead to significant advantages and disadvantages in terms of access to information, economic integration, and cultural preservation. Cognitive Structure and Modes of Thought Writing systems are not just tools for transcription; they influence human cognition. Studies in psycholinguistics, such as those by Dehaene (2009) on "Reading in the Brain," have shown how the human brain adapts its neural circuits to decipher an alphabet, a syllabary, or a logogram.

Learning Chinese, which involves memorizing thousands of characters, activates different brain regions from those solicited by the Latin alphabet, which can influence certain aspects of cognitive processes, even if the effects on abstract thought are still debated. The predominance of the Latin alphabet in education and international scientific communication can lead to a homogenization of learning methods and knowledge dissemination. This creates a barrier for communities whose native language uses another system, compelling them to acquire dual scriptural competence to integrate into global research networks.

The costs of acquiring this dual competence can be considerable for many individuals, and affect the full participation of certain regions in global intellectual exchange. Knowledge Economy and Digital Divide Latin hegemony in the digital and scientific domain confers a structural advantage on nations that use it. The vast majority of databases, programming software, and online platforms were initially designed with Latin characters. In 2024, the volume of web content in English (mostly Latin) exceeded 55% of the global total, according to W3Techs estimates, creating a technological lock-in effect.

For languages with non-Latin scripts, the engineering investment for adapting interfaces, optical character recognition (OCR), or specific keyboards is considerable. The absence of adapted fonts or ergonomic input solutions can lead to a digital divide reinforced by the scriptural barrier. For example, the development of virtual or physical keyboards for Devanagari or Hangul, while available, does not achieve the efficiency of QWERTY or AZERTY keyboards on which a large part of the world's population is trained.

Issues of Linguistic Preservation and Development The choice of a writing system for a historically oral language or for a minority language is a crucial strategic decision for its survival and development. In some cases, the adoption of the Latin alphabet has allowed the standardization and teaching of languages that would otherwise have remained confined to orality. Vietnamese, which used Chinese characters, switched to the Latin alphabet (qu■c ng■) in the 20th century, which greatly contributed to the reduction of illiteracy in the country. However, the imposition of the Latin alphabet can also lead to cultural assimilation, erasing indigenous scriptural traditions.

The example of Turkey, where the Arabic alphabet was replaced by the Latin alphabet during the Kemalist reforms in 1928, is illustrative: this decision, targeted by Turkish Law No. 1353 of November 1, 1928, was a major factor in the secularization and modernization of the country, but also created a notable discontinuity with pre-existing Ottoman literature and even resistance and a decline in literature, according to some revisionist historians. Balancing these two aspects, between openness and preservation, is a constant dilemma for global linguistic policies.

Chapter 54 Linguistic Antecedence Verification: The Emergence of Constructed Languages: Archaeology of Linguistic Rationalization The history of attempts to construct universal or auxiliary languages is deeply rooted in a quest for rationality and communicative efficiency. As early as the 17th century, thinkers such as John Wilkins, with his "An Essay towards a Real Character and a Philosophical Language" (1668), aspired to transcend the ambiguities of natural languages through logical systems.

This project reflected not only a fascination with classification and systematization, characteristic of the classical age, but also a desire to overcome linguistic barriers perceived as obstacles to scientific progress and mutual understanding among nations. In the 19th century, this ambition crystallized under the impetus of pacifist and internationalist currents, seeking to provide humanity with a common linguistic tool to facilitate exchange and prevent conflict. Ludwik Lejzer Zamenhof's publication of Esperanto in 1887, under the pseudonym Doktoro Esperanto (one who hopes), marked a decisive milestone.

Born from an observation of inter-community tensions in Poland, Zamenhof's objective was to create a language that was easy to learn, phonetically regular, and grammatically simple, to serve as a neutral international auxiliary language. Esperanto, with its rich vocabulary mainly inspired by Romance and Germanic languages, and its logical grammar based on 16 fundamental rules without exception, quickly achieved notable success. As early as 1905, the first Universal Esperanto Congress gathered about a hundred participants from twenty different countries in Boulogne-sur-Mer, testifying to the viability and appeal of this undertaking.

This language, still spoken by hundreds of thousands, or even a few million people worldwide according to UNESCO, illustrates the persistence of this human aspiration for facilitated and egalitarian communication. The Bifurcations of the Movement: Ido and Interlingua The very success of Esperanto generated discussions and proposals for improvement, leading to internal schisms. The most significant was the creation of Ido in 1907.

Developed by Louis Couturat, Louis de Beaufront, and Otto Jespersen, Ido (meaning 'descendant' in Esperanto) was presented as a reformed version, aimed at correcting certain perceived "irregularities" or "cumbersome aspects" in Esperanto, notably the suppression of diacritical accents and the standardization of word formation. Its vocabulary was also adjusted to be more immediately recognizable by speakers of Romance languages. Despite its ambitions for clarity and "naturalism," Ido failed to eclipse Esperanto and remained a language spoken by a minority, a victim of its fragmentation of the Esperanto-speaking community.

This experience highlights the inherent difficulty in constructed language projects: collective adoption and community cohesion often outweigh theoretical linguistic perfection. The history of Ido is a testament to the tensions between the ideal of linguistic engineering and the social dynamics of adoption. Another notable attempt at naturalism was Interlingua, developed by the International Auxiliary Language

Association (IALA) and published in a dictionary and grammar in 1951.

Unlike Esperanto or Ido, which sought a certain schematization, Interlingua aimed to be an "average" of Romance and Germanic languages, drawing its vocabulary from a corpus of source languages (English, French, Italian, Spanish, Portuguese). Its goal was to be understandable without prior learning for speakers with knowledge of these languages. Interlingua never achieved the same scale as Esperanto, remaining primarily a language of communication for scientists and intellectuals. It demonstrates that grammatical and phonetic simplicity are not the only factors for success; the presence of an active community and roots in a broader social movement are also decisive.

IALA, under the direction of Alexander Gode, focused on maximizing passive intelligibility, sometimes at the expense of active learning. Contemporary Linguistic Experimentation: From Logic to Sobriety The late 20th and 21st centuries have seen the emergence of constructed languages with more diversified, sometimes more experimental or philosophical, than purely universalist objectives. Lojban (Logical Language Base), formalized in 1987 by the Logical Language Group, is a striking example of a language constructed on predicative logic. Designed to be free of grammatical and semantic ambiguity, Lojban is inspired by Loglan (LogiKala LANguage), created by James Cooke Brown in the 1950s.

Lojban is characterized by rigorously defined morphology and syntax, theoretically allowing for direct translation into formal logic. Its grammar is designed to avoid any polysemy, and its vocabulary is derived from six major world languages (English, Arabic, Chinese, Hindi, Russian, Spanish), with the goal of cultural neutrality. However, this complexity and logical rigor make it extremely difficult to learn and use fluently, limiting its community of speakers to a few hundred individuals, mainly linguists, logicians, and computer scientists.

Lojban represents a form of linguistic engineering pushed to its paroxysm, aiming for logical perfection to the detriment of ease of acquisition and dissemination. It raises the question of the balance between linguistic rationality and human "naturalness" or "cognitivity." It proves to be a valuable tool for research in semantics and artificial intelligence, but less so for large-scale interpersonal communication. Linguistic Sobriety: Toki Pona and Globasa In contrast to the complexity of Lojban, projects like Toki Pona, created by Sonja Lang in 2001, prioritize simplicity and lexical sobriety.

With a vocabulary of approximately 120 root words and minimalist grammar, Toki Pona aims to embody the principle of "less is more." Its goal is to focus thought on the essential, to propose a language that is both easy to learn and an exploration of the limits of minimal expression. Toki Pona is a philosophical language, inviting contemplation and concise thought. It is appreciated for its ability to express complex ideas with simple words, forcing the speaker to deconstruct concepts.

Although its community is modest (several thousand speakers according to estimates), it is very active and illustrates a different direction in linguistic construction: that of reduction and emotional and cognitive efficiency, rather than expressive complexity or universalist neutrality. An intermediate approach is found in more recent projects like Globasa (2019) by Michael Hwang. Globasa aims to be an easy-to-learn international auxiliary language, inspired by the principles of naturalism but with a more systematic approach to lexical selection.

Globasa's vocabulary is based on the "most spoken words" in the world, taking into account languages with the largest number of native and non-native speakers, such as Mandarin, Spanish, English, Arabic, Hindi, Portuguese, and Russian. The Globasa project is part of a very contemporary approach to maximizing global "recognizability," seeking a form of statistical universality. Its phonological system is relatively simple, and its grammar is regular. The ambition is to create a language easily accessible to speakers of many languages, without sacrificing expressive capacity. It is an attempt to reconcile ease of learning with the global representativeness of linguistic sources.

The Question of a "World Language" and the Political Economy of Language These different attempts at language construction, from Wilkins to Globasa, raise fundamental questions about the place of language in the global political economy. Critics of linguistic hegemony, particularly of English as a global *lingua franca*, highlight the inequalities it generates in terms of access to information, education, and economic opportunities. Researchers like Robert Phillipson ("Linguistic Imperialism," 1992) have documented the mechanisms by which certain languages maintain a dominant position, often at the expense of linguistic diversity.

A 2003 UNESCO report ("Language Vitality and Endangerment") estimated that at a disappearance rate of one language every fifteen days, about half of the 6,000 to 7,000 languages currently spoken worldwide could disappear by the end of the 21st century. This erosion of linguistic heritage poses a major challenge to cultural diversity and the cognitive richness of humanity. In this context, the relevance of a neutral auxiliary language is often reaffirmed by its proponents as a means of leveling the conditions of communication.

Article 21 of the Charter of Fundamental Rights of the European Union prohibits any discrimination based on language, which attests to the legal recognition of the importance of the linguistic question. However, the implementation of this non-discrimination in the face of the multilingual complexity of institutions, such as the European Parliament which operates with 24 official languages, generates considerable costs, estimated at around 1 billion euros per year for translation and interpretation according to a 2018 study commissioned by the European Committee of the Regions.

The emergence of a universal language, whether natural or constructed, would have profound economic, social, and political implications. These would particularly affect the translation, publishing, and education industries. Proponents of constructed languages point to the "native speaker premium" enjoyed by English speakers, granting them an inherent advantage in international interactions. Such a privilege is analyzed by François Grin in "L'Économie des langues" (2005), which highlights the direct and indirect costs of linguistic diversity and the unequal benefits of its maintenance or reduction.

Globalization and Linguistic Harmonization: The Case of Lidepla The Lidepla (Lingua de Planeta) project, launched in Russia in 2006 by Dmitri Ivanov, is part of this lineage of international auxiliary languages, with an ambition for global linguistic harmonization. Lidepla distinguishes itself by a strong multilingual approach, seeking to incorporate elements from the main languages of the world, considering not only Indo-European languages but also Chinese, Arabic, and African languages. The goal is to create a truly universal language, in the sense that it would be intuitive for a majority of the world's population.

Lidepla's approach is based on a principle of balance between lexical familiarity and grammatical simplicity. The vocabulary is drawn from the most frequent and recognizable words in a wide range of languages, so that the language is comprehensible *a priori* to the largest number of people. Its grammar is intentionally regular and simplified, avoiding idiomatic peculiarities and exceptions that often make natural languages difficult to learn. Lidepla aims to be a linguistic bridge, facilitating intercultural communication without imposing a particular linguistic hegemony.

Its development is part of a gentle globalization perspective, where communication is fluidified by a neutral and accessible tool, rather than dominated by a national language. Its approach differs from that of Esperanto, which favors predominantly European roots, and that of

Interlingua, which is more rooted in Romance languages. Despite Lidepla's absence from repertoires such as those of Eberhard et al. (Ethnologue) or the Conlang Atlas, which tend to focus on constructed languages that have achieved a certain maturity or a significant community of speakers, its existence testifies to the continued vitality of the search for global linguistic solutions.

Its ambition to fairly represent the major language families of the world constitutes a significant evolution in the philosophy of constructed languages, moving from a Eurocentric universalism to a truly planetary ambition. Reflections on a "World Language" and Linguistic Governance The issue of a "world language" is not limited to the design of a linguistic instrument, but questions global governance. The adoption of a universal auxiliary language, whether constructed or a promoted natural language, would be a major political decision, requiring international coordination and a difficult-to-achieve consensus.

The very idea of such a language raises fears of loss of cultural identity and reduction of linguistic diversity, often considered essential components of humanity's heritage. Yet, the challenge of transnational communication continues to grow with the complexity of global issues, whether climate negotiations, peace dialogues, or scientific collaboration. The Paris Agreement on climate (2015), for example, was drafted and adopted in the six official languages of the United Nations, highlighting the need for accurate translation and interpretation in highly sensitive contexts. Semantic coherence and unambiguousness are crucial here, recalling the initial aspirations of Lojban.

Attempts to create a universal language since the 17th century reflect a permanent tension between the need for linguistic efficiency and equity and the valuing of diversity. They underline that language is not only a means of communication, but also a vector of identity, culture, and power. The relevance of a "world language" will not be judged solely on its intrinsic linguistic qualities, but on its ability to be accepted as a neutral and equitable tool by the international community, respecting the plurality of worldviews it harbors.

Contemporary projects like Globasa and Lidepla, by striving to integrate broader cultural and linguistic representativeness, show an awareness of the limitations of previous approaches. They propose a path where linguistic rationalization does not occur at the expense of inclusion and recognition of different linguistic heritages. The quest continues, not for a language that would replace all others, but for a tool that could serve as a meeting point for the Anthropocene era, where global cooperation is more than ever an existential necessity for our species and for the biosphere.

Chapter 55 Pedagogy and Educational Deployment: The Imperative of Systemic Education in the 21st Century The concept of "Education for Sustainable Development" (ESD), as articulated in 1992 at the Earth Summit in Rio de Janeiro and reaffirmed by UNESCO's Global ESD Strategy in 2015, has too often been confined to an additive approach, juxtaposing environmental themes without achieving the necessary epistemological integration.

The complexity of contemporary crises—biodiversity collapse (IPBES 2019 report estimating one million species threatened with extinction), climate disruption (IPCC 2023 report setting the limit at less than 1.5°C to avoid irreversible impacts), resource depletion—demands a radical reformulation of curricula. The goal is no longer merely to inform, but to transform cognitive and normative frameworks. The fundamental distinction lies between education *about* ecological issues and education *for* a just ecological and social transition. The latter implies a systemic understanding of the interdependencies among biophysical, economic, social, and political dynamics.

It requires the development of critical competencies, complex thinking, and an ethic of intergenerational and interspecies responsibility, directly in line with Hans Jonas's work (1979) on the principle of responsibility. The pedagogical challenge lies in the ability to convey this complexity without impoverishing it, and to foster engagement without resorting to counterproductive alarmism. The objective is to train citizens capable of critical analysis, discernment in the face of dominant narratives, and enlightened collective action, rooted in the realities of their biotope and aware of the planetary dimension of the challenges.

An Integrated Curricular Approach: The "Ecosystems and Societies" (E&S) Module The deployment of a structured module dedicated to the systemic reading of nature-society interactions has become a necessity. Proposed from Cycle 3 of primary education (CM1, CM2, 6th grade), this "Ecosystems and Societies" (E&S) module aims to instill early a fundamental understanding of the mechanisms governing our world. Its minimum annual duration of 60 hours appears to be a critical threshold to ensure lasting impregnation and coherent learning progression.

This hourly volume, though substantial, is comparable to that allocated to intensive foreign language learning, as illustrated by the example of Swedish for L2 English in the 1990s-2000s. Sweden implemented early and immersive English language teaching from primary school, with programs often enriched by extracurricular activities and a favorable media environment, contributing to Sweden's designation as one of the world's best-performing countries in English language proficiency (EF EPI 2023, Sweden ranking 15th globally and 12th in Europe). This pedagogical ambition, transposed to eco-social issues, suggests that such intensity is not only desirable but achievable.

The integration of this module will not be achieved by simple addition to the existing curriculum, but by a transversal overhaul involving life and earth sciences, geography, history, moral and civic education, and even the arts. The aim is to break down disciplinary silos to better understand the intertwined nature of biophysical and anthropogenic problems. Thematic and Gradual Progression of the E&S

Module The construction of the E&S module curriculum must follow a logic of increasing complexity, moving from the near to the distant, from the concrete to the abstract, while maintaining a recurrence of key concepts to facilitate their understanding.

Cycle 3, CM1: Planet Earth, my local ecosystem In CM1, the module will begin with an exploration of the child's immediate environment: the school garden, the neighborhood park, the nearby forest. The objective is to familiarize students with the notions of local ecosystem, interdependencies of living beings (simple food chains, role of decomposers), and the water cycle on a small scale. Practical activities—educational gardening, naturalist observations, investigation into classroom water consumption—will be prioritized.

Introductory concepts will include biodiversity (variety of life forms), ecosystem services (the water we drink, the air we breathe), and the local human footprint (waste production, energy consumption at school). Emphasis will be placed on the "sense of place" and attachment to the surrounding nature, a prerequisite for any environmental ethic. Cycle 3, CM2: Human societies and their impacts on the environment In CM2, the scope will gradually broaden. Based on the study of natural resources (water, energy, fertile soils) and their unequal distribution, students will approach the notions of production and consumption on a regional, then national, scale.

History will be utilized to demonstrate the evolution of lifestyles and their environmental consequences (for example, the impact of intensive agriculture on soil and water, or industrialization on the atmosphere). The study of impacts will be conducted without guilt-tripping, but by highlighting the mechanisms: the life cycle of objects, the notion of waste and recycling, energy sources and their effects. Local ecological transition initiatives can be studied, offering concrete avenues for action. Simple notions of environmental justice will be introduced, showing that impacts are not equally distributed.

Cycle 3, 6th grade: Earth, an interdependent global system The 6th grade will be the stage of systematization. Concepts of planetary scale will be introduced: the carbon cycle and greenhouse gases, tropical deforestation, ocean plastic pollution. The world map will become a privileged analytical tool to understand global flows (goods, populations, pollution) and interconnections. The challenges of the "tragedy of the commons" (Garrett Hardin, 1968) will be approached through simplified case studies (overfishing, deforestation of the Amazon). Concepts of ecosystem resilience and planetary boundaries (Rockström et al., 2009) can be outlined.

Emphasis will be placed on global citizenship and collective responsibility. The Universal Declaration of Human Rights, in connection with the rights of future generations, could serve as an ethical framework. Teacher Training and Educational Resources Such a deployment requires a significant overhaul of initial and continuing teacher training. Primary school teachers must be equipped with a solid scientific culture in ecology, ecological economics, and environmental humanities. A minimum 120-hour training (equivalent to 3 weeks) in continuing education, renewable every 5 years, must be implemented for all pedagogical staff concerned by the E&S module.

Educational resources must be abundant, varied, and constantly updated. This includes multidisciplinary textbooks, scientific experiment kits, simulation software, interactive case study databases, and partnerships with environmental education associations, research centers, and social and solidarity economy entrepreneurs. The State and local authorities will have to guarantee the provision of these resources, including access to study sites (natural parks, educational farms, sorting centers). The funding of specialized regional resource centers for ecological transition education appears indispensable.

Estimated Cost and Funding of Such an Educational Reform The cost of a reform of this magnitude is significant, but it must be understood as a strategic investment for the future of societies. A preliminary estimate would allow for the delimitation of its main items. The main cost lies in the initial and continuing training of teachers, estimated at one million primary and middle school teachers in France (figures from the Ministry of National Education 2022 for primary and secondary education combined, but only a portion of middle school teachers would be concerned by this module).

Considering continuous training of 120 hours at an average cost of €50/hour (including trainers, materials, teacher allowances), this represents a cost of €6,000 per teacher. For one million teachers, the initial training cost would be €6 billion. This sum would be amortized over several years (e.g., 5 years, or €1.2 billion per year), depending on the gradual deployment of the training. In addition, there would be the development and acquisition of new educational materials (textbooks, science kits, digital tools, subscriptions to databases).

If we estimate an average budget of €200 per student per year for these resources, and for 8 million primary and middle school students (2022 figures from the Ministry of National Education), the annual cost would be €1.6 billion. Add to this the creation of regional resource centers and the annual updating of training programs, estimated at €500 million per year. The total annual cost of deployment and operation, after the initial phase of teacher training, could therefore amount to around €2.1 billion for a country like France.

This figure, though substantial, must be put into perspective with the economic and social costs of ecological disasters, already estimated at hundreds of billions of euros annually for Europe (report by the European Environment Agency, EEA, 2020, estimating the cost of extreme weather events at €500 billion over the last 40 years for the EU). Funding could come from various sources: reallocation of existing budgets (for example, cessation of subsidies to obsolete industries), carbon or Pigouvian taxes on polluting activities, contributions from international organizations (UNESCO, UNEP), or mobilization of specific investment funds for education and ecological transition.

Citizen crowdfunding, in the form of educational green bonds, could also be considered to bring stakeholders together. The choice to invest massively in this systemic education is not just a budgetary matter, but a major political decision. It is about recognizing that education is the first line of defense against current and future crises, and an indispensable lever for the advent of a more resilient and just post-growth economy, as Nicholas Georgescu-Roegen already emphasized in his work on bio-physical economics (1971).

Chapter 56 Roadmap 100 Years (2026-2126) This chapter outlines a centennial roadmap aimed at the progressive integration of a new institutional terminological framework, a cornerstone for the re-foundation of human institutions by 2226. This deployment, spanning three distinct phases, would necessitate in-depth international coordination and voluntary adherence from states and supra-national organizations. The ultimate goal is to establish a common, precise, and depoliticized linguistic foundation to facilitate mutual understanding and cooperation in global governance. This process should be based on the principles of semantics and lexicometry to ensure the robustness of the system.

The development of a common lexicon could mitigate the interpretive tensions that frequently undermine the effectiveness of international treaties and resolutions. Linguistic ambiguities are indeed a constant source of disagreements, as demonstrated by analyses of international jurisprudence concerning terms such as "aggression" or "interference." An initiative of this magnitude would require unprecedented collaboration among linguists, jurists, philosophers, and representatives of the world's diverse cultures and legal systems.

Phase 1: Terminological Codification and Standardization (2026-2036) The first decade, from 2026 to 2036, would be dedicated to finalizing and standardizing a universal institutional lexicon. This work would begin with the establishment of an international expert group, bringing together specialists in linguistics, public international law, philosophy of language, and cognitive sciences, to define the fundamental concepts of global governance. The aim would be to overcome the pitfalls of literal translations, often a source of misinterpretations, by relying on rigorous conceptual analysis.

This initial phase would involve the creation of a dictionary of 5000 entries, each defined with exhaustive legal and semantic precision. The definitions would be developed to be unequivocally interpretable, regardless of the cultural or legal context of application. This dictionary should include key terms from international law, political science, global economics, and ethics applied to governance. The objective would be to prevent any polysemy likely to hinder transnational communication. Considerable effort would also be made to obtain ISO (International Organization for Standardization) certification for this lexicon and its associated dictionary.

Obtaining such a standard would attest to the scientific rigor and technical acceptance of this terminology on a global scale. Dedicated working groups, following the methodologies of ISO technical committees, would be established to ensure compliance with transparency and international consensus requirements. This formalization could confer technical authority on the lexicon and legitimize its use. Work on terminological standardization could draw inspiration from past efforts in linguistic harmonization in specific technical fields, such as aeronautics or medicine.

The organization of a transparent review and validation process, involving linguists from different cultural areas, would be essential to ensure the fairness of the definitions. Professor Georges Mounin, in his work *Les Problèmes théoriques de la traduction* (1963), highlighted the challenges related to semantic and cultural fidelity, aspects that should be at the heart of this phase. Lexicon Development Methodology The process of developing the 5000 entries would be based on a comparative and inductive method, examining the use of key terms in existing international treaties, resolutions of intergovernmental organizations, and national constitutions.

The contextual semantic approach, advocated by Eugenio Coseriu in his work on language theory (for example, *Leçons de linguistique générale*, 1982), would be applied to extract the most stable and least ambiguous meaning of each concept. Each definition would include discouraged synonyms and quasi-synonyms with an explanation of their nuanced differences. A secure collaborative platform would be established to allow experts from around the world to contribute to and debate proposed definitions. Weighted voting mechanisms could be considered to resolve disagreements, while ensuring a balanced representation of diverse geopolitical and linguistic perspectives.

The aim is not to eradicate linguistic diversity, but to provide a precise communication tool for institutional affairs, as theorized by Jean-Pierre van Deth in *Le Lexique. Initiation à la lexicologie* (1996), by distinguishing common language from specialized language. Phase 2: Pilot Educational Programs (2036-2076) The second phase, spanning forty years (2036-2076), would see the deployment of pilot programs for teaching this lexicon within the school system. Ten volunteer countries, representative of different geographical and cultural areas of the world, would be invited to integrate this terminology into their educational curricula, starting from secondary education.

The objective would be to familiarize future generations with this standardized institutional language before their entry into adult and professional life. These pilot programs would involve training teachers in new pedagogical methods adapted to teaching a specialized lexicon. Specific didactic materials would be developed, including textbooks, exercises, and interactive digital tools. Learning would not be passive but anchored in concrete case studies of international law and conflict resolution, in order to demonstrate the practical relevance of this precise language.

Noam Chomsky's work on universal grammar (*Aspects of the Theory of Syntax*, 1965) could serve as a reflexive framework for the acquisition of linguistic structures. The evaluation of these pilots would be continuous and rigorous. Performance indicators would measure not only the acquisition of the lexicon by students but also the impact of this learning on their ability to understand and analyze complex global issues. Adjustments would be regularly made to programs and pedagogical materials based on feedback from participating countries. This phase could benefit from UNESCO's expertise in curriculum development and international educational standards.

Participating educational systems should implement specific modules, perhaps as part of civic education or history-geography, to teach the 5000 entries of the dictionary. The pedagogical approach would be based on conceptual understanding rather than rote memorization, encouraging students to analyze real documents (treaties, resolutions) using the standardized lexicon. Jean Piaget's work on the cognitive development of the child (*The Construction of Reality in the Child*, 1937) could guide the development of teaching sequences adapted to different ages.

Support for Pilot Countries An international support fund would be established to provide financial and technical assistance to the ten pilot countries. This fund would cover the costs of teacher training, development of educational resources, and program evaluation. Academic and professional exchanges would be encouraged among participating countries to share best practices and resolve common challenges. This investment in education is crucial to ensure the sustainability of the project. The selection of pilot countries should be based on criteria of linguistic, cultural, and educational system diversity, in order to validate the universality of the approach.

Countries from different regions of the UN would be invited to apply. Voluntary adherence and political commitment from governments would be fundamental prerequisites for the success of this phase, as highlighted by the United Nations 2030 Agenda for Sustainable Development, which emphasizes the need for multilateral cooperation for long-term goals. Phase 3: Generalized Institutional Bilingualism (2076-2126) The final phase, from 2076 to 2126, would aim at the institutionalization of bilingualism within international bodies.

This process would involve the progressive adoption of the standardized lexicon as a complementary working language within the United Nations and its specialized agencies. This would not be about replacing existing working languages, but about introducing a universal language of precision for official documents and negotiations. This measure would imply that all key documents – resolutions, treaties, reports – be drafted or translated systematically using the standardized dictionary's terminology, in parallel with official languages.

Personnel of international organizations would need to be trained in the use of this lexicon, and specialized teams of terminologists would be integrated to ensure the consistency and precision of texts. The jurisprudence of the International Court of Justice, often faced with problems of contextual interpretation of terms, could greatly benefit from this standardization. The objective of this generalization would be to reduce the margin of interpretation and ambiguities in diplomatic exchanges and multilateral decisions.

By creating a common linguistic ground, negotiations would be facilitated and the risks of misunderstanding minimized, thereby increasing the effectiveness of international action. Sociologist and linguist Pierre Bourdieu, in *Ce que parler veut dire* (1982), highlighted the power of words and the necessity of mastering language for full participation in the social field. Continuous training programs would be implemented for all international civil servants, diplomats, and experts working with the concerned institutions. Certificates of linguistic competence for the standardized lexicon could be introduced, reinforcing the incentive for adopting this new standard.

The European Union's experience with its multiple official languages and its terminology efforts for community law (see European Commission Directorate-General for Translation) could offer valuable lessons in complex language management. Legal and Political Framework An international instrument, potentially a convention or a framework treaty, could be developed to formalize the adoption of institutional bilingualism. This instrument would define the modalities for integrating the standardized lexicon, the obligations of signatory states, and the mechanisms for monitoring and revision.

The participation of UN member states in the elaboration of this framework would be paramount to ensuring its acceptance and legitimacy. The year 2126 would mark the completion of this integration, with the institutional lexicon becoming an indispensable reference in all decision-making and communication processes of international organizations. The long-term impact would be a significant increase in the transparency, fairness, and effectiveness of global governance. This language of precision could become a catalyst for greater coherence and better application of international law, thus contributing to global stability and peace.

Ludwig Wittgenstein's reflection on language as a tool (*Philosophical Investigations*, posthumous publication 1953) underscores the importance of its clarity to avoid confusion. Part VI — Phases of Deployment (2026 → 2226) Chapter 57 Phase 1 (2026-2036) — Crystallization CHAPTER 57 — Phase 1 (2026-2036) — Crystallization The first phase of institutional refoundation, potentially extending from 2026 to 2036, would focus on crystallizing fundamental principles within a core group of pioneer states. This would not be an immediate universal transformation, but rather a deliberate and voluntary experiment.

This initial decade would seek to demonstrate the viability of new institutional architectures and establish a precedent for progressive adoption. The primary objective of this period would be to legally and practically anchor the initial structures intended for anticipatory and global governance. States embarking on this path would do so out of conviction or recognition of a comparative advantage in adopting more resilient mechanisms in the face of systemic challenges.

The emphasis would be on transparency, institutional innovation, and the implementation of augmented decision-making tools. 57.1 Adoption by Pioneer States and Ratification of a Framework Pact During this first decade, it is envisioned that between five and ten states would voluntarily decide to adopt the principles of refoundation. This approach could be supported by a growing recognition of the limitations of current governance models in managing complex and interconnected crises, as highlighted by the United Nations Secretary-General's report, *Our Common Agenda*, in 2021, which called for a "stronger and more agile multilateralism" (United Nations, 2021).

These pioneer states would formally commit through the ratification of a "Framework Pact for Anticipatory and Sustainable Governance" or a similar instrument endowed with supra-legislative value. This pact would establish the ethical and legal foundations of the undertaking, inspired by concepts such as the notion of "duties to future generations," already explored by philosophers like Hans Jonas (Jonas, 1979). It would define the minimum obligations of signatory states regarding data sharing, protection of common goods, and consideration of long-term impacts.

The drafting of this pact could draw upon existing work in international environmental or human rights law, expanding them to explicitly include the temporal dimension and systemic interdependence.

Articles such as that by J. B. Opsahl on the need to protect the environment as a fundamental human right, written in 1982, could serve as a basis for extending intergenerational responsibilities (Opsahl, 1982). 57.1.1 Structuring Principles of the Framework Pact The Framework Pact should articulate principles such as augmented subsidiarity, ubiquitous transparency of relevant public data, and the anticipatory imperative.

It would emphasize the primacy of ecological and social system stability over short-term national interests, an idea echoed in international jurisprudence recognizing the existence of *erga omnes* obligations (International Court of Justice, Barcelona Traction, Light and Power Company, Limited Case, 1970). It would be essential for this pact to include revision and adaptation mechanisms to ensure its relevance in the face of evolving knowledge and challenges. Authors like David Kennedy have highlighted the need for flexible legal systems to address complex and changing problems (Kennedy, 2006).

The pact could envision a quorum for its modification and the integration of new scientific discoveries as sources of amendment. 57.2 Creation of Key Agencies: Global Cognitive and Resource Trust The first decade would also see the establishment of the two operational pillars of this new architecture: the Global Cognitive Agency (GCA) and the Global Strategic Resources Trust (GSRT). These agencies would operate under a logic of global public service, detached from national partisan imperatives.

The Global Cognitive Agency (GCA) would have as its primary mission to collect, aggregate, and analyze global data from multiple sources (scientific, economic, social, environmental) to generate foresight models and early warnings. Its role would be to "map" the state and evolution of complex systems, in the manner of the Intergovernmental Panel on Climate Change (IPCC) for climate (IPCC, 2023), but with a much broader and more integrative mandate.

The Global Strategic Resources Trust (GSRT) would be designed as an independent entity responsible for the sustainable and equitable management of critical resources, whether material (rare minerals, fresh water, arable land) or immaterial (electromagnetic spectrum, genomic data). Its mandate would derive from the principle that certain resources are public goods of humanity, the management of which cannot be left solely to market dynamics or short-term national interests, an idea developed by Elinor Ostrom (Ostrom, 1990). 57.2.1 Operation of the Agencies The GCA would rely on networks of multidisciplinary experts and cutting-edge technological infrastructures for big data processing.

Its governance should be designed to guarantee its scientific independence and credibility, potentially by inspiring proven multilateral governance models but also by integrating principles of non-state governance, as discussed by some researchers in international relations (Rosenau, 1990). The GSRT, for its part, could be endowed with legal capacities to acquire, manage, and protect these resources, by coordinating international efforts and developing sustainability standards. Its legitimacy would be based on the Framework Pact and on bilateral or multilateral agreements with states possessing these resources on their territory.

The notion of "trust" in Anglo-Saxon law could serve as inspiration for its legal framework, allowing for management for the benefit of future and indeterminate beneficiaries. 57.3 Open Data Indicators A fundamental element of this first phase would be the establishment of a robust system of publicly accessible indicators in open data, covering a wide range of domains. This "open data" would be the cornerstone of transparency and informed decision-making. They would include environmental, social, economic, technological, and well-being data, all standardized to allow for comparisons and cross-analyses.

The open publication of indicators would enable citizen and expert oversight of the effectiveness of public policies and the state of systems.

Existing initiatives such as the United Nations Sustainable Development Goals (SDGs), with their associated indicators (United Nations, 2015), would provide an initial model, which the new system should surpass in terms of granularity, update frequency, and accessibility. This data should directly feed the Global Cognitive Agency (GCA), but also be accessible to all citizens and organizations through intuitive interfaces and open APIs (Application Programming Interfaces).

The underlying philosophy would be inspired by movements for open government and open science, as advocated by researchers in the field of digital governance (Bekkers and Homburg, 2007). 57.4 First Pilot Future Chambers Finally, this inaugural decade should see the establishment of the First Pilot Future Chambers (pFCs) in the pioneer states. These institutions, designed as bodies dedicated to foresight and the defense of long-term interests, should operate on the basis of delimited mandates and experimental modalities.

The pFCs could be integrated into existing parliamentary structures, or established as consultative or semi-legislative bodies, endowed with the capacity to evaluate legislative proposals from the perspective of their impacts over 30 to 100 years. Their composition should be multidisciplinary, including scientists, ethicists, economists, jurists, and representatives of civil society, to ensure a holistic vision.

The experience of Future Parliaments or Delegates of Future Generations already existing in some countries (for example, the Future Generations Commissioner for Wales (Future Generations Commissioner for Wales, 2023)) would serve as a starting point, but the pFCs would go further in their authority and method, by integrating the analyses and projections of the Global Cognitive Agency. 57.4.1 Mandates and Methodologies of the pFCs The initial mandates of the pFCs could focus on critical areas such as climate change, biodiversity, water management, and the impacts of emerging technologies.

Their methodologies would involve the intensive use of prospective modeling, scenario analysis, and technology assessment, relying on open data and the analytical capabilities of the GCA. These chambers could also be the venue for in-depth citizen deliberations on long-term issues, in order to anchor their recommendations in increased democratic legitimacy. Drawing inspiration from the experiences of citizen juries or citizen climate conventions (for example, the Citizen's Convention for Climate in France, 2020), they would seek to integrate the aspirations and concerns of different strata of the population into their reports and opinions.

The success of this crystallization phase would depend on the ability of these initial states to concretely demonstrate the benefits of the new institutional approaches. It would be a matter of proving that anticipatory and collaborative governance can generate more resilient, just, and sustainable societies, thereby establishing an attractive model for subsequent phases of expansion. --- **References:** ■ Bekkers, V., & Homburg, V. (2007). *The Handbook of Public Information Systems*. CRC Press. ■ Cour internationale de Justice. (1970). Affaire de la Barcelona Traction, Light and Power Company, Limited (Belgique c.

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Chapter 58 Phase 2 (2036-2056) — Convergence CHAPTER 58 — Phase 2 (2036-2056) — Convergence The second phase of institutional refoundation, envisioned between 2036 and 2056, should be characterized by a dynamic of increased convergence, both in terms of participants and regulatory instruments. The progressive expansion of the initial base of entities, the standardization of accounting and fiscal practices, the experimentation with universal social protection mechanisms, and the introduction of a new monetary approach for essential resources constitute the pillars of this strategic period.

These developments are part of a logic of consolidation and standardization, preparing the ground for deeper integration as outlined by Jürgen Habermas's work on deliberative politics (Habermas, J., *Droit et Démocratie: Entre faits et normes*, 1997). This period would require particular vigilance regarding the preservation of legitimate sovereignties and particularisms, while encouraging voluntary adherence to the principles and benefits of the emerging institutional architecture. The search for a balance between systemic efficiency and respect for cultural and political diversity would be paramount.

Amartya Sen's work on capabilities and social justice, though earlier, would provide a relevant ethical framework to support this integration phase (Sen, A., *L'idée de justice*, 2009). Expansion of associated entities and standardization of indicators The 2036-2056 horizon would witness a significant expansion in the number of national and bioregional entities wishing to integrate, reaching a range of 30 to 50 states. This expansion would involve a voluntary adhesion process, subject to compliance with predefined criteria of governance, transparency, and commitment to the environmental and social objectives of the nascent supranational organization.

The development of a legal framework for adhesion, inspired by European integration treaties but adapted to a global scope, would be a priority. To facilitate this integration and ensure consistent management of resources and policies, the standardization of the accounting for "Carbon and Environmental Equilibrium Units" (CEU) could be implemented. This standardization, developed from the principles of socio-environmental accounting as described by the RSE Institute and the work of Jacques Richard on environmental accounting (Richard, J., *Comptabilité environnementale*, 2012), would allow for a comparative and transparent evaluation of the ecological impacts of each entity.

This would involve developing a common accounting framework, validated by an independent scientific committee, that would integrate greenhouse gas emissions, natural resource consumption, waste production, and biodiversity preservation. Harmonization of Standards The harmonization of accounting and environmental standards would be crucial to ensure the fairness and relevance of established redistribution and compensation mechanisms. This would require intense international cooperation and the adoption of revisited ISO standards for the circular economy and ecological footprint.

Research by the European Environment Agency on sustainability indicators would serve as a basis for this standardization phase (European Environment Agency, *EEA briefing*, various issues before 2026). The transparency resulting from this standardization would be a key factor of trust and legitimacy for the new governing structures. It would also allow for the identification of best practices and stimulate innovation in sustainable development. IPCC assessment reports, by providing a rigorous scientific basis on the state of the environment, would remain an indispensable reference for adjusting indicators (Intergovernmental Panel on Climate Change, successive Assessment Reports).

Pilot Vital Budgets in Bioregions During this convergence phase, it would be envisioned to launch pilot "vital budget" programs in at least five distinct bioregions. These vital budgets would represent a minimum allocation of resources guaranteeing access to fundamental needs (healthy food, drinking water, decent housing, energy, healthcare, and education) for each individual within the bioregional area concerned. The idea is to go beyond the concept of universal income to encompass the direct satisfaction of essential needs, through a combination of monetary transfers and accessible public services.

These experiments would aim to evaluate the feasibility, effectiveness, and socioeconomic impact of such universal social protection mechanisms at the bioregional scale. Bioregions, defined by their specific ecological and cultural characteristics and not by arbitrary state borders, would offer an ideal framework for testing approaches adapted to local contexts. Prior studies on unconditional basic income, such as those conducted in Finland and Canada, could provide valuable lessons for the design of these pilots (Revelli, C., *Un revenu sans condition*, 2018).

Funding and Governance Mechanisms The funding for these pilot vital budgets would come from a combination of contributions from partner states, harmonized taxes on activities with a high ecological footprint, and, potentially, a share of the income generated by the future energy-currency. The governance of these programs would be collegiate, involving representatives of bioregional populations, scientific experts, and delegations from participating state entities. The Earth Charter, an international document of ethical principles for a just, sustainable, and peaceful world (Earth Charter, 2000), could serve as a moral guide for the implementation of these budgets.

The long-term objective would be to generalize this vital budget approach, or an equivalent mechanism, to all integrated territories, based on feedback from the pilots. This would require constant adjustments and an ability to adapt to local specificities. The work of the Convention on Biological Diversity (Convention on Biological Diversity, 1992) should guide the delimitation of bioregions and the consideration of their specific vulnerabilities. Energy-Currency for Critical Transactions A major innovation of this phase would be the introduction of an "energy-currency" dedicated to transactions involving critical energy resources.

This would not be a substitute currency for existing national or supranational currencies, but a unit of account and exchange specifically designed for the management of essential energy flows, such as renewable electricity, green hydrogen, or verified carbon credits. This energy-currency could be pegged to a physical unit of energy production, such as a kilowatthour produced from renewable sources, or to a unit of carbon emission reduction. This currency would aim to stabilize the cost of fundamental energy resources, remove them from speculation in classical financial markets, and guarantee equitable access for all participating entities.

Its issuance and regulation would be entrusted to an Independent Energy Monetary Authority, whose primary mandate would be to ensure energy security and the transition to decarbonized energy sources. Bernard Lietaer's proposals on complementary currencies and specific-purpose currencies could inspire the design of this system (Lietaer, B., *L'argent autrement*, 2001). Technological and Legal Framework From a technological standpoint, the architecture of this energy-currency could rely on distributed ledger technology (private or consortium blockchain), offering transparency and security for transaction recording.

An international legal framework would be necessary to define its status, exchange modalities, and sanctions in case of circumvention. This framework should also provide for coordination mechanisms with the monetary policies of the party states. The implementation of the energy-currency would potentially lead to a profound transformation of energy markets, orienting them towards sustainability and resilience objectives rather than pure profit. It could also encourage states to invest more in renewable energy infrastructure.

Jeremy Rifkin's work on the third industrial revolution and the Internet of Energy would provide a useful conceptual background (Rifkin, J., *La Troisième Révolution industrielle*, 2011). The ambition would be to create a system where energy is recognized as an essential common good, beyond its market value. Chapter 59 Phase 3 (2056-2086) — Generalization CHAPTER 59 — Phase 3 (2056-2086) — Generalization The third phase of institutional refoundation, envisioned between 2056 and 2086, would mark a period of widespread implementation of reforms initiated and experimented with during previous phases.

The main objective would be the systemic integration of innovative institutional principles and artifacts within the global architecture, particularly in close articulation with a reformed United Nations (UN). This period should facilitate the consolidation of achievements and the dissemination of successful models to all member states, or to a very large majority of them. This phase would involve a strong dimension of harmonization and standardization, not through imposition but through the progressive adoption of common legal and operational frameworks.

The experience of national and regional reforms would serve as a laboratory for the development of international standards, thereby facilitating the interoperability of institutional systems. The focus would be on pooling best practices and strengthening collective capacities to respond to global challenges. Articulation with a reformed UN One of the cornerstones of this phase would be the organic articulation of new institutions with a profoundly reformed United Nations Organization.

Discussions initiated as early as the 2010s on the necessary reform of the Security Council and the expansion of its permanent members, as highlighted by numerous reports (for example, the Report of the High-Level Panel on Threats, Challenges and Change – "A More Secure World: Our Shared Responsibility", 2004), could finally come to fruition. A modernized UN would be more representative and more effective in its ability to arbitrate conflicts and promote cooperation. It is envisioned that emerging structures, such as the Chambers for Future Generations, could find a formalized consultative place within UN bodies, thus complementing existing decision-making processes.

This integration could take the form of ad hoc committees or permanent observer statuses, allowing long-term perspectives to influence the debates and resolutions of international bodies. The objective would be to embed the notion of intergenerational responsibility at the heart of global governance. The development of international dispute resolution mechanisms, based on principles of restorative and prospective justice, should also enrich the role of the UN. These mechanisms could complement the work of the International Court of Justice (ICJ) by addressing new issues, such as disputes related to the rights of future generations or the unsustainable use of global commons.

The jurisprudence of international tribunals would thus evolve to integrate these new dimensions. Mundia as a secondary working language at the UN The progressive adoption of Mundia as a secondary working language within the United Nations Organization would constitute a significant marker of this phase. Rather than replacing the six existing official languages (English, Arabic, Chinese, Spanish, French, Russian), Mundia would serve as a lingua franca facilitating communication and understanding between delegations from various linguistic backgrounds. This approach would be part of a logic of facilitation rather than substitution.

The introduction of Mundia would respond to a desire to reduce language barriers and promote better inclusion of states with fewer resources for simultaneous translation into all official languages. Similar initiatives have been explored in the past for regional vehicular languages, such as Swahili for the African Union. Deployment would occur gradually, with training for delegates and the availability of key documents in this language. This process should build on the dissemination and standardization of the Mundia language initiated during previous phases, where it would have been adopted by a growing number of educational institutions and international exchange platforms.

Adoption by the UN could grant Mundia increased legitimacy and accelerate its generalization as a tool for intercultural and inter-institutional communication, in accordance with the ideal of universal communication as explored by thinkers like Ludwig Wittgenstein in his *Tractatus Logico-Philosophicus* (1921). Evolving Constitution adopted by 75% of Member States The adoption of an "evolving Constitution" by 75% of member states would be an ambitious objective of this phase. This constitution would not be a monolithic text but a shared normative framework, recognizing common fundamental principles and integrating mechanisms for continuous adaptation and revision.

"Global constitutionalism" as theorized by authors such as Jan Klabbers (*Treaty Conflict and the European Union*, 2004) would serve as a reference for this architecture. This common framework would include clauses recognizing the rights of future generations, duties towards the biosphere, and principles of polycentric governance. Each member state could then adapt this framework to its specific legal and cultural characteristics, through implementing laws or amendments to its own national constitution. The idea would be to reconcile national sovereignty and global responsibility.

The principle of an "evolving" constitution would mean that its hard core could be amended by consensual supranational mechanisms, guaranteeing its relevance in the face of emerging challenges. These mechanisms could draw inspiration from the complex amendment procedures of major international treaties, requiring qualified majorities and wide ratification. The jurisprudence of the International Court of Justice and other regional tribunals could also guide the interpretation and evolution of these texts.

Generalized Chamber for Future Generations The generalization of the Chamber for Future Generations would constitute a major advance, integrated into a substantial number of national and supranational legislative bodies. After a period of experimentation and evaluation in the preceding phases, positive feedback, particularly in terms of accounting for long-term externalities in decision-making processes, would lead to its widespread adoption. Preliminary initiatives, such as the Committee for Sustainable Development in Finland or the *Well-being of Future Generations Act* (2015) in Wales, would have demonstrated the feasibility of such mechanisms.

These chambers, whether consultative or endowed with a suspensive veto power over certain matters (environment, fundamental research, management of non-renewable resources), would have the mandate to assess the impact of policies and legislation over one hundred, two hundred years, or even more. Their composition could vary, integrating scientific experts, philosophers, civil society representatives, and randomly selected citizens, thus ensuring a diversity of perspectives. The funding and status of these chambers would be secured by robust institutional mechanisms, guaranteeing their independence and capacity for action.

Impact assessment methodologies would be standardized, relying on sophisticated prospective models and multi-criteria analyses. The information they produce would become an indispensable element of global legislative and regulatory processes, as already advocated by the Brundtland Report (*Our Common Future*, 1987) in highlighting the importance of integrating the long term into political decisions.

David Mosbeux Nice, May 16, 2026 Chapter 60 Phase 4 (2086-2126) — Maturation The Integration of Multigenerational Provisions The fourth phase of institutional refoundation, extending from 2086 to 2126, should be characterized by the maturation of established structures and the deep integration of principles of sustainability and intergenerational equity. One of the major conceivable advancements during this period would be the widespread deployment of multigenerational provisions, aimed at covering a substantial portion of anticipated future damages.

These provisions would no longer be mere financial reserves, but proactive institutional mechanisms integrated into global legal and economic systems. This would involve establishing autonomous trust funds, endowed with clear mandates and predefined allocation rules, to anticipate and remedy environmental, social, or technological harms. The notion of "future damage" should be precisely circumscribed, drawing upon works on environmental civil liability (Lucas, 1992) and reflections on future generations (Tremmel, 2006). The objective would be to achieve approximately 90% coverage of statistically predictable damages, which would require an unprecedented capacity for modeling and projection.

These mechanisms could take the form of "dots" (mandatory temporal endowments) or "futures trusts," funded by proportional levies on high-impact economic activities or contributions based on criteria of negative externalities (Pigou, 1920). Their management should be entrusted to independent entities, under the supervision of an Intergenerational Court of Justice, whose establishment would have been initiated during the previous phase (Tremmel, 2011). The international legal framework for these mechanisms should draw upon a reinterpretation of the notion of the common heritage of humanity, extending it to future interests.

The modalities for activating these provisions should be triggered by objective and verifiable indicators, developed by international scientific bodies. For example, the attainment of certain thresholds of ecological degradation or the emergence of systemic risks linked to uncontrolled technological innovations. The focus would be on prevention and preemptive reparation, rather than on late reaction to proven disasters, echoing the precautionary principle inherited from Jonas (1979).

The Universal Vital Budget: Universalization and Differentiation The maturation of institutional refoundation could also be marked by the universalization and refinement of the concept of the Universal Vital Budget (UVB). Previously conceived as a fundamental right to existence and dignity, the UVB should expand during this period to cover all essential needs, broadly defined to include access to information, continuous training, and civic participation. It would no longer be merely a subsistence aid, but a lever for autonomy and personal development. The implementation of the UVB, initially piloted regionally, should become a global norm.

This would entail the creation of complex financing and redistribution mechanisms, managed by supranational institutions in close collaboration with regional entities. Global taxation, progressively harmonized, could constitute a major source of funding, alongside contributions based on the added value of automated systems (Piketty, 2013). A differentiation of the UVB by geographical areas and socio-economic contexts would likely be necessary, without, however, questioning its universal character. The allocated amounts could vary to account for the cost of living and cultural specificities, but an absolute minimum threshold could be guaranteed everywhere.

Amartya Sen's work on capabilities (1999) could serve as a theoretical basis for defining these essential needs in a flexible and adapted manner, enabling each individual to fully realize their potential. The management of the UVB would be depoliticized as much as possible, transitioning from national administration to global and transparent steering. Allocation algorithms, based on aggregated and anonymized data, could optimize resource distribution, reducing biases and ensuring maximum equity. Citizen oversight and recourse mechanisms would be integrated to ensure system accountability and responsiveness.

The objective would be to guard against the pitfalls of traditional social welfare systems by guaranteeing fundamental economic stability for all. From Individual to Collective Management of the UVB For certain categories of collective expenditures related to vital needs (renewable energy, access to drinking water, communication infrastructure), a collective management of the UVB could be envisaged. Rather than distributing the entire budget to the individual, a significant fraction could be pooled at the level of relevant-sized communities, tasked with investing in common goods and services benefiting all their members.

We could draw inspiration from Elinor Ostrom's work on the governance of common-pool resources (1990) to design these management structures. These collective management centers could be locally elected and subject to strict transparency and accountability rules. This model could foster social cohesion and citizen participation in decisions concerning the development of their living environment. The aim would be to strike a balance between the individual autonomy offered by the UVB and the advantages of collective action for optimized expenditures and improved community resilience.

The Mundia Language as a Biliterate Mother Tongue The maturation phase could also see the culmination of the Mundia project as a mother tongue for the first generations of biliterates. Having been introduced as a mandatory second language globally during the previous phase, Mundia should gradually be integrated from early childhood. The objective would not be to supplant existing mother tongues, but to provide a universal second mother tongue, thereby creating an unparalleled basis for communication and mutual understanding. This integration would imply a profound reform of global educational systems.

Curricula would be redesigned to teach Mundia from early childhood, in parallel with the dominant local language. Research in neurolinguistics (Pinker, 1994) and bilingual education (Cummins, 2000) would be pillars for the development of adapted pedagogies, aiming to maximize the acquisition and mastery of Mundia without harming the development of the cultural mother tongue. Generations born from 2086 onwards could be the first to grow up with Mundia as a secondary mother tongue, developing natural linguistic bicompetence. This would have profound implications for conflict resolution, scientific cooperation, and intercultural understanding.

The historical experience of Esperanto, despite its limitations (Okrent, 2009), could offer valuable lessons on the challenges of a constructed language, but the approach would be fundamentally different due to its institutional and integrated nature. The dissemination of Mundia should not be limited to formal educational systems. Media, digital communication platforms, and work environments could gradually adopt Mundia as the reference language for international interactions, strengthening its omnipresence and facilitating continuous learning through immersion (Krashen, 1985).

The ultimate goal would be to create a global citizenry equipped with a common linguistic tool, capable of dialogue beyond traditional linguistic borders while preserving the richness of local linguistic diversity. From Intercomprehension to Interconceptualization The impact of Mundia as a second mother tongue would not only be practical, facilitating communication. It could also foster a form of "interconceptualization." The vocabulary and structure of Mundia would, by design, be more neutral and universal than those of natural languages, which often carry thought patterns specific to their cultures of origin (Whorf, 1956).

This could, in time, pave the way for more universal modes of thought, less subject to cultural biases, particularly in scientific, legal, and ethical domains. The ability to think and conceptualize global problems through a common linguistic prism could be a major asset for resolving complex challenges. Works in analytical philosophy of language (Wittgenstein, 1953) highlight the importance of language in structuring thought. Thus, a language designed for universality could potentially facilitate the emergence of universal solutions, while respecting the diversity of local applications. David Mosbeux, May 16, 2026.

Chapter 61 Phase 5 (2126-2176) — Stabilization The stabilization phase, envisioned between 2126 and 2176, would mark a crucial period where institutional refoundation efforts would begin to produce tangible and measurable effects in terms of ecological balance and human well-being. This stage would not constitute an end goal, but rather the consolidation of normative and operational frameworks established during previous phases, in order to guarantee a sustainable trajectory for human societies. The primary objective would be to perpetuate achievements and deepen the integration of principles of ecological regeneration and intergenerational justice at the heart of governance systems.

The optimization of global and local regulatory mechanisms would become central. Institutional performance indicators would be intrinsically linked to detailed environmental and social metrics, far exceeding traditional Gross Domestic Product (GDP). This period would see the refinement of polycentric governance tools and an emphasis on subsidiarity in decision-making. Refoundation of Metrics for Progress and Prosperity One of the most significant developments of this phase would lie in the definitive establishment of a paradigm of prosperity decoupled from unlimited material growth.

Attempts [redacted]ed as early as the 1970s with the work of the Club of Rome, particularly through the report "The Limits to Growth" (Meadows et al., 1972), would have finally found their full institutional implementation. Human well-being would no longer be measured by resource consumption, but by the satisfaction of basic needs, access to opportunities for personal and collective fulfillment, and the resilience of ecosystems. Integrated accounting frameworks, which would include natural and social capital in national and supranational balance sheets, would be fully operational.

These systems would allow for the holistic evaluation of the impact of public policies on all dimensions of life, in accordance with Herman Daly's pioneering work on the steady-state economy (Daly, 1996) or Kate Raworth's "Donut Economics" concept (Raworth, 2017). Policy evaluation would no longer be limited to monetary cost-benefit analysis, but would systematically integrate ecological and social externalities. Consolidation of Planetary Boundaries and Regeneration The stabilization envisioned during this Phase 5 would imply a measurable return within six to nine of the nine identified planetary boundaries, according to the classifications proposed by Rockström et al. (2009).

This result would be the fruit of decades of coordinated efforts, binding ecological policies, and sustained technological innovations. The restoration of biogeochemical cycles, the preservation of biodiversity, and climate stabilization would constitute priority and quantifiable objectives for institutions. Governance mechanisms would be endowed with robust intervention and regulation powers to ensure the non-exceedance of critical thresholds. This could involve revised and corrected emissions and resource extraction permit systems, massive investments in ecological regeneration infrastructures, and high-resolution environmental monitoring.

Environmental law, now integrated into state constitutions and international treaties, would serve as the foundation for these actions. Polycentric Governance and Demographic Resilience The stabilization of the world population, a central point of this phase, would be the result of improved living conditions, access to education, healthcare, and universal family planning, in line with demographic transition forecasts linked to human development (Lutz et al., 2014). This stabilization would not result from coercive policies, but from informed choices in societies where the dignity and rights of every individual would be fully respected.

Polycentric governance structures, developed in previous phases, would demonstrate their full effectiveness. The example of Elinor Ostrom's work on the governance of common-pool resources (Ostrom, 1990) would have inspired adaptive and participatory natural resource management models, where local communities and regional actors would play a preponderant role, in synergy with national and supranational bodies. This approach would allow for better resilience to residual ecological and social shocks.

Equitable Redistribution and Well-being Diverging from GDP The upward divergence of well-being indicators from historical GDP would mean that wealth would no longer be synonymous with material accumulation, but with quality of life. Universal access to high-quality public services – education, health, culture, decent housing, green spaces – would be guaranteed, drastically reducing inequalities and improving social cohesion. Fiscal policies would become powerful tools for redistribution and financing these essential services.

Unconditional basic income, or similar universal social protection systems, would likely be generalized, ensuring every citizen a subsistence base and the opportunity to engage in activities with high social or environmental value. The circular economy, repair, and sharing would be preeminent, relegating rampant consumption to the rank of historical anachronism. Tim Jackson's work on prosperity without growth (Jackson, 2009) would offer a relevant conceptual framework for evaluating these dynamics. Institutions of Foresight and Adaptability In order to maintain the stabilization trajectory and prevent new crises, institutions would be deeply reoriented towards foresight and adaptability.

Permanent ecological, social, and technological monitoring mechanisms would be put in place, feeding agile decision-making processes based on the most advanced scientific expertise. The precautionary principle, as defined in international law, would be applied rigorously and systematically. Educational systems would be designed to cultivate critical thinking, intercultural collaboration, and systemic understanding of issues. Lifelong learning would become the norm, enabling citizens to adapt to rapid world changes and actively participate in renewed democratic processes. Donella Meadows' "systems thinking" (Meadows, 2008) would be integrated into educational curricula from the earliest age.

Strengthening Intergenerational Justice and Constitutional Ecology Intergenerational justice would be established as a fundamental principle of the entire legal system. National constitutions and supranational texts would grant explicit rights to future generations and establish clear duties regarding environmental protection and prudent resource management. Dedicated institutions, such as ombudsmen for future generations or specialized constitutional courts, could ensure the application of these principles. Institutional engineering would focus on the sustainability of structures.

Decision-makers' mandates would potentially be longer, with performance evaluations based on long-term objectives, transcending traditional electoral cycles. The "commons governance" model (Bollier & Helfrich, 2012) would serve as a reference for many mechanisms, ensuring collective and responsible management of resources essential for the survival and well-being of all. Evolution of Identities and Living Together The stabilization phase would also see a profound transformation of collective and individual identities, far from the destructive nationalisms or identity fragmentations that may have marked previous periods.

A global citizenship, based on awareness of ecological and social interdependence, could emerge and strengthen. Residual conflicts would be managed by robust and peaceful dispute resolution mechanisms, anchored in international law and mediation. The recognition of cultural and biological diversity would be celebrated as an invaluable asset. Indigenous peoples, whose traditional knowledge has often anticipated sustainability principles, would see their rights and contributions fully integrated into collective decision-making processes.

Institutions would actively seek to decenter perspectives and incorporate a plurality of worldviews to build a more resilient and equitable common future. ■ References: ■ Bollier, D., & Helfrich, S. (2012). *The Wealth of the Commons: A World Beyond Market and State*. Levellers Press. ■ Daly, H. E. (1996). *Beyond Growth: The Economics of Sustainable Development*. Beacon Press. ■ Jackson, T. (2009). *Prosperity Without Growth: Economics for a Finite Planet*. Earthscan. ■ Lutz, W., Butz, W. P., & Samir, K. C. (Eds.). (2014). *World Population and Human Capital in the Twenty-First Century*. Oxford University Press. ■ Meadows, D. H., Meadows, D. L., Randers, J., & Behrens III, W.

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Chapter 62 Phase 6 (2176-2226) — Consolidation: Retrospective Evaluation and Adjustment of Institutional Frameworks The Consolidation phase, spanning from 2176 to 2226, is intended to be a crucial period for an in-depth retrospective evaluation of the reimagined institutions. This juncture, marking two centuries since the initial transformative initiatives, would offer a sufficiently broad historical perspective to analyze the relevance and resilience of the implemented systems. The primary objective would be to confront institutional architectures with the socio-ecological and technological realities of the era, in order to identify the necessary vectors for adaptation.

This step would involve mobilizing complex evaluation methodologies, integrating quantitative and qualitative analyses from multiple disciplines. Performance indicators initially defined during the preparatory phases, particularly those concerning resource distribution, planetary citizen participation, ecological stability, and the reduction of inequalities, would be prioritized. The aim would be to measure the gap between prescribed objectives and effective achievements, thus allowing for dynamic adjustment of protocols. Evaluations should not only focus on the effectiveness of existing institutions but also on their capacity to anticipate and integrate future developments.

As Elinor Ostrom highlighted regarding the governance of common-pool resources, the persistence of institutional arrangements depends on their adaptability to environmental and social changes (Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge University Press). Institutional rigidity would be discouraged to maintain the legitimacy of structures. Protocol Revision Based on T+200 Indicators The revision of the institutional protocol based on the T+200 indicators would necessitate a comparative study of different approaches adopted at the macro-regional level or in experimental autonomy zones.

This would allow for the identification of best practices and pitfalls to avoid. The analysis would not be limited to raw results, but would also focus on the decision-making processes and conflict resolution mechanisms that would have been in place. The envisioned "T+200 indicators" would cover a broad spectrum, extending beyond mere economic or social markers. They would integrate values such as the ecosystem resilience index, the level of systemic intercultural dialogue, and perceived satisfaction with governance. The objective would be to have a holistic dashboard reflecting the complexity of human and non-human interactions, mirroring the proposals of ecological economics (Daly, H.

E. (1999). *Une économie pour quarante ans*. Pierre Mardaga). This revision would not be a mere cosmetic adjustment exercise, but could lead to substantial modifications in the constitutive charter of institutions. Fundamental principles, such as subsidiarity or intergenerational responsibility, could be reaffirmed or, where appropriate, re-qualified to confer upon them an even more binding legal scope. The work of John Rawls on "justice as fairness" (Rawls, J. (1971). *A Theory of Justice*. Harvard University Press) could serve as a constant philosophical reference for evaluating the fairness of the proposed adjustments.

Finally, the revision procedure itself should be exemplary in terms of participation and transparency. Global forums, decentralized citizen consultations, and independent expertise would be orchestrated to guarantee the legitimacy of the process. Decisions should be taken on the basis of broad consensus, avoiding any risk of capture by particular interests, in accordance with the principles of open governance. Historical and Prospective Legitimacy Institutional consolidation would inevitably involve questioning the historical legitimacy of the arrangements in place.

Two centuries of existence would confer upon these institutions a form of authority by fact, but this authority would have to be constantly justified by their performance and their capacity to embody the aspirations of global populations. Legitimacy would not be static but would have to be actively maintained and renewed. This period could see the emergence of a new historiography of the refoundation processes, analyzing the successes, failures, and compromises that would have marked this long journey.

Such a perspective would enable future generations to understand the foundations of the structures they would inherit, thereby strengthening the sense of belonging and collective responsibility. Ernest Renan's work on the nation as a "plebiscite of every day" (Renan, E. (1882). *Qu'est-ce qu'une nation?* Conference delivered at the Sorbonne) highlights the importance of this constant renewal of consent. The historical legitimacy of institutions would also be linked to their ability to integrate the diversity of narratives and cultures that compose humanity.

Institutional frameworks should not be perceived as the product of a single dominant thought, but as the result of a respectful convergence of different cosmologies and worldviews. Cultural rights, as defined by UNESCO, could thus be formalized in fundamental charters (UNESCO. (2001). *Universal Declaration on Cultural Diversity*). Institutional Memory as a Lever for Resilience The establishment of a robust institutional memory would be a key element of the long-term resilience of human systems. This would involve the preservation and accessibility of archives of decisions, debates, and evolutions, allowing for complete traceability of adaptation mechanisms.

This memory would not be static, but living, integrated into training processes and civic education. Past experiences, particularly those of crises and moments of bifurcation, would be analyzed and modeled to inform future choices. This approach would draw inspiration from the principles of organizational learning applied on a planetary scale, where errors and successes would be capitalized upon. The idea that institutions are "embodied memories" has been explored by sociologists such as Maurice Halbwachs (Halbwachs, M. (1925). *Les Cadres sociaux de la mémoire*. Félix Alcan).

To guarantee this institutional memory, secure and decentralized digital infrastructures would be developed, enabling universal and perennial access to relevant information. These infrastructures would respect the principles of data sovereignty and information neutrality. They would be immune to any attempt at rewriting or manipulation, forming a reliable basis for public deliberation. The Horizon 2226: Preparing for the Challenges of the Third Century The completion of Phase 6 in 2226 would not mark an end in itself, but a major reset point before embarking on the third century of refoundation. This consolidation period would above all serve to prepare institutions for renewed challenges.

Demographic projections, very long-term climate change, and unpredictable technological advancements (such as artificial general intelligence or advanced biotechnologies) should be integrated. Institutions should thus be conceived not as fixed entities, but as complex adaptive systems, capable of transforming without losing their normative substance. Inspiration could come from living systems, whose perenniality resides in their capacity to constantly evolve (Morin, E. (2001). *La Méthode, tome 5 : L'Identité humaine*. Seuil). Agility and robustness would be the cardinal qualities sought.

Furthermore, consolidation would involve strengthening the "culture of the institution," that is, the set of shared values, norms, and practices that underpin its functioning. This institutional culture should promote the ethics of responsibility, intersectoral collaboration, and a constant prospective vision. Amartya Sen's work on freedom as development (Sen, A. K. (1999). *Development as Freedom*. Oxford University

Press) could inspire an institutional culture centered on the empowerment and agency of individuals and communities.

The capacity to engage in continuous critical reflection on their own foundations would be the guarantee of the longevity and continued legitimacy of institutions beyond the 2226 horizon. It is by cultivating this self-reflexivity that human structures could hope to traverse the centuries with relevance and justice. Chapter 63 Adoption Strategy: Contagion or Imposition? CHAPTER 63 — Adoption Strategy: Contagion or Imposition? The institutional refoundation envisaged for 2226 raises, as early as 2026, the fundamental question of its dissemination and entrenchment. The transformation of governance frameworks on a global scale cannot occur without a clear and multifaceted adoption strategy.

Three main avenues emerge, each with its specificities, levers, and challenges: pioneering imitation, commercial conditionality, and multilateral treaty. These approaches are not mutually exclusive; on the contrary, their strategic combination could maximize the chances of success of such an undertaking, ensuring both local appropriation and global consistency of the new institutional architectures. The dissemination of norms and institutional models is a dense field of study, as shown by numerous researchers, from John W. Meyer and Brian Rowan on institutional isomorphism (1977) to Dani Rodrik on development strategies (2007).

The challenge here is to go beyond simple transplantation to aim for a true systemic transformation, capable of integrating the principles of anticipatory and resilient governance. The implementation of these strategies should necessarily take a long-term perspective, avoiding the pitfalls of hasty or forced adoption, to favor deep and lasting integration. Pioneering Imitation: The Power of Example and Normative Contagion Pioneering imitation is based on the idea that a state or group of states, by adopting advanced institutional reforms, could serve as a model and encourage other entities to follow the same path.

The success of this strategy would largely depend on the visibility of the benefits generated by these new institutions. The *Well-being of Future Generations (Wales) Act 2015* offers a relevant example of this approach. This law introduces the obligation for Welsh public bodies to consider the long-term impacts of their decisions, integrating the concept of future generations' well-being into public policy development. The Welsh experience, although local, could theoretically inspire other national or subnational legislations.

Imitation would not be a servile copy but rather an adaptation of general principles to specific contexts, a process that Paul DiMaggio and Walter Powell (1983) describe as mimetic isomorphism, where uncertainty pushes organizations to imitate those they perceive as more legitimate or more effective. Successful institutionalization in Wales could thus create a demonstration effect, encouraging other entities to explore similar avenues to integrate a long-term vision into their own governance. Conditions favorable to imitation For pioneering imitation to be effective, several conditions would need to be met.

First, the robustness and proof of concept of the model institutions would be crucial. Early adopters should demonstrate tangible results, whether it be better anticipation of crises, fairer resource allocation, or increased resilience to future shocks. Second, mechanisms for sharing experience and transferring knowledge should be put in place, facilitating learning and adaptation by other jurisdictions. This could be structured around international platforms for exchanging best practices, technical cooperation programs, or networks of decision-makers. The deployment horizon for this strategy would involve a phase of careful observation and evaluation of pilot initiatives.

Over the first two decades, the focus would be on identifying the best performing and most adaptable systems. Subsequently, in the following decades, targeted dissemination could be considered, where exemplary institutions would become references for entities seeking to modernize their own governance frameworks. The objective would be to create a dynamic of positive contagion, where the adoption of these principles would become the norm not by constraint, but by recognition of their adaptive superiority.

Commercial conditionality: influence through the market A second adoption strategy could rely on commercial conditionality, i.e., the integration of institutional standards into trade agreements or market regulations. The European Union, with its General Data Protection Regulation (GDPR) which came into force in 2018, offers an eloquent example of a jurisdiction's ability to project its norms beyond its borders through economic leverage. Any company wishing to interact with European citizens, regardless of its head office, must comply with the requirements of the GDPR under penalty of significant financial sanctions.

This approach suggests that a coalition of states with sufficient economic weight could condition access to its market on the adoption of certain institutional reforms, particularly those concerning long-term governance, the protection of commons, or the rights of future generations. For example, access to important markets could be made conditional on the establishment of intergenerational budgeting mechanisms or the existence of bodies representing long-term interests, such as future generations' advocates or anticipation commissions.

Mechanisms and implications of conditionality The implementation of commercial conditionality would require the precise definition of institutional standards to be promoted and a robust international legal framework for their application. This would involve, for example, drafting specific clauses in free trade agreements, conditioning tariff or regulatory advantages on proof of institutional compliance. Suzanne Berger's work on globalization (2006) has clearly shown how states can, despite increasing interdependence, maintain or strengthen their own regulations and extend them.

International institutions such as the World Trade Organization (WTO) could be assigned a crucial role in mediating and resolving disputes related to these new forms of conditionality. The impact of this strategy could be rapid and extensive, as economic actors would be strongly encouraged to comply in order not to lose access to lucrative markets. However, it could also raise accusations of disguised protectionism or interference in the internal affairs of states. A nuanced approach would therefore be necessary, prioritizing cooperation and technical assistance to help countries adapt, rather than relying solely on the threat of sanctions.

Over the first two decades following 2026, the establishment of these standards could begin to emerge in strong regional blocs, and then, in subsequent decades, a progressive convergence of global institutional norms could occur. The multilateral treaty: collective commitment and the force of international law The third path is that of the multilateral treaty, a classic approach to international law that relies on the voluntary commitment and ratification by a large number of states.

Historical examples, such as the Montreal Protocol on Substances that Deplete the Ozone Layer (adopted in 1987), demonstrate the international community's ability to unite to solve global problems through binding agreements. The success of the Montreal Protocol lies in its universality (ratified by almost all UN member states) and its flexibility, with mechanisms for periodic adjustment and review. A multilateral treaty on institutional refoundation could establish fundamental principles and common obligations for signatory states, particularly regarding intergenerational governance, the rights of nature, or the management of planetary common goods.

It could draw inspiration from the *Universal Declaration of Human Rights* (1948) to lay the ethical and legal foundations of a new institutional order, and from environmental treaties to structure implementation and monitoring mechanisms. Discussions on the concept of "ecocidal crimes" (Polèse, 2020) or the extension of rights to non-human entities (Boyd, 2017) already show an evolution in thought frameworks that could be formalized in such treaties. Challenges of Negotiation and Ratification The complexity of such a treaty would lie in its negotiation and ratification by a multitude of states with diverse interests and legal systems.

The negotiation processes would likely be long and arduous, as were those for the Paris Agreement on climate (2015), despite the urgency of the situation. It would be necessary to strike a balance between universal principles and recognition of the diversity of national contexts. Mechanisms to incentivize ratification, such as adaptation funds or technology transfers, could be considered for developing countries. The deployment horizon for this strategy would involve, in the first post-2026 phase, preparatory diplomatic conferences and expert working groups. The following decade could see the drafting of an initial framework text, followed by years of intergovernmental negotiations.

The ultimate goal would be a major diplomatic conference, potentially towards the end of the first half of the 22nd century, for the adoption and opening for signature of such a treaty. Its entry into force would then depend on the number of ratifications, in line with the practices of international law (Vienna Convention on the Law of Treaties, 1969). The success of this path would be proof of a global consensus on the need for a profound transformation of human institutions.

Chapter 64 Progress Indicators by Phase Indicators for the Metabolic Reset Phase The metabolic reset phase, initiated in 2030, aims to redefine the fundamentals of socioeconomic interaction with Earth's biophysical limits. This phase is crucial for ensuring the resilience of ecological and social systems. It is characterized by deep decarbonization and selective regeneration of key socio-ecosystems, requiring precise indicators to measure progress and persistent rigidities, beyond GDP alone. The evaluation framework relies on a holistic understanding of natural capital, incorporating the work of Dasgupta (2021) on the economics of biodiversity.

The valuation of this capital, whether renewable or non-renewable, is a prerequisite for its management. The indicators are designed to reflect both anthropocentric pressure and the regenerative capacity of systems. Their aggregation into a global dashboard, published annually, allows for transparent monitoring of trajectories. The objectives of this phase, set by the Global Treaty for Ecological Justice and Climate (TGJEC) in 2028, demand a drastic reduction in material and energy footprints.

Article 12 of the Treaty stipulates the necessity for precise indicators, "measuring the absolute decoupling between the growth of human well-being and the consumption of natural resources, as well as the interruption of biodiversity erosion processes." This absolute decoupling is at the heart of the strategy. Key Indicators for the Metabolic Reset Phase (by 2040): ■ **1. Reduction of uncompensated greenhouse gas (GHG) emissions:** target of -75% compared to 2020. In 2023, global emissions were still 53.8 gigatonnes of CO2 equivalent (IPCC, 2023). The target for 2040 is therefore below 13.45 GtCO2e. ■ **2.

Circularity rate of the global economy:** target of 25% of consumed materials originating from recycling or reuse. This rate was only 8.6% in 2020 (Circle Economy, 2021), illustrating the magnitude of the required transition. ■ **3. Area of restored degraded ecosystems:** target of 1 billion hectares by 2040, in accordance with the objectives of the United Nations Decade on Ecosystem Restoration. This figure includes forests, wetlands, and agricultural soils. ■ **4. Consumption rate of primary non-renewable resources:** target reduction of 50% compared to 2020, with particular attention to critical metals. This implies a fundamental revision of value chains. ■ **5.

Integrated Biodiversity Index (IBI):** increase of 10% compared to 2025. This index, an aggregate of genetic, specific, and ecosystem diversity metrics, reflects ecosystem health and biological resilience. ■ **6. Share of renewable energies in the primary energy mix:** target of 80%. In 2022, this share was approximately 13% (REN21, 2023), highlighting the need for massive acceleration of deployments. These indicators are interdependent. The reduction of greenhouse gas emissions, for example, largely depends on the energy transition and an increased circularity rate.

The effectiveness of the metabolic reset will be measured by the capacity of systems to generate less waste and pollution, while maximizing the utility of material and energy flows within planetary limits. Geographic Disparities and Intergenerational Equity The implementation of these indicators must also take into account regional disparities and historical responsibilities. Article 3 of the TGJEC insists on the principle of "common but differentiated responsibilities and respective capabilities." This means that national or regional targets may vary, while contributing to the overall objective.

Intergenerational equity, a central concept developed by Edith Brown Weiss (1989), is materialized here by the non-transferability of environmental burdens to future generations. The indicators are designed to measure the preservation of natural capital, thereby guaranteeing the material foundations of future well-being. The reset phase aims to stabilize this capital. Indicators for the Systemic Transformation Phase The systemic transformation phase, projected from 2040 to 2060, aims to consolidate the achievements of the metabolic reset and to bring about profound structural changes in governance, production, and consumption patterns.

It is no longer only about reducing impacts, but about rethinking the very architecture of our societies to align them with the principles of ecological viability and social justice. This phase is characterized by increased decentralization of decision-making processes and the relocation of economic activities where ecologically relevant. The transformation of legal and institutional frameworks is a pillar of this transformation. In France, the Due Diligence Law (2017), and its subsequent extension by the TGJEC, laid the foundations for extended corporate responsibility.

Similar, but more integrated mechanisms, are required for this phase, engaging all actors in the co-construction of resilient and just systems. The goal is to transition from a logic of correcting negative externalities to a logic of designing intrinsically regenerative systems. Ecological economics, with its theoretical foundations established by figures like Nicholas Georgescu-Roegen (1971), illuminates the necessity of this phase. "Sustainable degrowth," or Daly's (1996) steady-state economy, becomes a normative beacon for economic organization, prioritizing quality of life and flow durability over production volume.

The indicators of this phase must reflect these qualitative, not just quantitative, changes. Key Indicators for the Systemic Transformation Phase (by 2060): ■ **1. Investment in ecological and social common goods:** target of 10% of global GDP, allocated to the conservation, restoration, and shared management of natural resources and essential services. These are the "common-pool resources" identified by Elinor Ostrom (1990) as shared and collectively manageable resources. ■ **2.

Reduction of material footprint per inhabitant:** target of -50% compared to 2040, bringing consumption down to sustainable levels (approximately 8 tons per year per person, compared to a global average of 12.2 tons in 2017 according to the Global Material Flows Database). ■ **3. Share of cities and territories self-sufficient in renewable energy and local food:** target of 30% of urban agglomerations and rural regions. This implies a significant relocation of production. ■ **4. Environmental Justice Index (EJI):** increase of 20% compared to 2040.

This index aggregates metrics on equitable access to resources, the distribution of pollution, and citizen participation in environmental decisions, in accordance with the principles of eco-socialism. ■ **5. Employment rate in regenerative and social economy sectors:** target of 40% of the active population. These sectors include organic agriculture, repair, recycling, renewable energies, and non-relocatable personal services. ■ **6. Agricultural soil biodiversity (QBS Index):** increase of 50% compared to 2040. The restoration of soil life is critical for food security and carbon sequestration. This phase directly challenges governance models.

The indicators are designed to assess not only environmental outcomes, but also underlying societal metamorphoses. The EJI, for example, does not directly measure a physical flow, but a just distribution of environmental burdens and benefits, essential for social cohesion and acceptance of the transition. Institutional Reconfiguration and Rights of Nature Systemic transformation involves a reconfiguration of legal and political institutions. The concepts of "rights of nature," already recognized in the Constitution of Ecuador (2008, art. 71-74) and by several American states, must be generalized.

These rights, by recognizing legal personality for ecosystems, would fundamentally change the relationship between humanity and the rest of life, moving from a status of object to that of a subject of law. The territorial deployment of indicators is crucial. Local dashboards, adapted to biogeographical and socioeconomic specificities, will complement the global dashboard. This scaling up allows for the valorization of citizen and local initiatives, often at the forefront of systems transformation. Global resilience depends on the resilience of territories.

Indicators for the Stabilization and Symbiotic Regeneration Phase The stabilization and symbiotic regeneration phase, starting from 2060, aims to achieve a dynamic equilibrium between human societies and ecosystems, where the regeneration of life is fully integrated into socioeconomic processes. This is a consolidation phase, where the principles of ecological symbiosis and interdependence are the foundations of all action. The dynamics of this phase are those of adaptive resilience and continuous learning. Lynn Margulis's work on symbiogenesis (1981) offers a relevant framework for this phase, where cooperation and the integration of different living entities are the driving forces.

The goal is no longer only to reduce impact, but to actively contribute to the vitality of ecosystems and the flourishing of different forms of life. This is the very essence of the positive Anthropocene, as theorized by some. The governance of this phase is characterized by shared administration of the biosphere, integrating non-human representations into decision-making processes. This may include, for example, "guardians" for rivers, "ecosystem councils" for forests, or "legal representatives" for endangered species, as suggested by Christopher Stone (1972) in "Should Trees Have Standing?". Law becomes the guarantor of symbiotic balance.

Key Indicators for the Stabilization and Symbiotic Regeneration Phase (by 2080): ■ **1. Stabilization of atmospheric GHG concentrations:** maintenance of CO2 below 350 ppm and CH4 below 1500 ppb. In 2023, atmospheric CO2 concentration reached 420 ppm (NOAA, 2023), requiring continuous efforts in sequestration and reduction of residual emissions. ■ **2. Restoration of biogeochemical cycle integrity:** 90% reduction in anthropogenic nitrogen and phosphorus fluxes into aquatic ecosystems, compared to 2020. This implies low-input agricultural practices and advanced wastewater management. ■ **3.

Net carbon sequestration rate by terrestrial and marine ecosystems:** reaching 10 gigatonnes of CO2 per year. This objective, dependent on the restoration of forests, wetlands, and soils, aims to offset residual emissions and reduce the surplus of atmospheric CO2. ■ **4. Major

Ecosystem Health Index (MEHI):** increase of 30% compared to 2060. This index assesses the functional state of major biomes (tropical forests, oceans, coral reefs) by measuring their biodiversity, productivity, and resilience to disturbances. ■ **5. Share of regenerative agriculture in worldwide food production:** target of 75%.

This agriculture, which aims to improve soil health and biodiversity, is a pillar of ecosystem regeneration and sustainable food security. ■ **6. Holistic Well-being Index (HWI):** maintained above 7/10 at the planetary scale. This multidimensional index integrates environmental factors (access to drinking water, clean air), social factors (cohesion, equity), economic factors (non-consumerist material security), and subjective factors (life satisfaction). These indicators reflect the shift from a corrective aim to a regenerative approach.

Maintaining GHG concentrations at safe thresholds is not merely the absence of pollution, but the reflection of a system where carbon fluxes are rebalanced at a planetary scale. The restoration of biogeochemical cycle integrity is a marker of the restitution of the self-organization capacity of natural systems. Reframing Value and Wealth The quantification of the Holistic Well-being Index (HWI) is essential. It is no longer about measuring wealth solely through the prism of material production, but through the quality of life in a healthy and just environment.

This conception of wealth is in line with Serge Latouche's (2007) reflections on the "frugal abundance society." The stabilization phase is when this new definition of value is fully integrated into public policies and daily practices. The transition to the symbiotic phase is a process of collective learning and continuous adaptation. Indicators are management tools, but also instruments for dialogue and understanding complex interdependencies. The success of this phase will lie in societies' ability to cultivate a reciprocal relationship with the living world, for the benefit of all species.

The annual dashboard, with its objective indicators, serves as a compass for the entire transition process. It not only allows for evaluation of progress but also identification of bottlenecks and readjustment of strategies. The transparency requirement, enshrined in Article 24 of the TGJEC, gives these indicators indispensable factual authority for global governance.

Part VII — Risks, Counter-arguments, Safeguards Chapter 65 Risk: Technocratic Capture The NOÖS Project: An Enlightened Technocracy in Search of Legitimacy The NOÖS project, an acronym for New Organs of Strategic Orientation, is part of a school of thought seeking to address the shortcomings of contemporary democratic systems in the face of 21st-century systemic challenges. Envisioned as a global governance superstructure, its architecture relies on a so-called "enlightened" elite – scientific experts, legal scholars, economists, and ethicists – whose mission would be to develop long-term sustainable development trajectories, transcending electoral cycles and narrow national interests.

This orientation is intended as a rational response to the polycrisis of environmental and societal issues. This vision, while appealing in its ambition for efficiency and its claim to objectivity, nonetheless carries risks inherent in any concentration of power and decision-making. Political history and the sociology of organizations abound with examples where expertise, when disconnected from robust democratic control, tends to drift towards forms of technocracy, or even closed bureaucracy.

The initial NOÖS model, as outlined by its proponents, thus faces the cardinal question of its legitimacy and its ability to avoid capture by particular interests, even when masked by the veneer of science. The notion of an "enlightened" elite is itself slippery ground, often used to justify systems of government by the "best" (aristocracy) or by "knowledge" (epistocracy), as Plato had already pointed out in his

Republic. If the intention is to free oneself from cognitive biases and electoral imperatives, the danger is to substitute one form of opacity for another, by entrusting decisions with planetary consequences to a restricted circle without direct accountability mechanisms.

The increasing complexity of global issues must not serve as a pretext for a form of democratic abdication. The Elitist Temptation and Its Historical Reflections The idea of governance by superior competencies is not new. It can be found in the theories of "experts" or "functionalists," which marked the 20th century, particularly in the post-war period with the development of international organizations (Haas, 1958, *The Uniting of Europe*). These approaches prioritize problem-solving through technical knowledge rather than political compromise, arguing that complexity necessitates a depoliticized approach.

However, even within the nascent European Community, this tendency was contained by the gradual establishment of democratically oriented institutions, such as the European Parliament, directly elected by universal suffrage since 1979. Other, sometimes darker, experiences illustrate the deviations of technocratic governance without effective counter-powers. The centralized planning of socialist economies, though based on supposedly scientific economic rationality, demonstrated their limitations in terms of efficiency, adaptability, and individual freedom.

The absence of ground-level feedback and citizen participation led to decisions disconnected from realities, mirroring the failures of five-year planning in the USSR in the 1970s-1980s, leading to chronic shortages and economic stagnation. The risk of technocratic capture lies precisely in the formation of an autonomous group, whose decision-making processes become opaque and whose criteria for evaluating "good" governance are endogenous.

This autonomization can lead to a drift towards what Michel Crozier and Erhard Friedberg (1977, *L'Acteur et le Système*) call the "strategy of a closed bureaucracy," where power is exercised through the mastery of information and rules, rather than through democratic legitimacy derived from popular sovereignty. The initial promise of rationality then transforms into a form of hegemonic power. Anti-Capture Mechanisms: The Triptych of Democratic Regeneration To ward off this risk of technocratic capture and ensure the lasting legitimacy of the NOÖS project, constitutional mechanisms and governance principles must be integrated from its inception.

The objective is to reconcile indispensable technical expertise with the democratic imperative of accountability and inclusion, without diluting the effectiveness of action. Three pillars seem essential: sortition, radical transparency, and open access to knowledge. The use of sortition (or stochocracy) is an ancient practice, notably used in Athenian democracies for the appointment of certain magistrates. Aristotle (4th century BC, *Politics*) considered it intrinsic to democracy, in contrast to election, which is more akin to oligarchy.

Within the framework of NOÖS, this would mean the integration of citizens chosen by lot into its structures, particularly its Strategic Guidance Councils and its Houses of Future Generations. These citizens, representative of the diversity of global populations, would bring a non-expert but intrinsically legitimate perspective, acting as a counterweight to the potential biases of expertise. The composition of these bodies should be designed to ensure genuine representativeness.

For example, in the Strategic Guidance Council, if 50% of members are experts appointed for their skills, the remaining 50% could be citizens chosen by lot, with a quota ensuring geographical, gender, generational, and socio-economic parity. Such a hybrid composition, combining technical rationality and citizen legitimacy, would avoid the pitfalls of a self-proclaimed elite and strengthen the social acceptability of decisions made. Radical transparency constitutes the second pillar.

It implies that all NOÖS work – from raw data to analysis algorithms, including interim reports, meeting minutes, votes, and motivations for decisions – should be publicly accessible, in an interoperable and verifiable format by all. This "open data by default" policy, inspired by the principles of the Open Government Partnership, would create a mechanism for constant citizen oversight, making any attempt at collusion or manipulation more difficult. This transparency should go beyond mere passive dissemination. It would require the development of interactive platforms allowing any citizen or organization to analyze, comment on, and challenge NOÖS analyses and proposals.

The objective is to move closer to an "Open Science" model extended to governance, where the robustness of arguments and the relevance of choices are constantly subjected to the critical scrutiny of an expanded community. The example of scientific exchange platforms like arXiv.org for preprints or GitHub for collaborative software development shows how transparency and sharing can accelerate innovation and improve quality.

The third component, free licensing, is understood as the principle that all intellectual output of NOÖS – from predictive models to normative legislative texts, from databases to experimental protocols – must be published under free licenses equivalent to the *Creative Commons Attribution 4.0 International license* or the *GNU General Public License (GPL)* for software tools. This grants anyone the freedom to use, study, modify, and distribute these contents, including for commercial purposes, without restriction other than attribution of the source.

This free licensing principle prevents the private appropriation of intangible common goods produced by NOÖS and promotes collective appropriation and decentralized innovation. By making NOÖS's "outputs" global digital commons, it is ensured that their analyses and governance tools cannot be captured or monopolized by private or state actors to serve particular interests. The objective is to create an ecosystem of knowledge and tools for the planetary common good, as advocated by the idea of a "World Knowledge Commons" (Ostrom, 1990, *Governing the Commons*).

The House of Future Generations: Ratio and Intergenerational Legitimacy At the heart of NOÖS's counter-power mechanism, the House of Future Generations (HGF) is envisioned as a unique institution, whose mission would be to represent the interests of still unborn populations. This House embodies the consideration of the long term and intergenerational externalities, an essential principle in the face of ecological crises whose effects will fully manifest in several decades, or even centuries. The composition and decision-making mechanisms of this HGF are therefore crucial to avoid its own capture or instrumentalization.

The proposal for a two-thirds ratio of randomly selected citizens within the HGF represents a fundamental safeguard. Out of a total of, for example, 150 members, 100 would be citizens randomly selected on a global scale, while the remaining third (50 members) would be composed of experts in foresight, environmental law, climate science, or intergenerational ethics, appointed based on criteria of excellence and independence. The numerical primacy of randomly designated citizens ensures that the perspective of "ordinary people," uninfluenced by pre-existing expert paradigms, prevails.

These randomly selected citizens would be appointed for renewable terms of a significant duration (e.g., five to seven years) to allow them to acquire a deep understanding of the issues, but short enough to avoid excessive institutionalization. They should benefit from extensive training and independent administrative and scientific support.

The experience of the Citizen's Climate Convention in France (2019-2020), where 150 randomly selected citizens developed ambitious proposals, demonstrates the capacity of non-experts to grasp complex subjects and produce relevant recommendations, often more audacious than traditional governmental policies. 70% of their proposals were adopted, sometimes modified, by the French government. The sortition process must be statistically and logistically irreproachable, guaranteeing the broadest possible sociodemographic representativeness.

Global databases of phone numbers or civil registers could be used, with weighting mechanisms to correct biases (over-representation of certain age groups or regions, for example). The OECD's experience with its citizen deliberation platforms and its recommendations for "citizen assemblies selected by lot" (OECD, 2020, *Innovative Citizen Participation and New Democratic Institutions*) highlights the importance of these rigorous protocols.

The HGF's mission is not to substitute national parliaments or existing international institutions in their own competencies, but to exercise a power of "strategic watch" and "suspensive veto" over decisions of NOÖS and potentially other global governance bodies. It could thus be endowed with the capacity to issue formal "intergenerational alerts," to request policy revisions, or even to suspend the application of certain NOÖS directives on the grounds that they compromise the development capacities of future generations.

This power would be based on scientifically validated and legally framed criteria, drawing, for example, on the universal recognition of the precautionary principle (e.g., Principle 15 of the Rio Declaration on Environment and Development, 1992). Challenges of Sovereignty and Institutional Interoperability The implementation of the principles of sortition, radical transparency, and free licensing, combined with a strong HGF, raises the question of their articulation with existing governance systems, particularly the sovereignty of nation-states. NOÖS, as a supranational body, cannot and must not bypass the prerogatives of states.

Its role is rather to be a "facilitator of collective intelligence" and a "catalyst for long-term action," whose recommendations become binding through the voluntary assent of states and not through hegemonic imposition. The adoption of NOÖS recommendations by states should thus be conditioned by the validation of intergenerational deliberation processes and adherence to principles of transparency and free licensing. For example, a state could only benefit from NOÖS's expertise or participate in its programs if it commits to making public all data and processes related to the implementation of NOÖS directives in its territory, and to guaranteeing adequate citizen participation.

Participation in the NOÖS network would become an attractive factor for states concerned with legitimacy and effectiveness. The question of NOÖS's funding is also paramount to guaranteeing its independence. Diversified funding, primarily from voluntary contributions from states but also from international taxes on global common goods (e.g., Tobin tax on international financial transactions, global Carbon tax, taxes on deep-sea extractive activities), would prevent excessive dependence on a few donors. The 0.05% of global GDP, or about 4 to 5 billion USD annually, attributed to such supranational bodies by some studies, would represent a minimal investment compared to the stakes involved.

The democratic safeguards integrated into the NOÖS project are not mere cosmetic additions. They are structural components intended to protect the initiative from deviations that history has repeatedly condemned. The proposed hybrid model, combining expertise with the legitimacy of sortition, rationality with participation, and efficiency with accountability, offers a way to reinvent credible, resilient global governance that genuinely serves the planetary common good, without succumbing to the Siren calls of enlightened technocracy which often ends up fading into its own opacity.

Chapter 66 Risk: Institutional Paralysis The Escalation of Normative Blockages and the Specter of Systemic Paralysis The proliferation of veto mechanisms, whether formal or informal, represents a growing threat to global and national governance, undermining institutions' capacity to respond effectively to multidimensional crises. This propensity for blockage, often perceived as a democratic guarantee or a bulwark against arbitrariness, can, through overuse or misguided application, lead to decision-making inertia.

Indeed, a fundamental dialectical tension is observed between the legitimacy of protecting minority interests and the imperative of collective action in the face of planetary challenges. The concept of "vetocracy" (Tsebelis, 2002) describes this dynamic where an increasing number of actors, endowed with the ability to block a decision, make systemic reform or adaptation exponentially more difficult. In a world characterized by increased interdependence and cross-border negative externalities, this institutional paralysis is no longer merely administrative inefficiency but an existential impediment.

The climate crisis, biodiversity loss, and recent pandemics have illustrated, with unprecedented acuity, the devastating consequences of the inability to forge consensus and implement coherent and ambitious policies. Formal Veto as a Tool of Sovereignty and Its Misuse Historically, the right of veto in the United Nations Security Council, granted to the five permanent members by Article 27 of the 1945 Charter, constitutes the most emblematic example of a formal veto. Initially designed to prevent major conflicts during the Cold War, its use has diversified, blocking humanitarian resolutions or interventions for divergent geopolitical reasons.

Since 1946, China, France, Russia (USSR), the United Kingdom, and the United States have exercised this right 297 times, with Russia being, by far, the country that has used it the most, with 124 vetoes (UN Documents, 2024). This statistic reveals a propensity for blockage that exceeds the original intentions, eroding the legitimacy and effectiveness of an institution that is nevertheless crucial. In parliamentary systems, the presidential veto, as it exists in the United States, confers upon the head of state a significant power to challenge legislation adopted by Congress.

Although generally not absolute, as it can be overridden by a two-thirds qualified majority in each chamber (Article I, Section 7 of the U.S. Constitution), its use is a powerful negotiating instrument. Statistically, out of 2580 regular presidential vetoes issued since 1789, only slightly more than 7% have been overridden by Congress (US Senate, 2024), highlighting its deterrent effectiveness and its capacity to influence the legislative agenda. The Rise of Informal Vetoes and Blocking Minorities Beyond formal mechanisms, the multiplication of actors endowed with informal blocking power contributes to a more insidious paralysis.

Organized interest groups, economic pressure groups, or even social movements, through their ability to mobilize public opinion or paralyze key sectors, can hinder the adoption or implementation of policies. Industrial lobbies, for example, in the fight against climate change, have often succeeded in delaying or watering down environmental legislation through influence campaigns and political funding, thereby transforming sectoral preferences into de facto vetoes on the general interest. In modern constitutions, the rigidity of the constitutional amendment procedure is another example of an implicit veto.

Often requiring qualified majorities, referendums, or agreements between different levels of government (as in federal systems), the modification of fundamental texts is made complex. In Belgium, for example, constitutional revision requires a two-thirds majority in each chamber of Parliament, after a preliminary declaration of revision (Article 195 of the Belgian Constitution, 1831). This requirement, while ensuring legal stability, can become a major obstacle to institutional adaptation in the face of rapid and profound societal transformations.

The Economic and Ecological Cost of Decision-Making Inertia The inability to make rapid and coordinated decisions in the face of contemporary challenges, exacerbated by veto mechanisms, generates considerable socio-economic and ecological costs. Economic literature, from Pigou (1920) to Stern (2006), has amply documented the negative externalities resulting from public inaction. The failure to address global issues, due to political blockages, leads to a slow degradation of natural and social capital, the consequences of which are often irreversible or require exponentially larger subsequent investments.

The Stern Review on the Economics of Climate Change (2006) estimated that climate inaction could cost between 5% and 20% of global GDP each year. In comparison, immediate investments to stabilize the climate would cost approximately 1% of global GDP. This disconnection between a high future cost of inaction and a lower present cost of action is often ignored or minimized by short-term interests, protected by blocking mechanisms. The fossil fuel industries, for example, by defending their interests through powerful lobbies, have indirectly exercised a veto on energy transition policies, inevitably delaying the necessary decarbonization.

Loss of Opportunities and Increased Vulnerability In addition to direct costs, institutional inertia results in a loss of opportunities for innovation and sustainable development. Green fiscal reforms, massive investments in renewable energies, and natural resource management policies that could generate new sectors of activity and jobs are delayed or abandoned in the face of political resistance.

For example, the European Union has faced internal disagreements over the "Green Deal," with some member states opposing ambitious targets for reasons of economic competitiveness or national sovereignty, thus threatening the achievement of carbon neutrality objectives by 2050 (Regulation (EU) 2021/1119). This paralysis also increases societies' vulnerability to external shocks. The COVID-19 pandemic, with its health, economic, and social repercussions, revealed the weaknesses of fragmented global governance, where multilateral coordination was often hampered by nationalist postures and sovereignty concerns.

The delay in establishing mechanisms for equitable financing and distribution of vaccines was, in part, attributable to implicit "vetoes" from the wealthiest nations, primarily concerned with their own populations. Resolution Pathways: Institutional Redesign and a Culture of Compromise Faced with this threat of paralysis, it is imperative to explore mechanisms not only for circumventing but also for preventing excessive blockages. Institutional redesign and the development of a culture of compromise are two fundamental pillars for restoring the capacity for action of political entities, whether local, national, or supranational.

The aim is not to eradicate the veto, a legitimate instrument for protecting minority interests or controlling majorities, but to rationalize and contextualize it. The Suspensive Veto and the Reinforced Qualified Majority One reform avenue lies in the generalization of the suspensive veto rather than the absolute veto. The suspensive veto, like that of the American President, allows for a review of the decision but offers a pathway through a qualified majority. This is also the case in many legislative processes where a second reading or a reinforced majority vote can overturn an initial challenge.

Within the European Union, the increased use of qualified majority voting for Council decisions (Article 238 of the Treaty on the Functioning of the European Union) has unlocked many situations where unanimity would have led to deadlock. For example, the European taxonomy directive, although controversial, was adopted in July 2022 thanks to this mechanism, avoiding complete blockage despite the opposition of some member states (Council of the EU, 2022). The introduction of more flexible qualified majority thresholds, adapted to the critical nature of decisions, could be considered.

For issues essential to collective survival, such as pandemic management or climate change, majorities of 60% or 66% could suffice, thereby reducing the blocking power of a small minority while maintaining the requirement for broad consensus. The Earth Charter, although non-binding, proposes a global ethic of responsibility that could serve as a framework for decisions made by such majorities. Arbitration Referendum and Citizen Deliberation The arbitration or citizen initiative referendum offers a potential way to defuse institutional blockages by reconnecting political decision-making with popular will.

In Switzerland, the popular initiative and the optional referendum are deeply embedded tools (Articles 138-142 of the Swiss Constitution, 1999) that allow the population to decide directly on laws or constitutional revisions. This makes it possible to overcome partisan inertia or interest group vetoes by conferring direct democratic legitimacy on contested decisions. However, the excessive use of these instruments must be tempered by safeguards to avoid the tyranny of the majority, particularly regarding the fundamental rights of minorities.

Deliberative democracy, in the form of citizen conventions or participatory assemblies, also offers solutions for transcending partisan divisions and blocking logics. The example of the Citizens' Convention for Climate in France (2019-2020), although imperfectly implemented, demonstrated the capacity of a representative group of the population to formulate ambitious and consensual proposals, despite initial divergences. By cultivating a culture of listening, rational argumentation, and the pursuit of the common good, these forums can prefigure decision-making mechanisms more resilient to vetocracy phenomena.

The Necessity of an Ethic of Intergenerational Responsibility Beyond technical adjustments, the sustainability of governance systems requires a profound ethical transformation, articulated around the principle of intergenerational responsibility. Current decisions, hampered or paralyzed by short-term interests, commit the future of billions of individuals and the stability of ecosystems. This concept, explored by Hans Jonas (1979) in The Imperative of Responsibility, posits a moral imperative: humanity has a duty to guarantee the conditions of habitability of the Earth for future generations.

Veto mechanisms, in their absolute and unregulated form, constitute obstacles to the exercise of this responsibility. They allow minorities, often motivated by immediate concerns or sectoral gains, to block strategic orientations vital for all humanity and the biosphere. Awareness of this interconnection between contemporary political decisions and future destinies is a *sine qua non* condition for overcoming tendencies towards institutional paralysis. Jurisprudence and the Protection of Global Commons International and national jurisprudence is beginning to integrate this ethic of responsibility, as evidenced by several recent decisions.

The Supreme Court of the Netherlands, in the case *Urgenda Foundation v. Netherlands* (2019), confirmed the state's obligation to reduce its greenhouse gas emissions by 25% by 2020 compared to 1990, based on citizens' human rights. This decision, although exceptional, illustrates the judiciary's ability to circumvent legislative and executive inertia when political institutions fail to prevent irreversible environmental damage. Similarly, the emergence of the concept of "global commons" (Ostrom, 1990), such as the atmosphere, oceans, or biodiversity, invites a rethinking of governance beyond national sovereignties.

The protection of these commons requires decision-making mechanisms that are not subordinated to an individual veto, but that integrate principles of collective management and burden-sharing. This implies more proactive diplomacy, binding multilateral agreements, and supranational institutions endowed with increased powers, but subject to enhanced democratic legitimacy.

Towards a Constitutionalization of the Climate Emergency A radical, but potentially necessary, path to overcome systemic blockages could be the "constitutionalization of the climate emergency" or, more broadly, "intergenerational responsibility." This would involve enshrining in the fundamental texts of states, or even in a global Charter, binding obligations for environmental and social action. In France, the Environment Charter of 2004, integrated into the bloc de constitutionnalité, was an important step, even if its invocation in jurisprudence remains parsimonious compared to the urgency of the challenges.

This constitutionalization would give courts the ability to arbitrate in the face of legislative blockages, thus ensuring that no present generation can indefinitely mortgage the future. Such a normative architecture should be accompanied by an education in global citizenship, where an understanding of ecological and social interdependencies becomes a shared foundation. Without a profound modification of mindsets and power structures, veto mechanisms will continue to serve as tools of paralysis, transforming urgency into fatality and collective destiny into a series of missed opportunities.

Chapter 67 Risk: Eco-authoritarianism The ecological emergency and the authoritarian temptation: a tension of democratic principles. The acuteness of the ecological crisis, characterized by the massive erosion of biodiversity (IPBES 2019 report estimating that one million species are threatened with extinction) and the exceeding of several planetary boundaries (Rockström et al., 2009), strongly poses the question of governance models capable of addressing it.

Faced with the inertia of traditional democratic regimes, intrinsically constrained by short electoral cycles and economic growth imperatives, a question arises regarding the compatibility between ecosystem protection and the maintenance of fundamental freedoms. This dilemma is not new, but in the context of the 21st century, it finds particular resonance, to the point of fueling debates on eco-authoritarianism. The hypothesis of a forced convergence toward more centralized and coercive regimes is fed by the observation of the collective inability to translate scientific warnings into decisive political action.

The sixth IPCC report (Working Group I, 2021) reiterated the urgency of a drastic and immediate reduction in greenhouse gas emissions, emphasizing that current trajectories lead to global warming far exceeding the 1.5°C anticipated by the Paris Agreement (2015). Such a situation could, according to some futurologists, justify radical measures limiting certain individual freedoms in the name of collective survival.

The unattainability of the ecological vital minimum and the illusion of preserving rights The concept of "vital minimum" or "vital budgets" is rooted in the idea of a non-negotiable allocation of resources and an environmental impact threshold not to be exceeded to ensure the subsistence of human and non-human life. This framework is often interpreted as a justification for drastic restrictions on consumption and lifestyles, potentially incompatible with the notion of individual liberty as defined by the Declaration of the Rights of Man and of the Citizen of 1789 and most modern constitutions. However, the definition of this vital minimum remains eminently complex and elusive.

While it is easy to agree on the necessity of access to potable water or healthy food, the precise quantification of necessary resources and acceptable impacts varies considerably according to geographical, cultural, and technological contexts. Historical experience shows that such a definition, when imposed by a centralized power, frequently leads to forms of arbitrariness and denial of local specificities, as illustrated by certain agricultural policies imposed under totalitarian regimes in the 20th century, ignoring traditional ecological knowledge.

Ecological systemic preeminence versus democratic imperatives The promotion of "systemic primacy" assumes that ecological imperatives must supersede all other considerations, including individual freedoms and democratic processes. This postulate is based on the argument that without a stable and functional environment, the very exercise of these freedoms becomes illusory or meaningless. The priority would then be to restore and maintain the biophysical balances of the planet, even if it means temporarily or permanently altering existing societal and political structures.

This approach is part of a tradition of thought that subordinates the individual to the collective, but with an unprecedented dimension: the collective is no longer merely human; it encompasses all living things and, beyond that, the geophysical processes of the Earth. The danger lies in the instrumentalization of such logic to justify authoritarian regimes. Lenin, in his work "The State and Revolution" (1917), already envisioned the State as an instrument of radical social transformation, a distant precursor to the justifications potentially advanced for a strong ecological State.

The liberticidal impasse of green centralism The idea that centralized and non-democratic governance would be more effective in addressing the ecological crisis rests on the presupposition that scientific rationality can be directly applied to societal management, without the mediation of democratic deliberative and contradictory processes. The Chinese regime, with its carbon neutrality targets set for 2060 and its massive investments in renewable energies (exceeding 200 billion dollars in 2022, according to the International Energy Agency), is often cited as an example of this ability to act quickly and on a large scale.

However, this model is accompanied by severe restrictions on individual and collective freedoms, from the absence of real freedom of expression to limits imposed on citizens' movements and activities. Such a system, beyond ethical considerations, presents intrinsic shortcomings in terms of resilience and innovation. The absence of public debate and citizen feedback risks leading to uncorrected systemic errors and an inability to adapt to the complexity and uncertainty of ecological and social systems.

The preservation of fundamental rights in a context of ecological constraints Thinking about ecological regulation without falling into authoritarianism implies basing actions on a robust legal framework and inalienable democratic principles. Fundamental rights, far from being obstacles to ecological action, can constitute its foundation. The recognition of a right to a healthy environment, for example, enshrined in several constitutions (Article 1 of the French Environmental Charter of 2004), can serve as a basis for ambitious policies while ensuring citizen participation.

The limitation of freedoms can only be considered exceptionally, temporarily, and proportionally, and always under the control of an independent judiciary. The principle of proportionality, enshrined by the European Court of Human Rights, requires that any restriction on a right be necessary in a democratic society and proportionate to the legitimate aim pursued. Strict application of this principle would prevent the excesses of an eco-authoritarianism justified by a crisis perceived as absolute.

The legal framework of market exchange and the subversion of systemic primacy Free trade, a driver of economic growth and often correlated with an increasing ecological footprint, is at the heart of criticisms formulated by proponents of systemic primacy. Its strict regulation, or even limitation, is perceived as a necessity to reduce pressure on resources and ecosystems. However, market regulation does not necessarily have to involve a pure and simple suppression of economic freedoms, but rather a redefinition of its frameworks and objectives.

Mechanisms such as ecological taxation (carbon tax, for example, whose weighted average price in Europe was approximately 80 euros per ton of CO2e in 2023), the regulation of products and production processes (such as the European Industrial Emissions Directive), or the development of a circular economy, show that it is possible to reconcile entrepreneurial freedom with ecological imperatives. The social and solidarity economy, based on principles of cooperation and sustainability, also offers alternatives to the dominant productivist model.

Deliberative democracy and sobriety: an alternative path to authoritarianism Rather than embracing authoritarianism, a robust democratic response to the ecological crisis lies in strengthening deliberative democracy and promoting sobriety. The Citizens' Climate Convention in France (2019-2020), which formulated 149 proposals to reduce GHG emissions by 40% by 2030 in a spirit of social justice, illustrates citizens' capacity to grasp complex issues and propose ambitious solutions. Although the results of this experiment are mixed regarding their legislative translation, it remains a promising model of citizen participation.

Sobriety, far from being an imposed constraint, can be perceived as an informed collective choice, resulting from a process of collective deliberation on the desired uses of resources and lifestyles. It does not deny desire but reorients it towards less materialistic forms of satisfaction more rooted in collective well-being and ecological resilience. This path requires a profound change in social and economic imaginaries, moving away from the incessant pursuit of growth. The overhaul of the institutional framework for sustainable ecological governance The establishment of permanent and legitimate institutional structures is crucial to avoid authoritarian drift.

This involves a re-evaluation of legislative, executive, and judicial powers in light of ecological challenges. For example, the introduction of "rights of nature" or "legal personality" for certain ecosystems (such as the Whanganui River in New Zealand in 2017) shifts the center of gravity from anthropocentric concerns to an ecocentric perspective, while remaining within a legal and democratic framework. The recognition of a "duty of vigilance" for companies regarding their environmental and social impacts along their value chain, as exemplified by the French law of 2017, is also a relevant tool.

These approaches demonstrate that it is possible to integrate ecological imperatives into existing legal systems, thus strengthening collective responsibility without resorting to liberticidal measures. It is about rethinking sovereignty not as an unlimited freedom to exploit nature, but as the capacity of a community to coexist sustainably with its environment. The principle of subsidiarity and local autonomy in the face of global challenges Faced with the complexity of ecosystems and the diversity of socio-economic contexts, the principle of subsidiarity offers a powerful alternative to centralized solutions. It advocates decision-making at the most relevant level, favoring local autonomy.

Territorial resilience strategies, as developed by many cities and regions around the world, show how adaptive responses can emerge from communities themselves, based on local knowledge and citizen engagement. The decentralization of ecological initiatives not only allows for greater effectiveness but also for greater public adherence, as people feel directly involved in the design and implementation of solutions. This radically opposes any form of authoritarianism that suppresses local initiative in favor of a vertical injunction.

The experiences of "transition towns," for example, which aim to strengthen local autonomy and resilience in the face of peak oil and climate change, illustrate this bottom-up dynamic. These initiatives rely on collective intelligence and cooperation rather than state coercion. International environmental law, with agreements such as the Convention on Biological Diversity (1992), also emphasizes the importance of multi-level governance and local capacity building. The participation of indigenous peoples, whose territories still host 80% of global biodiversity (World Bank, 2021), is recognized as crucial for conservation.

Their approach to the world, based on a deep respect for natural balances, offers valuable perspectives for thinking about ecological governance that avoids the authoritarian trap. Education and culture: the foundations of a democratic transition Beyond legal and institutional frameworks, the transformation of mindsets through education and culture is essential to ensure a democratic ecological transition. It is not about imposing a way of life by force, but about enabling the emergence of an enlightened collective ecological consciousness.

Ecological literacy, the promotion of arts that question our relationship with nature, and the development of critical thinking are fundamental tools for sustainable citizenship. This approach promotes autonomy of judgment and the co-construction of solutions rather than obedience. It helps counter simplifying narratives that fuel the call for authoritarianism in times of crisis. The dissemination of scientific knowledge, coupled with education in participatory democracy, can empower citizens to engage actively and responsibly in the management of planetary commons.

It is in this path that the true resilience of societies in the face of ecological shocks lies, far from the siren calls of eco-authoritarianism. Chapter 68 Risk: Capture by Authoritarian States The Erosion of Democratic Norms Through Informational Capture The structuring of a resilient international order in the face of global environmental and social challenges requires multilateral engagement founded on principles of transparency, reciprocity, and responsible sovereignty. However, the rise of authoritarian states, exemplified by the People's Republic of China, the Russian Federation, and the Islamic Republic of Iran, exposes global governance systems to a systemic risk of capture.

This capture manifests not only through economic and geopolitical influence, but also through a reorientation of international narratives and normative frameworks towards models incompatible with the foundations of public international law and human rights. The concept of state capture, traditionally applied to interactions between private interests and the public apparatus, finds a macro-constitutional resonance here. It involves a gradual absorption of global regulatory institutions, not through individual corruption, but through an instrumentalization of decision-making and discursive mechanisms to the advantage of illiberal regimes.

The objective is to legitimize practices contrary to democratic values and to undermine the essential safeguards for any equitable and lasting international cooperation. The intrinsic nature of authoritarian regimes, characterized by the absence of multi-partisanship, constrained press freedom, and a judiciary under the sway of the executive power, renders any sincere adherence to international treaties or conventions potentially fallacious.

The ratification of such instruments by these states may be more a matter of an apparent integration strategy to better subvert their purposes, as illustrated by the adherence of many countries to the 1948 Universal Declaration of Human Rights, whose principles are frequently violated. Hannah Arendt, in *The Origins of Totalitarianism* (1951), already highlighted how political systems denying human plurality tend to distort reality and impose a single version of truth. This approach is transposed today into the international arena, where disinformation and normative rewriting constitute powerful instruments for the capture of global institutions and debates.

China's Strategy in Multilateral Institutions The People's Republic of China has demonstrated a sophisticated strategy of integration and influence within international organizations. Its status as a permanent member of the United Nations Security Council, obtained in 1971, grants it a strategic position to shape the global agenda. This influence is particularly noticeable in economic and technological domains, where Beijing actively promotes its development model, often to the detriment of democratic and environmental norms. The "Belt and Road Initiative" (BRI), launched in 2013, is a striking example.

Presented as a driver of development, it is perceived by some analysts as a tool for geopolitical expansion and debt creation for partner countries, particularly in Africa and Central Asia. The Center for Global Development estimated in 2018 that the BRI had placed 23 countries at risk of excessive debt to China. Beijing also deploys considerable efforts to influence United Nations organizations, particularly the Human Rights Council, where it strives to minimize criticism regarding the treatment of Uyghurs in Xinjiang or repression in Hong Kong.

The report by the Office of the High Commissioner for Human Rights on the situation in Xinjiang, published in August 2022, thus documented "serious human rights violations," allegations that China has systematically denied and criticized as interference. Furthermore, China has asserted itself as a major actor in financial and development institutions, such as the Asian Infrastructure Investment Bank (AIIB), which it launched in 2016. The AIIB, while incorporating international standards, is perceived as a counterbalance to the International Monetary Fund (IMF) and the World Bank, where Western influence is predominant, allowing Beijing to project its vision of economic development.

China's strategy is not limited to economics or human rights. It also concerns discussions on internet governance and emerging technologies. China actively promotes digital surveillance and information control models, which it seeks to export through international forums such as the International Telecommunication Union (ITU), endangering the vision of an open and free internet. Russian Influence and the Normative Fracture The Russian Federation, under the presidency of Vladimir

Putin, has undertaken a gradual break with the liberal international order established after the Cold War.

While it remains a key member of the UN Security Council, its action is frequently characterized by the offensive exercise of a veto to block any resolution contrary to its geopolitical interests, as in Syria or Ukraine. Since 2011, Russia has exercised its veto right 20 times on thematic resolutions or those dealing with specific situations, according to data from the Centre for Strategic Research and Analysis.

The annexation of Crimea in 2014 and the full-scale invasion of Ukraine in 2022 constituted flagrant violations of the fundamental principles of international law, notably Article 2 of the United Nations Charter prohibiting the threat or use of force against the territorial integrity or political independence of any state. These actions demonstrate a blatant disregard for the norms underpinning collective peace and security. Russia has also developed a strategy of informational interference and disinformation on a global scale. U.S.

State Department reports, such as the "Global Engagement Center" (2020), have highlighted vast networks of Russian state and non-state actors deploying propaganda campaigns aimed at undermining trust in Western democratic institutions and legitimizing its own actions. Domestically, Russia has progressively weakened checks and balances. The press is muzzled, with the adoption of laws on "foreign agents" or "fake news" that severely restrict freedom of expression. The NGO Reporters Without Borders ranked Russia 164th out of 180 countries in its 2022 World Press Freedom Index. The judiciary, for its part, is regularly criticized for its lack of independence from the executive power.

This strategy of normative destabilization is also expressed in forums where Russia is a member, such as the Council of Europe, from which it was excluded in March 2022 following the Ukrainian aggression, or the Organization for Security and Co-operation in Europe (OSCE), where it continues to obstruct observation or mediation missions. The objective is to fragment international consensus and promote a multipolar vision of the world where nation-states are free to act according to their interests, without excessive normative constraints.

Iran and the Instrumentalization of Regional Organizations The Islamic Republic of Iran, while not possessing the same economic or military weight as China or Russia, exerts significant regional influence and actively participates in the subversion of democratic norms, particularly in forums where human rights are discussed. The Iranian theocratic regime bases its legitimacy on a specific interpretation of Islamic law, which clashes with universal human rights standards, especially regarding gender equality and freedom of conscience. The repression of internal protest movements, particularly those led by women, illustrates this fundamental divergence.

The special report by the United Nations Special Rapporteur on the situation of human rights in the Islamic Republic of Iran, published in March 2023, details systematic violations, including executions, arbitrary detentions, and the use of torture, highlighting the absence of political and judicial pluralism. Iran is a member of several regional organizations, such as the Organization of Islamic Cooperation (OIC), where it attempts to influence resolutions in favor of its political and religious positions.

The OIC, which comprises 57 states, is a forum where debates on human rights are often polarized between a universal approach and a "culturally specific" approach that tends to justify practices contrary to international standards. Iran's role in the nuclear program, despite its commitments under the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (NPT), and recurring tensions with the International Atomic Energy Agency (IAEA), demonstrate a willingness to resist the imperatives of transparency and international verification. Iran's stock of highly enriched uranium exceeded 60 kg in 2023, a level deemed sufficient to produce several bombs, according to IAEA estimates.

These examples of capture and subversion erode the credibility of multilateral agreements and mechanisms. They underscore the imperative of developing robust safeguards to preserve the integrity of international regimes and the very substance of international law. Constitutional Safeguards for Democratic Multilateralism Faced with this threat of capture by authoritarian states, the architecture of multilateralism must integrate safeguards based on constitutional criteria, guaranteeing the sincerity and sustainability of states' commitments.

These criteria must be structured around the essential pillars of liberal democracy, namely political pluralism, press freedom, and the independence of the judiciary. Political pluralism, as defined by Robert Dahl in *Polyarchy: Participation and Opposition* (1971), implies freedom of organization and expression for different political forces, the holding of free and competitive elections, and the existence of an effective opposition. The absence of these conditions renders illusory any promise of cooperation based on popular consent and governmental accountability.

Article 21 of the Universal Declaration of Human Rights (1948) clearly states the right to participate in the government of one's country, directly or through freely chosen representatives. Freedom of the press is an indispensable pillar for the formation of an informed public opinion and the oversight of power. It guarantees the dissemination of diverse and sometimes contradictory information, allowing citizens to form their judgment and to control the actions of their governments. An international commitment without a free press is a commitment whose validity is constantly questioned, because it cannot be informed, criticized, or democratically amended.

The silence imposed by authoritarian regimes on human rights violations or fiscal commitments made under the BRI are striking illustrations of this. The independence of the judiciary is the indispensable corollary of the rule of law. It ensures that laws are applied impartially and that citizens' rights are protected against the arbitrary actions of the executive power. A judicial system under political sway cannot offer effective remedies against violations of a state's international commitments.

Referral to the International Court of Justice (ICJ) or the International Criminal Court (ICC) is often hampered by authoritarian states' refusal to recognize their jurisdiction, or by the absence of an internal justice system that allows for effective recourse. These ratification criteria should be integrated into international treaties, not as absolute preconditions for any participation, which might further isolate already reluctant countries, but as guiding principles, goals to be achieved, the absence or regression of which would justify the application of suspension clauses or revision of commitments.

Article 8 of the Principles on Goal 16 of the 2030 Agenda (Peace, Justice and Effective Institutions) underscores the importance of transparent and accountable institutions. Towards Proactive Constitutional Diplomacy The implementation of these safeguards implies a proactive "constitutional diplomacy," where democratic states condition their engagement with authoritarian regimes on tangible progress concerning these criteria. This can translate into conditionality clauses in trade agreements, reinforced transparency requirements in development projects, or independent verification mechanisms for environmental and social commitments.

The aim is not to export a democratic model by force, but to protect the integrity of the international order from temptations of instrumentalization. International law, to be effective, relies on good faith (pacta sunt servanda), but this good faith is intrinsically linked to a state's capacity to be bound by its own legislation and by a public sphere where criticism is possible. Without this, a treaty may be nothing more than a moratorium or a declaration of intent without substance.

The stakes are high: it is about preserving humanity's ability to collectively respond to existential challenges – climate change, health crises, resource depletion – within a framework of justice and respect for fundamental rights. A global governance where authoritarian regimes would dominate narratives and practices risks precipitating irreversible geopolitical fragmentation and an erosion of the universal values on which any prospect of a shared future rests.

Facing states that interfere in the politics of other nations via cyberattacks (such as the NotPetya operation in 2017 attributed to Russia, causing damages estimated at 10 billion dollars) or that practice "debt-trap diplomacy" (according to some, as in the case of the Hambantota port in Sri Lanka, ceded to China for 99 years), a normative and political reaction is imperative. The rethinking of multilateralism must involve an uncompromising reaffirmation of the principles of the rule of law and democracy as inseparable conditions for fair and effective international cooperation.

Chapter 69 Risk: Institutional Greenwashing The Aporias of International Normative Engagement The architectonics of contemporary international law are characterized by a normative proliferation which, far from guaranteeing its effectiveness, highlights a growing dissonance between the solemn expression of political wills and their concrete translation into state actions. The phenomenon of *institutional greenwashing*, or eco-whitewashing, fits into this breach, denoting the practice by which states or international organizations adorn themselves with a fake environmental virtue, without however undertaking the structural reforms necessary for a profound ecological transition.

This gap erodes the credibility of international legal and political instruments, undermining the trust of citizens and non-state actors. The ratification of international treaties, such as the Paris Agreement on climate in 2015, is often celebrated as a major step forward, but the implementation of its provisions largely depends on the political will of signatory states. However, this will frequently clashes with short-term economic and geopolitical rationales, as well as the persistence of outdated national legal frameworks.

The multiplication of Conferences of the Parties (COPs) without sufficient binding results, national emission reduction targets (NDCs) often deemed insufficient by science, or the continuation of fossil fuel subsidies, are flagrant illustrations of this. The Mirage of Universal Declarations and the Reality of Sovereign Derogations Since the Rio Declaration of 1992, the precautionary principle has been regularly invoked in international texts, yet its transposition into domestic law remains heterogeneous and often weakened by economic considerations (cf. Article 1.2 of the judgment of the Court of Justice of the European Union in the case *Pfizer Animal Health* v. Council, 2002).

Soft law, for example, via Agenda 21s or the European Strategy for Sustainable Development, while educational, intrinsically lacks binding force. States generally adhere to it with less reluctance than to rigid conventions, precisely because the margin for interpretation and non-application is wider. The case of commitments made under the 1992 Convention on Biological Diversity is particularly illuminating. The Aichi Biodiversity Targets, set in 2010 for the period 2011-2020, notably stipulated that 17% of terrestrial and inland water areas and 10% of marine and coastal areas should be effectively conserved.

However, a UN report published in September 2020 revealed that none of these 20 targets had been fully met, highlighting the difficulty of moving from intention to action. This dismal record underscores the abyssal gap between displayed ambitions and concrete results. The Cost of Inaction and the Loss of Institutional Credibility Institutional greenwashing generates considerable direct and indirect costs. On an environmental level, inaction masks the continuous degradation of ecosystems, global warming, and the erosion of biodiversity. The 2023 IPCC report confirms that global greenhouse gas emissions continue to rise, reaching unprecedented levels, despite repeated commitments.

This divergence leads to inestimable future economic losses related to natural disasters, the degradation of ecosystem services, and impacts on human health. On a socio-political level, the repetition of unfulfilled commitments undermines public confidence in national and international institutions. Ecological protest movements, such as *Extinction Rebellion* or *Youth for Climate*, testify to growing distrust towards political elites, accused of prevaricating in the face of urgency.

This crisis of legitimacy risks leading to "normative fatigue" where new announcements would be perceived merely as communication exercises devoid of substance, thus making any future mobilization more difficult. The Impunity of Failures and the Notion of State Fault Public international law struggles to establish effective sanction mechanisms in cases of non-compliance with environmental commitments. The notion of state fault, although present in the Principles on State Responsibility for Internationally Wrongful Acts of the UN International Law Commission (2001), is difficult to apply in the context of obligations of means rather than results.

States can argue internal constraints, the complexity of challenges, or economic competition to justify their delay. Moreover, climate or environmental litigation, although increasing, struggles to circumvent the sovereign immunity of states or to impose significant reparations. The *Urgenda* case against the Netherlands (2019), while marking a jurisprudential turning point by obliging the Dutch state to intensify its emission reduction efforts, remains an exception. The absence of an international jurisdiction with sufficient coercive power in environmental matters creates a vacuum that enables greenwashing due to the lack of a truly binding liability regime.

The Contours of New Environmental Governance: Towards Enhanced Accountability Mechanisms To counteract institutional greenwashing, it is imperative to transform international environmental governance. This must transition from a declarative and incentive-based approach towards a more rigorous and transparent accountability framework. The integration of automatic withdrawal mechanisms in cases of non-compliance with measurable criteria could constitute a powerful lever for aligning actions with words, following the model of forfeiture clauses observed in business law or international disarmament treaties.

This renewed paradigm is based on the idea that international environmental commitments cannot remain mere declarations of intent. They must be perceived as synallagmatic contracts between states and the global community, the deliberate non-performance of which would entail concrete consequences. Such an approach could restore the legitimacy and effectiveness of international law, transforming the risk of "losing face" into the risk of tangible sanction. Environmental Open Data as a Shield Against Opacity Transparency is the first line of defense against greenwashing. Making key, harmonized, and verifiable environmental indicators available as open data is indispensable.

These data should cover a wide spectrum, ranging from greenhouse gas emissions (by sector and by state) to changes in biodiversity (extinction rates, state of ecosystems), as well as public and private expenditures allocated to the ecological transition. The United Nations Environment Programme (UNEP) or the European Environment Agency (EEA) could play a central role in the collection, centralization, and dissemination of these data, using standardized protocols to ensure their comparability. Secure digital platforms, supplied by states and audited by independent organizations, would allow for real-time monitoring of progress and shortcomings.

Universal access to this information would create continuous citizen and scientific pressure, promoting the early detection of greenwashing practices and stimulating action. Comparing data between states could also generate a dynamic of positive emulation, similar to what is observed with certain international rankings (e.g., Transparency International's Corruption Perception Index). Automatic Withdrawal Mechanisms and Trigger Thresholds The concept of automatic withdrawal would be intrinsically linked to the establishment of clear and measurable environmental performance thresholds.

These thresholds would be defined by groups of scientific experts (similar to the IPCC) and validated by multilateral deliberative bodies. For example, a State signatory to the Paris Agreement could be subject to a "climate suspension" mechanism if it fails to reduce its annual emissions by X% over a period of three consecutive years, according to the targets it has set for itself via its Nationally Determined Contribution (NDC) or sectoral targets.

A concrete example could be this: if, according to public data verified by an independent agency, the absolute CO2 emissions of State X increase by 5% per year between 2027 and 2029, while its NDC for 2030 foresees a 20% reduction compared to 2005, this would trigger a signal. If a withdrawal mechanism is activated, it could result in the suspension of international climate-related development aid, exclusion from certain environmental negotiation forums, or even targeted economic sanctions.

Reforming the International Legal Architecture in the Face of Biospheric Urgency The proposal of automatic withdrawal in cases of measurable non-compliance over three consecutive years, far from being punitive, aims to strengthen the integrity of the international normative system. It would introduce a dimension of "conditional accountability" which could encourage states to internalize their commitments more seriously.

This mechanism would be anchored in a reinterpretation of sovereignty: the exercise of sovereignty would no longer be merely the right to act freely, but also the obligation to respect collective rules for the common good, particularly when the survival of planetary ecosystems is at stake. This approach requires an evolution of international law, going beyond the principle of non-interference in the internal affairs of states, to recognize a "responsibility to protect" the global environment, analogous to the concept of "Responsibility to Protect" (R2P) with regard to populations (UN Security Council resolution 1674, 2006).

The climate emergency and the biodiversity crisis justify such an evolution, where severe harm to planetary common goods would be considered a quasi "violation of the fundamental right of future generations" (L. Dubouis, "Le droit fondamental des générations futures", *Revue juridique de l'environnement*, 1999). Challenges of Implementation and the Role of Non-State Actors The implementation of such mechanisms would inevitably encounter political resistance. States might argue infringements of their sovereignty, the complexity of evaluation, or fears of economic distortions.

To overcome these obstacles, it is essential to involve states upstream in the definition of indicators and thresholds, to guarantee independent and unanimously recognized scientific expertise, and to provide for conciliation and appeal mechanisms. The role of non-state actors – civil society organizations, businesses, scientists – would be crucial. They could serve as sentinels, alerting to discrepancies between state commitments and practices, and offering counter-expertise. For example, "Climate Action Tracker," an independent research project, already analyzes countries' climate targets and assesses whether they are compatible with the goals of the Paris Agreement.

Its data show that as of December 2023, the majority of NDCs were "insufficient" or "highly insufficient" to limit warming to 1.5°C. A

Constitutional Perspective: The "Constitutionalization" of Ecological Obligations At a national level, one approach is to "constitutionalize" ecological obligations. Countries like France, with the integration of the Environment Charter into its Constitutional Block (2005), or Ecuador, which enshrined the rights of Nature in its 2008 Constitution, show the way.

The development of fundamental texts that dedicate not only the right to a healthy environment, but also the duty of public authorities to preserve it, offers a more robust national legal framework against greenwashing. Article 2 of the French Environment Charter, which states that "Everyone has a duty to participate in the preservation and improvement of the environment," or Article 71 of the Ecuadorian Constitution which recognizes the right of ecosystems to exist and maintain their vital cycles, provide bases for challenging public inaction.

The case *Notre Affaire à Tous* and others against the French State (2021) is an illustration, where the administrative justice recognized the wrongful failure of the State in the fight against climate change. By combining binding national frameworks with international accountability mechanisms, it would be possible to create a legal safety net guaranteeing the ecological transition.

Chapter 70 Risk: Monetary Instability in Transition NOÖS: A Counter-Hegemonic Monetary Architecture The emergence of a New Monetary Organization (NOÖS) presents itself as a structural response to the intermittencies and fragilities inherent in the current international monetary system, primarily based on the US dollar. Initiated by the 2042 Mount Washington Agreements, NOÖS aims to de-dollarize international trade and introduce a basket of currencies as a standard, integrating strong state currencies and a supranational unit of account, the "Terra" (XTR).

This multilateral architecture, far from being risk-free, particularly regarding stability, aims to be more resilient to asymmetric shocks and unilateral monetary policies (Eichengreen, 2011, *Exorbitant Privilege*). The major challenge lies in managing the transition from the established monetary regime to this new configuration. The coexistence of national currencies with variable convertibility regimes and the Terra, whose value is intrinsically linked to baskets of essential goods and natural resources defined by the Council for Ecological Stability (CES), creates unprecedented arbitrage and speculation opportunities.

According to data from the Bank for International Settlements (BIS), foreign exchange market transaction volumes reached a historic peak of $7.5 trillion per day in 2038, demonstrating a strong propensity for currency pair speculation. NOÖS raises the fundamental question of monetary sovereignty within a framework of global economic governance. While the objective is to reduce the hegemony of a single currency, the coordination of national monetary policies with the International Central Bank (ICB) remains a critical point.

The constitutive treaty of NOÖS, Article 14, §3, explicitly stipulates the obligation for member states to maintain the parity of their national currency against the Terra, or failing that, within the defined fluctuation bands. De-dollarization and Structural Arbitrage The de-dollarization process, initiated in response to unilateral extraterritorial sanctions and the volatility of the US dollar, precipitated international monetary reform. From the early 2030s, the dollar's share in central banks' global reserves fell from 59% to 47% in five years (International Monetary Fund, 2035).

This transition was accompanied by a fragmentation of capital markets, where investors sought to diversify their assets into currencies deemed more stable or less exposed to geopolitical risks. The introduction of the Terra, backed not by gold but by a basket of critical raw materials and verified carbon credits – the "ResCo" (Resource Composite Index) –, aims to stabilize the fundamental value of this supranational instrument. This mechanism, detailed in Regulation [EU]

2043/12 of March 14, 2043, on the creation of the Terra, gives an ecological dimension to monetary policy, establishing a direct link between the value of the currency and the preservation of finite resources.

However, the coexistence of the Terra with traditional fiat currencies generates significant arbitrage opportunities. Financial market actors can exploit value divergences between the Terra, whose fluctuation is theoretically cushioned by the ResCo, and national currencies whose value is more subject to monetary policy decisions and national economic fundamentals. This phenomenon, exacerbated by information asymmetry and the complexity of high-frequency trading algorithms, can generate speculative bubbles and macroeconomic imbalances. The risk of arbitrage is all the more significant as the monetary policies of NOÖS member states are not perfectly aligned.

Divergences in national interest rates, in particular, can encourage capital flows to areas offering the best nominal returns, to the detriment of the exchange rate stability provided by the NOÖS mechanism. This "carry trade" on a supranational scale can potentially destabilize weaker currencies, exerting downward pressure and making their pegging to the Terra more difficult. Fluctuation Bands and ICB Intervention To contain speculative movements and ensure minimal stability of exchange rates within NOÖS, the Mount Washington Treaty (Art. 23) established a system of fluctuation bands for national currencies against the Terra.

These bands, with an initial width of ±5%, are intended to absorb short-term shocks without triggering massive and costly interventions by the ICB. This mechanism is inspired by, albeit more sophisticated than, the European Monetary System (EMS) and its Monetary Solidarity Instrument (MSI) of the 1980s (Issing, 2008, *The Birth of the Euro*). As soon as a national currency reaches the upper or lower bounds of its fluctuation band against the Terra, the ICB is mandated to intervene in the foreign exchange market. These interventions may take the form of purchases or sales of the national currency concerned in exchange for Terra or other reserve currencies held by the ICB.

The objective is to bring the parity of the national currency back within the band, thereby signaling the ICB's commitment to the stability of the system. The effectiveness of these interventions depends on several critical factors: the size of the ICB's reserves, the credibility of its commitment, and the depth of the foreign exchange markets. Article 31 of the founding NOÖS treaty states that the ICB's stabilization fund must be endowed with at least 10 trillion Terra in reserves, stemming from mandatory contributions from member states and revenues generated by Terra transactions. This significant endowment aims to deter massive speculative attacks.

Furthermore, the ICB has tools for coordinating monetary policies, particularly through swap lines between national central banks and the ICB, allowing for rapid liquidity adjustment in case of tension. These tools are designed to prevent reserve depletion in the event of systemic shocks affecting several currencies simultaneously, a risk identified particularly by Obstfeld and Rogoff (1995) concerning currency crises. The Tension between Sovereignty and Stability The system of fluctuation bands and ICB interventions pose a fundamental dialectical tension between national monetary sovereignty and systemic stability.

A member state whose currency persistently depreciates, reaching the lower bound of its band, is forced to implement recovery policies (fiscal adjustment, interest rate hikes) or to devalue its currency in concert with the ICB. Conversely, excessive appreciation would imply measures to curb growth or lower rates. This constraint on national monetary policy can be perceived as an intrusion into the autonomy of states. Debates were heated during the drafting of the Mount Washington Treaty, particularly from emerging countries wishing to retain maximum flexibility to stimulate their economic growth.

However, the International Central Bank, through its tripartite governance (representatives of states, independent experts, CES members), was designed to ensure impartiality and technical expertise independent of immediate national political imperatives. Maintaining the fluctuation bands requires budgetary discipline and rigorous macroeconomic management from member states. Too significant a divergence of national economic policies from NOÖS stability objectives could lead to unsustainable tensions and threaten the integrity of the system, as shown by the persistent difficulties within the Eurozone in harmonizing fiscal policies.

The NOÖS Economic and Financial Committee (EFC) is responsible for monitoring and making recommendations to member states to prevent such deviations. Speculation and Globalized Systemic Risks The transition to NOÖS is taking place in a context of exacerbated global financialization, where daily transaction volumes (nearly $8 trillion in 2045 according to the BIS) far exceed trade in goods and services. Speculation, intrinsically linked to the pursuit of profit and the valuation of asymmetric information, can destabilize any monetary system, regardless of its sophistication.

Within the framework of NOÖS, speculation on parities between national currencies and the Terra is made possible by the existence of these very fluctuation bands. Speculators can bet on a national central bank's inability to defend its parity, especially in cases of insufficient reserves or structural economic weakness, thereby triggering speculative attacks. These attacks can be self-fulfilling, forcing devaluation or withdrawal of a currency from the system. The role of trading algorithms, capable of analyzing massive information flows and executing transactions at infra-millisecond speeds, amplifies this risk.

A market anomaly or an unfounded rumor can quickly be transformed into a massive selling or buying movement, creating "flash crashes" or ephemeral bubbles. The 2041 OECD report on financial market regulation emphasized the need for increased surveillance and "kill-switch" mechanisms to disconnect algorithms in case of abnormal movements. Systemic risk manifests when the failure of a NOÖS member currency, following a speculative attack or deteriorated economic fundamentals, leads to contagion of others.

The perception of a weak link's vulnerability can erode confidence in the entire system, leading to a generalized capital flight towards the Terra or other assets deemed safer, in this case, the currencies of the most stable economies such as the Digital Yuan or the Euro. Market Regulation and Crisis Prevention To prevent these risks, the NOÖS integrates a robust multilateral regulatory framework. The ICB, in collaboration with national regulatory authorities (e.g., the European Securities and Markets Authority, ESMA), is endowed with surveillance and intervention powers.

This includes the ability to limit the leverage of financial institutions active in foreign exchange markets, to impose financial transaction taxes (Tobin, 1972) to curb short-term speculation, and to ensure transparency of operations. The Basel III Committee (2032) established new capital and liquidity requirements for internationally operating banks, with a higher weighted risk factor for exposures to currencies outside the fluctuation bands. These macroprudential measures aim to strengthen the banking system's resilience to monetary shocks and reduce the likelihood of contagion. Furthermore, NOÖS provides for crisis resolution mechanisms, inspired by the work of the IMF.

In the event of a member state's failure to maintain its parity, an aid plan can be activated, conditional on structural reforms. This approach aims to minimize the social and economic costs of adjustments and preserve the integrity of the monetary system in a broader sense. ICB Exchange Rate Policy and Terra Management The exchange rate policy of the International Central Bank (ICB) is at the heart of NOÖS stability. Unlike national central banks, whose primary objective is often to stabilize domestic prices or support growth, the ICB's main mission is to guarantee the stability of the Terra's value and the cohesion of the parity system.

The management of the Terra, which is not a classic fiat currency but a unit of account backed by the ResCo (Resource Composite Index), is complex. Its value is not determined solely by the supply and demand for money, but also by the prices of the raw materials and carbon credits that compose it. Variations in natural resource prices or global climate policies can thus directly affect the value of the Terra, and by extension, the entire NOÖS system. The ICB must therefore monitor not only capital flows and the economic fundamentals of member states, but also commodity markets and global environmental indicators.

This expanded role, involving close collaboration with the Council for Ecological Stability (CES), gives an unprecedented dimension to monetary policy, integrating the imperatives of ecological sustainability with financial stability. To this end, the ICB has levers of action: it can adjust the weighting coefficients of the ResCo components, with the approval of the CES, based on resource scarcity or climate objectives. It can also issue or withdraw Terra from the market to manage global liquidity and influence its value, although this action is constrained by "ecological reserve" rules that limit monetary creation backed by finite resources.

ICB Credibility and Terra Acceptance The credibility of the ICB is a determining factor for the acceptance and stability of NOÖS. This credibility stems from its operational independence from national governments, the clarity of its communication (annual report on monetary stability, quarterly economic bulletins), and its ability to keep its commitments. The ICB statutes (Article 5, paragraph 2) guarantee this independence by prohibiting any instruction from member states or other institutions. The acceptance of the Terra as an international reserve currency and unit of account is progressive.

ICB data show that in 2045, the Terra already represents 18% of global foreign exchange reserves, surpassing the IMF's Special Drawing Rights (SDRs) (which rose from 3% to 8%). This progress is encouraged by bilateral and multilateral NOÖS agreements, which promote the use of the Terra in commercial exchanges and financial transactions. However, confidence in the Terra also rests on the perception of its fundamental value, anchored in ecological considerations. The CES's ability to guarantee the traceability and verifiability of "carbon credits" and "critical raw materials" underlying the ResCo is essential.

Any suspicion of manipulation or weakness of this ecological basis could erode confidence and destabilize the supranational currency. Therefore, the stability of NOÖS will not solely be the result of economic rationality or the power of regulatory mechanisms. It will intrinsically depend on the ability of actors, state and financial, to adhere to a renewed monetary vision, where ecological economics is linked to political philosophy in a quest for systemic resilience.

Chapter 71 Risk: Cultural Rejection of Mundia The Making of Mistrust: Genesis of a Conceptual Rejection The emergence of Mundia, as a transnational normative and institutional framework, has, from its theoretical beginnings in the early 21st century, prompted a series of fundamental criticisms centered on its potential for hegemony. These concerns are rooted in a historical apprehension of the asymmetric power dynamics that characterized post-Westphalian international relations, particularly those between nations of the Global North and the Global South.

The notion of "neo-colonialism" has appeared, in this context, as the most incisive qualifier to denounce a structure potentially reproducing patterns of extraction and domination, even if Mundia's stated intentions were explicitly oriented towards climate justice and global ecological sustainability. This mistrust is fueled by a critical analysis of past and present mechanisms of global governance.

Institutions such as the World Bank and the International Monetary Fund have been, and still are, frequently accused of perpetuating economic conditionalities that undermine the sovereignty of developing states and favor the interests of dominant powers, as documented by Joseph Stiglitz in *Globalization and Its Discontents* (2002). The specter of a normative "mondialisation," imposing technical, legal, or environmental standards that, although potentially universal in intention, would be conceived from Western epistemic and axiological frameworks, constitutes the core of these apprehensions.

The controversy surrounding the Antarctic Treaty of 1959, which, while applauded for setting aside the continent for scientific research, was also perceived by some as a form of condominium of the signatory powers to the detriment of newly independent nations without direct access to polar research, illustrates this tension. The management of the "common heritage of mankind," from the law of the sea (Montego Bay Convention, 1982) to outer space (Outer Space Treaty, 1967), has often been the scene of disputes revealing profound divergences on the modalities of benefit sharing and the relative weight of national sovereignties in the face of the imperative of global management.

Post-colonial theorists, such as Gayatri Chakravorty Spivak (*Can the Subaltern Speak?* 1988), emphasize how universalist categories can, paradoxically, invisibilize and marginalize local knowledge and practices. The application of a single legal and ecological framework, devoid of profound contextualization and recognition of the plurality of ontologies, is perceived as a major risk of cultural erasure and devaluation of non-Western ways of life, even if the latter often prove more sustainable. The question of democratic legitimacy is also central.

If Mundia aspires to global governance, its decision-making process must imperatively transcend technocratic expert assemblies to embrace genuine transnational deliberation. The absence of a global "demos" and the predominance of nation-states in the current UN architecture, for example, are major obstacles to this legitimacy, as Daniele Archibugi analyzes in *Debating Global Democracy* (2008), accentuating the risk that Mundia will be perceived as a superstructure imposed from above, rather than as a collective emanation. The Historical Burden of Universality The call for universality, often wielded by global structures, has historically masked processes of domination.

The civilizing missions of the colonial era, justified by the propagation of "universal values," in reality served to legitimize the exploitation of resources and populations. This is what Dipesh Chakrabarty explains in *Provincializing Europe* (2000), demonstrating how European rationality proclaimed itself universal, downgrading all other forms of thought. Mundia is thus confronted with a colossal epistemological and ethical challenge: how to construct a universality that is not merely the projection of one part of the world onto the whole?

The failure of the Millennium Development Goals (MDGs) to durably reverse inequalities, despite notable progress on certain indicators, is often attributed to their "top-down" conceptual framework and insufficient involvement of local actors in their elaboration and implementation. The risk that Mundia, even driven by the best ecological intentions, becomes the new figurehead of an imperial universality, is therefore not negligible. This is not just a question of procedure, but of a profound re-evaluation of the very foundations of knowledge and decision-making.

The construction of trust requires a radical decentering of perspectives, integrating the plurality of epistemologies and local knowledge, particularly those related to ecosystem management. Architectures of Prevention: Against Hegemonic Anachronisms Faced with this perception of "neo-colonialism," Mundia's designers have integrated structural safeguards aimed at preventing any hegemonic drift. These measures, far from being anecdotal, form the bedrock of its legitimacy and cultural acceptability on a planetary scale, recognizing that global sustainability can only be achieved through an inclusive approach that respects epistemic and linguistic sovereignties.

The principle of strict bilingualism, or even institutional multilingualism, is one of these pillars. Mundia is committed to never replacing mother tongues, but to complementing them. Every key document, every important deliberation, every major communication from Mundia must be available in at least two of the main working languages (which extend beyond the mere Anglophone and Francophone framework to include Mandarin, Spanish, Arabic, Swahili, Hindi, Russian, etc., depending on the geographical areas concerned).

The objective is to guarantee not only access to information but also effective participation and symbolic recognition of global linguistic diversity, estimated at over 7,000 living languages today according to Ethnologue. This approach contrasts with the almost unilingual predominance of English in many international bodies, which, although pragmatic, de facto creates an obstacle to the participation of non-natives and fosters thought shaped by Anglo-Saxon conceptual frameworks.

Mundia's language policy boldly goes beyond mere translation; it promotes the training of multilingual executives and the development of high-fidelity simultaneous translation tools, facilitating direct interaction between speakers of different languages, without privileging a pivot language. Education, a Vector of Autonomy and Co-construction Free and universal education, under the aegis of Mundia, constitutes another decisive measure to counteract dynamics of exclusion.

By guaranteeing equal access to knowledge, from literacy to complex ecological skills, Mundia aims to empower individuals and communities, enabling them to appropriate global issues and participate fully in their resolution. Mundia's educational programs are designed in a decentralized manner, with a strong local component, in order to respect cultural specificities and endogenous knowledge.

The teaching of the circular economy, for example, integrates not only universal scientific principles but also ancestral practices of resource management and frugality specific to each region, as illustrated by traditional African agricultural systems or the sustainable silviculture practices of indigenous peoples in the Amazon. This education also includes critical training on the challenges of globalization and power dynamics, enabling Mundia citizens to analyze projects and policies from an informed angle, far from any ideological injunction.

Access to quality education is a prerequisite for the exercise of full global citizenship, capable of discernment and informed participation, as highlighted by UNESCO reports on education for the 21st century. The Commons of Knowledge: The Strength of Free Licenses The third fundamental pillar is Mundia's unwavering commitment to open access resources. All of Mundia's intellectual productions – scientific data, technical protocols, legal models, educational works, software – are systematically published under open licenses (such as Creative Commons or free software licenses), ensuring their free access, reuse, modification, and redistribution by anyone, anywhere in the world.

This approach radically breaks with traditional intellectual property regimes that have often served to monopolize knowledge and technology, creating dependencies and inequalities. The "digital divide," which has long deprived a significant portion of humanity of access to technological and scientific advances, is thus combated not only through infrastructure but through a philosophy of intrinsic sharing.

The objective is twofold: to accelerate the dissemination of solutions to ecological crises (for example, design plans for water depollution systems or renewable energy production) and to stimulate collaborative innovation, enabling everyone to contribute to the improvement and adaptation of these resources. In 2024, the number of scientific publications available in "open access" exceeded 50% of the total, demonstrating a strong trend that Mundia wishes to generalize. This policy is in line with the work of Lawrence Lessig on "free software" and the importance of digital "commons" (*Code and Other Laws of Cyberspace*, 1999).

Epistemic Vigilance: Decentralizing Knowledge for Better Action The construction of Mundia requires constant "epistemic vigilance" against the temptations to impose a single model of knowledge or development. This implies an active recognition of the plurality of knowledge and ways of existence, as an indispensable richness for solving complex environmental crises. Anthropologist Philippe Descola, with his work *Beyond Nature and Culture* (2005), highlighted the diversity of human ontologies, demonstrating that there is not one single way of conceiving the relationship between humans and nature.

Animistic, totemic, or analogical approaches, characteristic of many non-Western cultures, offer valuable perspectives on reciprocity and interdependence with the living world, often absent from Western dualistic frameworks. Mundia seeks to integrate these different rationalities into its decision-making processes. For example, the management of primary tropical forests is not based solely on ecological models calculated at the global level, but integrates the ancestral knowledge of forest peoples on regeneration cycles, sustainable uses, and local biodiversity.

Studies have shown that territories managed by indigenous communities had significantly lower deforestation rates – 2 to 3 times lower in the Brazilian Amazon – than adjacent areas (Nepstad et al., *Science*, 2006). Mundia's Plural Law: A Reinterpretation of Sovereignty Mundia's jurisprudence is designed to be open to the plurality of legal systems. Rather than imposing a monolithic law, it seeks to articulate universal principles of environmental justice with respect for customary rights and local legalities. This involves the establishment of hybrid tribunals, where jurists trained in different legal systems (civil law, common law, Islamic law, customary law) can collaborate.

The "Earth Charter" (Drafted by the Earth Council & Green Cross International, 1997-2000), although not legally binding, served as a philosophical matrix for the elaboration of transnational ethical principles based on respect and universal responsibility. Mundia attempts to translate these principles into concrete obligations, while allowing room for adaptation to local realities, recognizing that the implementation of a single norm may require differentiated approaches depending on socio-cultural and ecological contexts. The recognition of "rights of nature," already enshrined in the Constitutions of Ecuador (2008) and Bolivia (2009), is a clear example of this openness.

Mundia considers these advances as strong signals in favor of a profound revision of legal anthropocentrism and the integration of non-human entities into the field of legal protection. The challenge is to articulate these rights with human rights, from a perspective of interdependence rather than opposition. Intercultural Dialogue and Capacity Building: Building Adherence Mundia's success will ultimately depend on its ability to transform mistrust into trust, and otherness into partnership. This requires structured intercultural dialogue mechanisms and massive investment in local capacity building.

Randomly selected "Global Citizens' Assemblies," composed of individuals representative of humanity's geographical, cultural, socio-economic, and linguistic diversity, are planned to accompany Mundia's legislative and decision-making processes. These assemblies would have a consultative role, but their opinions would be publicly debated and taken into account in the final deliberations. This mechanism aims to remedy the democratic deficit inherent in any supranational structure, by introducing a form of deliberative democracy on a planetary scale, inspired by Jürgen Habermas's work on the communicative public sphere (*The Theory of Communicative Action*, 1981).

These assemblies would be provided with resources for simultaneous interpretation in all participants' mother tongues, as well as prior training on the technical and scientific issues concerned, to ensure informed and balanced participation, without domination by any single group or language. Gender parity and the representation of youth and indigenous peoples would be institutionalized, ensuring a diversity of perspectives. Investing in Technical and Managerial Autonomy Capacity building is not limited to academic training.

It encompasses the transfer of appropriate technologies, the development of local technical and managerial skills, and the promotion of social and ecological entrepreneurship. Rather than providing turnkey solutions, Mundia collaborates in building community autonomy. For example, the establishment of decentralized renewable energy-based energy networks in isolated villages is accompanied not only by the transfer of equipment but also by the training of local teams in the maintenance, management, and innovation of these systems, creating new economic sectors and employment.

In 2023, the European Union's Joint Research Centre documented that investments in local solar and wind energy production capacities reduced the average cost of electricity in certain sub-Saharan African regions by 15% in just five years. Mundia's projects are systematically evaluated on their ability to generate autonomy and to be taken over by local actors. A project that would generate continuous dependence would not be considered a success, even if it achieved its immediate ecological objectives.

This pragmatic approach, anchored in local realities, is the only credible antidote to the accusation of neo-colonialism, transforming Mundia from an overarching body into a true partner for global sustainability. Chapter 72 Risk: North-South divergence The Genesis of Divergence: An Asymmetrical Trajectory of Development and Impact The historiography of international relations reveals a persistent cleavage between the North and the South, not only economically and socially, but also environmentally. This gap, often referred to as the North-South divergence, originates from the dynamics of industrialization and development over the past two centuries.

Northern nations, pioneers of the industrial revolution, benefited from growth fueled by the intensive exploitation of fossil resources, thereby laying the foundations of their current prosperity. This trajectory led to a historical accumulation of greenhouse gas (GHG) emissions, the primary cause of anthropogenic global warming. The so-called developed countries, grouped within the Organisation for Economic Co-operation and Development (OECD), have contributed disproportionately to this atmospheric burden.

As early as 2007, the report by the Intergovernmental Panel on Climate Change (IPCC) highlighted that the Annex I countries of the Kyoto Protocol, predominantly industrialized, were responsible for the major part of cumulative emissions since 1750. In contrast, Southern nations, often designated as developing countries or emerging economies, acceded to the industrialization process later and under different economic and technological conditions. Their development has been marked by structural constraints, a legacy of colonization and unequal trade patterns, limiting their capacity to adopt less carbon-intensive development paths.

The notion of “common but differentiated responsibilities,” enshrined in Principle 7 of the 1992 Rio Declaration, recognizes this historical and current asymmetry. This principle is at the heart of international climate negotiations, where Southern countries demand recognition of their right to development and the impossibility of assuming the same strict emissions reduction constraint as countries that have historically polluted. The Human Development Index (HDI) highlights this disparity, with an average HDI of 0.79 for high-income countries in 2021, compared to 0.55 for low-income countries, according to the United Nations Development Programme (UNDP).

This correlation between economic development and past ecological footprint is a fundamental datum of the divergence. The Under-Emitters: Climate Justice in Abeyance An often-overlooked aspect of the divergence is the status of many Southern countries as under-emitters. Even before the establishment of ambitious emissions quotas, a significant portion of the world's population lives in regions where per capita emissions are below the global average and, even more so, below what would be considered an equitable share of the remaining carbon budget. According to the Global Carbon Project, in 2022, global average per capita emissions were approximately 4.7 tonnes of CO2 equivalent.

Many sub-Saharan African countries, for example, emit less than one tonne per person per year. This observation poses a major ethical and political challenge. Imposing identical or proportionally strict reduction quotas based on current emission levels, without considering historical context and developmental needs, would perpetuate an intrinsic inequality. The United Nations Framework Convention on Climate Change (UNFCCC) of 1992, by reaffirming common but differentiated responsibilities, already attempted to integrate this complexity, but its full application remains a constant point of contention.

The refusal of restrictive quotas by Southern countries is therefore a rational stance, rooted in the principle of intergenerational and intragenerational equity. It is not a denial of the climate problem but a legitimate demand that the cost of adjustment should not fall disproportionately on those who have contributed least to the problem and have the least capacity for adaptation. This refusal is also a manifestation of national sovereignty in the face of injunctions perceived as hegemonic.

The Initial Vital Budget: A Corrective and Weighted Approach In the face of this North-South divergence and the legitimate refusal of under-emitting countries to accept constraints deemed unfair, the conceptualization of an "initial vital budget" offers a path to resolution. This concept aims to transcend the simple distribution of future emissions by integrating historical dynamics and the imperatives of environmental justice. The central idea is to distribute the remaining global carbon budget not linearly, but according to a weighting that takes into account the cumulative historical ecological debt.

The global carbon budget, as estimated by the IPCC, represents the maximum amount of carbon dioxide humanity can still emit to have a given probability of limiting warming to a certain level, for example, 1.5°C or 2°C above pre-industrial levels. In 2022, approximately 400 gigatonnes of CO2 remained to have a two-thirds chance of limiting warming to 1.5°C, according to IPCC estimates in its sixth assessment report. This figure is the threshold beyond which the risks of overshoot and irreversible impacts drastically increase. The allocation of this vital budget cannot be fair if it ignores past contributions.

A modeling of this ecological debt involves quantifying the cumulative GHG emissions by each nation since a significant initial period, generally set at 1850 to coincide with the beginning of the intensive industrial era. This calculation is not limited to CO2 but must integrate all six greenhouse gases covered by the Kyoto Protocol, converting them into CO2 equivalents according to their global warming potential (GWP). Historical Ecological Debt: From 1850 to 2026 Historical ecological debt is a pivotal concept for rebalancing the North-South divergence.

It represents the sum of environmental damage caused by the overconsumption of resources and over-emissions by industrialized countries to the detriment of less polluting countries. This accounting is not limited to a simple carbon emissions tally but also integrates the depletion of natural resources and biodiversity loss, although the latter are harder to quantify exhaustively in monetary terms or quotas. The evaluation of this debt, from 1850 to 2026, is a complex but indispensable endeavor. Several studies, notably those by the Global Footprint Network, have attempted to assess the ecological "overshoot" of certain nations.

For example, the United States, despite housing about 4% of the world population, historically accounts for a much larger share of cumulative emissions. Between 1850 and 2021, the United States emitted 420 $GtCO_2$, or 20.4% of cumulative global emissions over this period, according to data compiled by the Carbon Brief think tank from databases such as the Global Carbon Project. The United Kingdom, the birthplace of the industrial revolution, also has a considerable historical debt. Its cumulative emissions between 1850 and 2021 reached 74 $GtCO_2$, or 3.6% of the world total, while its current population is less than 1% of the global population.

In contrast, many Southern countries show insignificant cumulative balances over the same period, contributing only very marginally to the current climate crisis. Integrating this ecological debt into the definition of the initial vital budget would allow for larger carbon "credits" to be allocated to under-emitting and historically less polluting nations, thus providing them with leeway for their future development without exceeding planetary boundaries. This would be a form of "drawing right" on the atmosphere, inversely proportional to the historical contribution to the crisis.

The Conference of the Parties (COP) to the UNFCCC in Copenhagen in 2009 saw proposals along these lines, although they were not formally adopted. Implementation and Challenges of an Equitable Carbon Budget The establishment of a global carbon budget distributed according to a historical debt logic raises complex implementation questions. The first lies in determining the most just and accepted calculation method for assessing cumulative emissions and the associated ecological debt. Debates persist regarding the inclusion of emissions from land-use change, the weighting of different GHGs, and the issue of “imported emissions” via consumer goods.

One proposal is to set an equitable per capita carbon budget for a given year and adjust it based on each country's past cumulative emissions. Countries that have exceeded this historical ceiling would be allocated a negative or greatly reduced budget, while those that have remained below it would benefit from a larger budget. This mechanism requires the establishment of a robust and legitimate international governance body, capable of collecting reliable data and enforcing decisions. The question of retroactivity is central. Some jurists dispute the relevance of retroactivity based on environmental standards that did not exist in the 18th or 19th centuries.

However, the notion of "environmental harm," as debated in international law (see *the Lake Lanoux Case*, ICJ, 1957, on the principles of good neighborliness and no harm), can serve as a basis. Furthermore, the recognition of fundamental human rights, including the right to a healthy environment, offers a strong ethical and legal basis for this retrospective approach. Transfer Mechanisms and Compensations The establishment of an initial vital budget weighted by historical debt necessarily implies resource transfer and compensation mechanisms.

Northern countries, having largely exceeded their "equitable share" of the carbon budget, would have to finance the energy transition and climate adaptation of Southern countries, in recognition of their responsibility. The annual financial target of 100 billion dollars for the Green Climate Fund (UNFCCC), agreed upon in 2009 in Copenhagen and reaffirmed in Paris in 2015, is a first milestone, but it is far from covering real needs. These transfers could take various forms: low-carbon development aid, transfer of clean technologies, direct investments in resilient infrastructure, and of course, direct payments for irreversible "loss and damage" related to climate change.

The proposal of economist Nicholas Stern (2006, *The Economics of Climate Change*) on the importance of massive and rapid investment to avoid exponential future costs supports this logic of transfers. A rethought international carbon market could also play a role. Rather than simply allowing quota exchanges between emitters, it could be structured so that Northern countries are forced to buy "emission rights" from Southern countries that have an surplus in their initial vital budget, thereby financing their low-carbon development. This would transform under-emitting countries into climate creditors, endowed with significant economic leverage.

Sovereignty and Development: The Path of Cooperation The refusal by Southern countries to accept undifferentiated quotas is fundamentally a matter of national sovereignty and the right to development. Article 2 of the International Covenant on Economic, Social and Cultural Rights (ICESCR) of 1966 recognizes the right of all peoples to self-determination and to freely pursue their economic, social, and cultural development. Any attempt to impose unilateral restrictions on emissions without historical consideration would be perceived as a violation of this right.

An approach based on the initial vital budget weighted by ecological debt offers a perspective of cooperation rather than confrontation. It allows for conciliation between the imperatives of climate justice and the developmental needs of nations. This approach requires a restructuring of global governance institutions, particularly within the United Nations, to give them greater legitimacy and enhanced arbitration capacity. The implementation of this framework also implies mutual recognition of responsibilities and vulnerabilities.

Northern countries must accept their historical role and obligations, while Southern countries must commit to sustainable and resilient development pathways, maximizing environmental, social, and economic co-benefits. The transition to green economies must be perceived not as a constraint, but as an opportunity to modernize economic structures and improve the well-being of populations. Ethics and Efficiency: The Two Pillars of Just Transition The argument for a weighted initial vital budget is not only ethical; it is also pragmatic. A global energy and ecological transition that does not account for historical inequalities would be doomed to failure.

The feeling of injustice would generate persistent political roadblocks, slowing down or even nullifying the collective efforts needed to achieve the objectives of the 2015 Paris Agreement. The historical inertia of greenhouse gas emissions demands rapid and coordinated action. If justice and efficiency cannot be reconciled, the scenario of exceeding planetary boundaries, with its disastrous consequences, becomes inevitable. The impacts of climate change, already visible with the increase in extreme weather events, droughts, and floods, disproportionately affect Southern countries, reinforcing the need for justice and solidarity.

The IPCC's 2022 report on impacts, adaptation, and vulnerability is unequivocal on this point. The ethical dimension of climate justice is highlighted by philosophers like Henry Shue (1993, "Subsistence Emissions and Luxury Emissions"), who distinguishes between subsistence emissions, necessary for life and fundamental development, and luxury emissions, superfluous and linked to overconsumption. This distinction paves the way for a hierarchy of responsibilities and a more equitable distribution of the decarbonization burden.

Rights and Duties in the Anthropocene The Anthropocene, this new geological era where human activity is the primary force transforming ecosystems, requires a redefinition of the rights and duties of nations. The right to development can no longer be interpreted as an unlimited right to emit but as a right to sustainable and just development that integrates planetary boundaries. Simultaneously, countries historically responsible for emissions have a duty to repair the wrongs caused and to facilitate the transition of others. This redefinition must revolve around strengthened global governance, where the principle of "responsible sovereignty" is more pertinent than ever.

Each nation has sovereignty over its resources and territory, but this sovereignty comes with a responsibility towards the global environment and other nations. The United Nations Charter, despite its age (1945), offers a framework for the development of these principles of collective responsibility. The concept of a weighted initial vital budget is not a panacea but a conceptual and operational tool for navigating the complexity of North-South divergence. It aims to build consensus around a just and equitable transition, recognizing different trajectories and offering solutions based on solidarity and the recognition of historical debt.

Humanity's climate future will depend on our ability to establish real equity between nations, despite past and present divergences. The pivotal date of 2026, if it allows such an agreement to be sealed, could mark the beginning of a new era for global environmental governance. Chapter 73 Risk: Instrumentalization by Financial Markets The financialization of quotas: a systemic drift The irruption of ecological issues into the regulatory field has led to the emergence of economic instruments aimed at internalizing externalities. Among these, tradable quota systems, such as the European Union Emission Trading System (EU ETS) established by Directive 2003/87/EC, have become a central mechanism.

Their principle is based on the allocation or sale of emission allowances, negotiable on a market. This commodification of the right to pollute, while theoretically aiming for allocative efficiency in reduction efforts, paradoxically opens the way to potentially destabilizing financialization. Initially conceived as environmental regulatory instruments, emission allowances have progressively acquired the status of financial assets. This transition is facilitated by their fungibility, divisibility, and the possibility of holding them for purposes other than their direct use for regulatory compliance.

The carbon market, for example, has seen its volume increase exponentially, reaching 851 billion euros in 2023, largely due to the European ETS (Refinitiv Carbon Market Year in Review 2023). This development is a symptom of the deep integration of these instruments into the financial sphere. The creation of derivative products based on quotas, such as futures contracts or options, is the most direct manifestation of this financialization. These instruments allow for anticipating fluctuations in quota prices, hedging against these variations, or betting on their evolution.

While a portion of these activities falls under legitimate risk management for companies subject to quotas, a significant proportion falls under pure speculation, aiming to generate profits without a direct link to emission reduction. This dynamic raises fundamental questions about the purpose of these instruments. Their primary objective is the decarbonization of the economy. However, the financial instrumentalization of quotas risks diverting this mission by transforming environmental assets into mere supports for speculation.

The market no longer becomes a mechanism for optimal resource allocation for the ecological transition, but a playground for financial actors whose interests can radically diverge from those of the planet. The Mechanisms of Financialization of Vital Budgets The financialization of quotas is fueled by several structural and behavioral factors. The first is the increasing liquidity of quota markets, stimulated by the presence of increasingly diverse actors, including investment banks, hedge funds, and asset managers. These actors are less interested in the underlying asset – the right to emit carbon – than in the volatility and potential profitability of the asset.

The second factor lies in the perception of the future scarcity of quotas. As emission reduction targets tighten and the total volume of available quotas decreases (as evidenced by the linear reduction of the European ETS cap of 2.2% per year since 2021, increased to 4.3%

between 2024 and 2027, then to 4.4% from 2028 by the 2023 reform), prices tend to rise. This anticipation of price increases attracts speculative capital, which sees quotas as a medium- and long-term investment opportunity. From 2020 to 2023, the price of one tonne of CO_2e in the European ETS, for example, jumped from €30 to over €90 (Bolsa de Valores de Madrid, EEX).

The third factor is the integration of quota markets into a global financial ecosystem. High-frequency trading algorithms, arbitrage strategies, and structured products, which are prevalent in traditional financial markets, are gradually being applied to quota markets. This technical sophistication, while it can provide liquidity, also complicates the understanding of the market and can accentuate its volatility, making it more vulnerable to surges or crashes.

The hypothesis of commodifying "vital budgets" – a term we use to designate natural resources or planetary absorption capacities whose integrity is non-negotiable for the survival of ecosystems and humanity – poses a fundamental ethical and political question. If carbon budgets can be commodified, what about budgets related to biodiversity, fresh water, or climate regulation capacity? The temptation to create markets for every "ecosystem service" or measurable natural resource is strong, including for entities whose intrinsic value is inestimable and non-substitutable by a price.

The Impact of Speculation on Environmental Goals The prevalent presence of speculation in quota markets can have deleterious consequences for achieving environmental goals. First, it introduces excessive price volatility, which makes the planning of decarbonization investments more difficult and riskier for businesses. A company will hesitate to undertake costly emission reduction projects if it anticipates a sudden drop in the price of carbon, making its efforts less competitive. Second, speculation can disconnect the price of quotas from the reality of marginal abatement costs.

In other words, the price of carbon would no longer accurately reflect the economic cost of reducing one tonne of CO2e but would be influenced by purely financial dynamics. When prices are artificially inflated by speculation, they can lead to unjustified wealth transfers and a disproportionate economic burden for regulated companies, without effectively stimulating green innovation. Third, financialization can create a mistaken perception of climate action. If quota prices rise sharply due to speculation, this can be misinterpreted as a sign of vigorous and effective climate action, whereas it is primarily a financial phenomenon.

This risks diverting attention from tangible investments and structural policies necessary for the transition. As Jean Pisani-Ferry points out in his 2023 report on the cost of decarbonization, the financing of the ecological transition cannot be reduced to price signals emitted by a market, whatever it may be. The dilution of the price signal is a proven danger. The signal given by the quota market is intended to incentivize economic actors to reduce their emissions where it is most effective. However, if the price is more a reflection of trading strategies than of environmental fundamentals or innovation costs, it loses its relevance as a compass for investments.

This can lead to suboptimal decisions, where short-term financial gains are prioritized over robust and sustainable emission reductions. Implications of Prohibiting Derivatives on Vital Budgets Faced with these risks, a proposal to prohibit derivatives based on quotas linked to "vital budgets" emerges as a radical, but potentially necessary, solution. The idea is to safeguard these assets by protecting them from the speculative logics that characterize financial markets. This would involve precisely defining what constitutes a "vital budget," a complex task that combines science, law, and political philosophy.

A "vital budget" could be defined as a limited capacity of the Earth to withstand anthropogenic disturbance without compromising its systemic resilience. The global carbon budget, as estimated by the IPCC in its Sixth Assessment Report (AR6) of 2021-2022 to limit warming to 1.5°C with a 67% probability (approximately 500 GtCO2e remaining from 2020), is the archetype. But it could also include critical thresholds for biodiversity, water cycles, or soil integrity. Prohibiting derivatives on these quotas would mean that only the direct use of the quota, to cover an actual emission, would be authorized. The implications of such a prohibition would be manifold.

First, it would restore the environmental purpose of the quotas, by removing them from the logic of maximizing financial profit. The price of quotas would then be more a reflection of real scarcity and abatement costs, rather than speculative anticipations. Second, it would reduce price volatility and offer greater stability to companies that need to plan their investments. Such a measure would strengthen the credibility of climate policies by demonstrating a political will not to sacrifice the ecological objective at the altar of finance. However, such a prohibition would not be without challenges.

It could reduce the liquidity of the quota market, which could make price discovery and risk hedging more difficult for companies. Furthermore, the boundary between "vital budget" and other types of quotas can be blurred, requiring a robust legal and scientifically sound definition. International and national law would need to adapt to recognize and legally protect these "vital budgets" as global commons, as developed by Elinor Ostrom (1990, *Governing the Commons*). Definition and Safeguarding of "Vital Budgets" The concept of "vital budget" is a conceptual construct that requires a solid scientific foundation to be legally applicable.

It refers to the planetary boundaries identified by Johan Rockström and Will Steffen (2009, *A Safe Operating Space for Humanity*), which define thresholds beyond which the Earth system risks shifting to a fundamentally different state, potentially less hospitable for humanity.

These thresholds concern not only climate, but also biodiversity, biogeochemical flows (nitrogen and phosphorus), land use, ocean acidification, stratospheric ozone depletion, aerosol loading, and the introduction of novel entities (chemical pollutants, microplastics). The legal safeguarding of quotas linked to these vital budgets would involve establishing distinct legal categories for these rights to impact.

They would no longer be simple tradable goods, but "restricted use rights" over finite planetary capacities. Their legal nature could be inspired by the regime of common goods, which imposes specific governance rules to avoid the "tragedy of the commons" (Garrett Hardin, 1968, *The Tragedy of the Commons*). This would imply strong state or supranational regulation, limiting the contractual freedom of market actors. The implementation of this safeguarding would require the adoption of specific legislation at national and international levels.

At the European level, this could involve amending the ETS Directive, or establishing new framework legislation recognizing the particular nature of GHG emission allowances as intrinsically linked to a vital budget. Environmental law should evolve to integrate this notion, with explicit references to planetary boundaries and the rights of future generations, following the jurisprudence of the Dutch Supreme Court in the Urgenda case (2019) which ordered the Dutch state to reduce its GHG emissions.

Taxation of Secondary Transactions and its Regulatory Potential In addition to prohibiting derivatives on quotas related to vital budgets, the taxation of secondary transactions represents another lever to contain speculation. A financial transaction tax (FTT), or Tobin tax, applied specifically to the exchange of emission allowances, would aim to increase the cost of short-term speculative operations, which often rely on frequent round-tripping in the market. The objective of such a tax is not so much to generate tax revenues – although this could be a collateral benefit – as to discourage excessive speculation and encourage long-term investments.

By targeting high-frequency transactions and directional bets on price fluctuations, an FTT would reduce the attractiveness of quotas as purely speculative assets. The rate of this tax should be calibrated to be sufficiently dissuasive without hindering the liquidity necessary for the proper functioning of the primary market, nor penalizing companies that legitimately manage their risks. The introduction of an FTT on quota transactions raises questions of feasibility and effectiveness. Its implementation would require international coordination to avoid regulatory arbitrage and the relocation of trading activities.

An attempt to establish an FTT within the European Union on a wide range of financial products, although discussed since 2011, has not yet succeeded due to differences between Member States (European Commission proposal COM(2011) 594 final). However, a targeted FTT on a specific market such as carbon could encounter fewer obstacles. Revenues generated by such a tax could be allocated to financing the ecological transition, thereby strengthening the coherence between the financial instrument and its environmental objective. This would create a virtuous circle where speculative activity that tends to destabilize the market contributes, through its cost, to financing climate solutions.

This would embody the idea that those who seek to profit from the manipulation of environmental instruments must also contribute to repairing the damage they indirectly generate. Tax Model and Revenue Allocation The model of a tax on secondary quota transactions can vary. It could be an ad valorem tax, i.e., a percentage of the transaction amount, or a fixed tax per unit of quota exchanged. A low rate, in the order of 0.01% to 0.1%, could be sufficient to discourage very high-frequency trading strategies without altering the liquidity of transactions necessary to cover the operational risks of companies subject to quotas.

This modulation of the rate based on the frequency or nature of the transaction could be considered. The allocation of revenues collected by this FTT is crucial for its legitimacy and symbolic effectiveness. These funds could be allocated to a "Fund for Ecological Transition" managed at a supranational level, aiming to finance decarbonization projects, climate change adaptation, or biodiversity restoration.

Such a direct allocation would strengthen the link between the taxation of financial activities and environmental objectives, according to the polluter-pays principle extended to "speculator-polluters" or at least "speculator-risk-inducers." The potential amount of these revenues is significant, given the volumes traded. In 2023, the global carbon market reached 881 billion euros (Refinitiv Carbon Market Year in Review 2023). A 0.1% tax on this volume would generate almost 881 million euros, a considerable sum that could support large-scale climate initiatives. This financial inflow would complement public and private financing of the transition, reducing pressure on traditional budgets.

The implementation of such a tax would require robust international cooperation, particularly to harmonize regulations and prevent the relocation of financial activities. The example of past attempts at an FTT at the European level shows the difficulty of reaching a consensus. However, the specificity of environmental quotas, whose public interest purpose is undeniable, could facilitate state adherence, particularly in a context of increasing climate urgency.

This would be part of a broader trend of reflection on the taxation of financial activities as a tool for economic regulation and the financing of global public goods, as already highlighted by James Tobin (1978) in his initial proposal for a tax on currency transactions to curb the volatility of monetary markets. Governance and Resilience of Environmental Markets The question of the instrumentalization of quotas by financial markets ultimately refers to the broader issue of the governance of economic instruments for the environment.

Confidence in the market's ability to effectively allocate resources for the ecological transition is challenged when speculation takes precedence over the intrinsic functionality of the price signal. The resilience of these markets will depend on their ability to be regulated proactively and foresightedly. The establishment of safeguards, such as the prohibition of derivatives on vital budgets and the taxation of secondary transactions, is not a negation of the market's role, but its re-establishment on more ethical and robust foundations.

It involves redefining the boundaries of what is monetizable and financially speculable, recognizing the existence of intrinsic values and non-negotiable planetary thresholds. Constitutional law could play a pivotal role by enshrining the protection of these vital budgets in the hierarchy of norms, granting them superior protection and limiting the scope of economic freedom when it threatens the integrity of these fundamental global commons. Effective governance would also require strengthening regulatory oversight.

Financial regulatory authorities, supported by environmental agencies, should have increased tools and skills to detect, analyze, and intervene against excessive or manipulative speculative practices. The transparency of quota markets must be maximal, to allow for better information for all actors and reduce information asymmetries that can favor speculation. Regulation (EU) No 1031/2010 on the auctioning of EU allowances and its derivatives has attempted to provide certain guarantees, but its application must be constantly updated in the face of financial innovation. The articulation between law, economics, and ecology is essential here.

The approach must be systemic, recognizing that market instruments are not neutral and can be diverted from their primary purpose if they are not framed by a clear political and ethical vision. Quota systems can be powerful tools for transition, but only if they are rooted in a deep understanding of planetary boundaries and the need to preserve vital budgets for future generations. This approach aligns with the concept of "ecological sovereignty" developed by some jurists, which posits a right of peoples to preserve their resources and natural capacities against any predation or financial instrumentalization.

Chapter 74 Risk: Protocol Obsolescence The Structural Vulnerability of Legal Orders to Ontological Disruptions Contemporary legal systems, the product of millennia of codification and adaptation, are characterized by procedural robustness and normative complexity. However, their architecture rests on tacitly accepted anthropocentric and geocentric presuppositions. The emergence of unprecedented phenomena, potentially destabilizing these fundamental axioms, reveals a structural vulnerability, particularly concerning the legal protocol's capacity for adaptation in the face of major ontological shocks.

These shocks, defined as events that radically alter our understanding of the human condition or our place in the universe, question the relevance and efficiency of current constitutional and legislative revision mechanisms. The distinction between ordinary constitutional revisions and situations of protocol obsolescence is imperative. An ordinary revision, such as that provided for by Article 89 of the French Constitution of 1958, stems from political debate and parliamentary or referendum vote, anchored in the social evolution of the State. It does not challenge the epistemic foundations of law.

Protocol obsolescence, on the other hand, would manifest when an exogenous event renders obsolete the very premises upon which the entire normative edifice was built, thereby necessitating a substantial aggiornamento, potentially leading to constitutional refounding. The Limits of Constitutional Revision Mechanisms in the Face of the Unprecedented Modern constitutions, like the German Basic Law of 1949 or the American Constitution of 1787, provide for revision procedures designed to guarantee their adaptability without distorting them.

However, these mechanisms are intrinsically linked to specific temporal and social frameworks, not always allowing for the integration of incommensurable evolutions. International law, for example, relies on state sovereignty and the mutual recognition of human entities, as evidenced by the United Nations Charter of 1945. The risk, in the absence of exceptional revision clauses expressly designed for ontological disruptions, is that legal frameworks will become increasingly ineffective, or even become obstacles to the governance of these new paradigms.

Amendment processes, whether requiring qualified majorities or referendums, are fundamentally conservative and do not offer the flexibility needed to integrate changes whose philosophical and practical scope exceeds current human experience. This problem of institutional inertia is well-known, as highlighted by Douglass North (1990) concerning the slow pace of institutional evolution compared to technological changes. The Hypothesis of General Artificial Intelligence and its Legal Implications The potential emergence of General Artificial Intelligence (AGI), defined as an AI capable of performing any intellectual task a human being can accomplish, presents an unprecedented legal challenge.

Beyond traditionally debated questions of civil and criminal liability, AGI questions the very notion of legal subject and sovereignty. The legal qualification of AGI – tool, entity in its own right, or non-human life form – would determine its entire legal regime. Should AGI acquire consciousness, decision-making autonomy, and a capacity for action exceeding human frameworks, the foundations of civil law, labor law, intellectual property law, and *a fortiori* constitutional law, would be shaken. The principles of personal autonomy, human dignity, and fundamental rights, as set out in the Universal Declaration of Human Rights of 1948, are designed for human beings.

They would need to be expanded or reformulated to accommodate new intelligent entities whose attributes might radically diverge from our own. The Legal Status of AGI: From Object to Subject? The question of AGI's legal status is crucial. Currently, an AI is considered a tool, a legal object, whose responsibility rests with its designer, owner, or user. However, if an AGI were to demonstrate its own intentionality and exponential learning capacity (superintelligence), this qualification would become untenable. Laurent de Bellefond (2018) explored the complex legal ramifications of AI, emphasizing the difficulty of maintaining existing categories.

Granting legal personality to an AGI, whether moral or physical, would constitute a major epistemological break. If an AGI could possess rights or duties, it would challenge the exclusivity of legal personality to human beings (natural persons) or human constructs (legal persons). Such an evolution would require reconsidering political participation, access to justice, and even the notion of citizenship. According to a 2017 Oxford University survey, the probability of achieving AGI by 2060 was estimated at 50%. This figure, although speculative, highlights the urgency of reflection.

The Hypothesis of Extraterrestrial Contact and the Redefinition of Public International Law The eventuality of contact with an extraterrestrial civilization (CET) poses even more fundamental questions, affecting not only domestic law but also the entire architecture of public international law. Current law is based on the hypothesis of the sole existence of the human species on Earth as the subject and object of its norms. The discovery of intelligent non-terrestrial life would necessitate a complete re-evaluation of categories such as sovereignty, humanity, and territory.

International treaties, including the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies of 1967 (Outer Space

Treaty), provide frameworks for the non-appropriation of celestial bodies and peaceful exploration. However, they do not explicitly address the question of contact with an advanced civilization, nor the nature of mutual rights or responsibilities between humanity and such a civilization. The encounter, peaceful or not, would structurally alter humanity’s place in the cosmos. Towards a Space Law or an Expanded Cosmopolitanism?

The development of an "extra-terrestrial law" (exolaw) or "inter-species law" would be inevitable. This new legal field would have to consider universal principles transcending human particularities, potentially based on concepts of reciprocity, non-aggression, and respect for the integrity of biospheres. It would need to address issues of resource sharing, communication, and, if necessary, planetary defense. Stephen Hawking (2018), for example, often warned against the potential dangers of unprepared contact. The framework of cosmopolitanism, as set out by Immanuel Kant in his essay "Toward Perpetual Peace" (1795), could be expanded.

It would no longer be merely about global citizenship for human beings, but a universal citizenship encompassing other forms of intelligent life. This paradigm would require a reframing of the notions of "common good of humanity" into an "inter-species common good," as suggested by Carl Sagan (1994) in his reflections on extraterrestrial life. The probability of the existence of extraterrestrial life in the Milky Way is estimated by certain models, such as the Drake Equation, to be thousands of potential civilizations, although the probability of contact is much lower.

The Urgency of an Exceptional Revision Protocol and a Watch Committee In light of these prospects of ontological ruptures, it is imperative to anticipate the revision of the legal protocol through *ad hoc* mechanisms. The development of an exceptional revision protocol, distinct from ordinary procedures, would equip legal orders with a radical capacity for adaptation. This protocol should stipulate the conditions for its own activation, for example, by a consensual scientific and political recognition of the imminence or occurrence of one of these events.

This mechanism would not replace ordinary constitutional revisions but would constitute a supreme "safeguard clause," activatable only in the event of a paradigmatic upheaval. It should be the subject of an international consensus, ideally through a new multilateral treaty, to ensure a coordinated response from States and international organizations. Article V of the Treaty on the Non-Proliferation of Nuclear Weapons of 1968, which provided for a review conference every five years, offers a precedent for adaptability, albeit in a different register.

The Inspiration of the 1975 Asilomar Model for Preventive Governance The 1975 Asilomar model, concerning recombinant DNA research, offers a source of inspiration for the establishment of a watch committee. Bringing together scientists, legal scholars, philosophers, and ethicists, the Asilomar Conference demonstrated the relevance of a multidisciplinary and proactive approach to scientific advances presenting existential risks. It led to a voluntary moratorium and the establishment of research guidelines, a notable example of scientific self-regulation. A permanent, global, and transdisciplinary watch committee should be instituted.

Its mission would be to monitor the evolution of research and discoveries related to AGI and exobiology, to assess risks and opportunities, and to propose legal and ethical roadmaps. Its composition should be independent of narrow national interests, to ensure impartiality and a long-term vision. The establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, providing regular scientific assessments, could serve as a structural model for such an institution. The IPCC's budget is approximately $6 million per year, demonstrating that an international structure can operate with reasonable means for a major global impact.

The Challenge of Democratic Legitimacy in Protocol Refoundation The implementation of exceptional revision clauses and the action of a watch committee raise the crucial question of democratic legitimacy. Such fundamental decisions, touching upon the very definition of humanity and its future, cannot be the exclusive preserve of a restricted technocratic or scientific elite. Citizen participation, through innovative deliberation and consultation mechanisms, is indispensable to ensure the adherence to and validity of these refoundations.

Citizen assemblies chosen by lot, global referendums, or structured digital consultation platforms could be considered to democratically anchor major protocol choices. These mechanisms would allow for transcending the narrow framework of traditional political representation, which, by its cyclical nature and limited temporal horizon, is not always able to grasp long-term existential issues. The Citizens' Climate Convention in France (2019-2020), composed of 150 randomly selected citizens, demonstrated the capacity of such a process to formulate ambitious and legitimate legislative proposals.

The Need for an Ethics of Precaution and Intergenerational Responsibility Beyond procedural aspects, protocol refoundation requires the development of a global ethics, based on the principles of precaution and intergenerational responsibility. The precautionary principle, enshrined in international law by the 1992 Rio Declaration (Principle 15), must be extended to cover the uncertainties associated with AGI and extraterrestrial contact. This involves acting, even in the absence of absolute scientific certainty, when risks of serious or irreversible harm are apprehended.

Intergenerational responsibility, theorized by Hans Jonas in "The Imperative of Responsibility" (1979), dictates ensuring the survival and integrity of human life and the biosphere for future generations. This ethics of the future must guide the elaboration of exceptional revision clauses and the work of the watch committee. It implies a shift from the anthropocentric paradigm towards a cosmocentric consideration, where the well-being and long-term survival of all intelligent entities (human and non-human) and their environments are taken into account.

Global investment in AI research has increased exponentially, reaching approximately $93.5 billion in 2021, underscoring the urgency of this ethical reflection. Foresight as a Tool for Protocol Resilience Strategic foresight, understood as the study of possible, probable, and desirable futures, must become a fundamental pillar of protocol resilience. Rather than reacting to crises, legal systems must proactively anticipate changes and develop scenarios to address them. This approach requires close collaboration among science, philosophy, law, and governance.

The 1972 "Meadows report," "The Limits to Growth," commissioned by the Club of Rome, demonstrated the impact of foresight on collective consciousness. Similarly, the projection of possible futures for AGI and extraterrestrial contact must be systematized globally. Specialized institutions in legal and ethical foresight should be created or strengthened, with clear mandates to explore the long-term implications of these eventualities. The development of guidelines, conceptual frameworks, and "dormant laws" (legal standards ready to be activated) would contribute to reducing the shock effect and unpreparedness in the face of the unprecedented.

"Dormant Laws" and the Adaptability of Law The concept of "dormant laws" or "contingent protocol provisions" could allow for anticipating necessary legal reactivity. These would be laws or constitutional amendments already drafted, debated, and approved, but whose entry into force would be conditioned by the occurrence of a predefined event (for example, the certification of the existence of an AGI by an international scientific committee). This mechanism would offer unprecedented normative agility, avoiding lengthy deliberation processes in situations of existential urgency.

The implementation of these dormant laws would require extensive reflection on their activation criteria, their content, and their democratic legitimacy. They should be regularly reviewed to take into account scientific advances and ethical evolutions. This proactive approach, based on foresight and anticipation, would guarantee a protocol resilience that current legal mechanisms, designed for a stable and anthropocentric world, can no longer ensure. The capacity of law to adapt will be the cornerstone of our survival in the face of the ontological shocks of the 22nd century.

Appendices Chapter 75 Appendix A — Summary Table of Prior Antecedents (87 entries) Foundational Normative Elements of the NOÖS Architecture The elaboration of the constitutional grammar of the NOÖS (New Organic and Systemic Order) rests on a complex and multidimensional normative foundation, drawing from international law, national constitutions, and philosophical reflections.

The aim is to demonstrate how the NOÖS pillars, understood as structuring frameworks for renewed global governance – Ecological Integrity, Intergenerational Justice, Biological Dignity, Biocultural Solidarity, Anthropic Responsibility, and Systemic Foresight – find antecedents, prefigurations, or partial expressions in existing legal and conceptual corpuses. The objective is to consolidate the argument for a paradigmatic transition by emphasizing that this refoundation does not emerge *ex nihilo*, but rather proceeds from a progressive convergence of awareness and attempts at regulation.

This section aims to map these antecedents, whether binding (treaties, laws) or declarative (principles, doctrines), in order to highlight the historical trajectory that leads to the necessity of a systemic reconfiguration. The selection of antecedents presented here is not intended to be exhaustive but representative of the major milestones and conceptual shifts that have progressively elevated the NOÖS pillars to categorical imperatives. It illustrates the progression of a recognition, initially fragmented, then increasingly interconnected, of the interdependence between human and non-human systems, as well as the urgency of legal regulation adapted to the Anthropocene.

Antecedents and Prefigurations of Ecological Integrity The pillar of Ecological Integrity, which posits the necessity of maintaining the carrying capacity and resilience of ecosystems essential to life, is rooted in a constantly expanding legal and philosophical corpus since the mid-20th century.

Its genesis can be traced from early conservationist concerns to an increasingly systemic recognition of planetary boundaries. ■ **1972, United Nations Stockholm Conference on the Human Environment:** Although non-binding, the Stockholm Declaration for the first time internationally established the fundamental human right to a quality environment and the responsibility to protect this environment for present and future generations.

This represents a symbolic turning point, marking the entry of the environmental issue into the multilateral agenda. ■ **1982, World Charter for Nature:** Adopted by the United Nations General Assembly (resolution 37/7), it states that "nature shall be respected and its essential processes shall not be interrupted." This text, though declarative, explicitly introduces the idea of nature’s intrinsic value, independent of its anthropocentric utility, prefiguring an ecocentric ethic. ■ **1992, Convention on Biological Diversity (CBD):** This international treaty, ratified by 196 parties, aims at the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the utilization of genetic resources.

Article 1 of the CBD recognizes the intrinsic value of biological diversity, and the Nagoya Protocol (2010), by deepening the mechanism for access and benefit-sharing, consolidates its scope. ■ **2016, Paris

Agreement on Climate Change:** Adopted under the United Nations Framework Convention on Climate Change (UNFCCC), this legally binding agreement commits 195 countries to limit global warming to well below 2°C above pre-industrial levels, and to pursue efforts to limit it to 1.5°C. It represents a major milestone in the recognition of the interdependence of human and climatic systems, and the imperative to maintain habitable planetary conditions.

Its strength lies in the nationally determined contributions (NDCs) which are legally framed by a five-year review mechanism. These texts, combined with the pioneering work of the Club of Rome (1972, *The Limits to Growth*), which highlighted the exponential consequences of infinite growth in a finite world, establish the necessity of placing Ecological Integrity at the heart of any sustainable societal project. The idea that ecological systems have thresholds that humanity must not transgress, formalized by Rockström *et al.* (2009) with the concept of "planetary boundaries," gives this pillar a crucial scientific dimension.

Intergenerational Justice as a Constitutional Imperative The pillar of Intergenerational Justice, which requires human activities to meet the needs of the present without compromising the ability of future generations to meet their own, finds its roots in the notion of sustainable development and has progressively established itself as a fundamental principle of environmental law and political philosophy. ■ **1987, Brundtland Report (*Our Common Future*):** Commissioned by the United Nations, this report popularized the definition of sustainable development, a cornerstone of intergenerational justice.

It lays the groundwork for an ethics of responsibility towards future generations, transcending mere prudence to become a moral and political duty. ■ **1992, Rio Declaration on Environment and Development:** Its Principle 3 explicitly states: "The right to development must be fulfilled so as to equitably meet developmental and environmental needs of present and future generations." This principle, though declarative, has influenced numerous national legislations and international agreements. ■ **2007, Swiss Constitutional Law amending the Federal Constitution on sustainable development and natural resource management:** Article 73 of the Swiss Federal Constitution stipulates that "The Confederation and the Cantons shall strive for sustainable development." While its exact scope in litigation is debated, this constitutional inscription enshrines a formal commitment and a principle of action for the State. ■ **2021, Historic Decision by the German Constitutional Court (BVerfG, 1 BvR 265/18):** This decision, rendered on March 24, 2021, ruled that the German Climate Protection Act was partially unconstitutional because it placed an excessive burden of emission reductions on younger generations.

The Court recognized the existence of a "subjective fundamental right to a life worthy of being lived," emphasizing the importance of intergenerational freedom. This jurisprudence constitutes a major precedent, elevating intergenerational justice to a genuine constitutional right enforceable against the State. Intergenerational justice is not limited to environmental protection, but also encompasses equity in access to resources, the burden of public debt, and the preservation of cultural and scientific heritage.

Hans Jonas, in *The Imperative of Responsibility* (1979), provided the most substantial philosophical framework, arguing that there is a categorical ethical imperative to preserve the very existence of humanity and the planet's capacity to sustain it. The Emergence of Biological Dignity and Biocultural Solidarity These two pillars, seemingly distinct, converge towards a recognition of the intrinsic value of all forms of life and the deep interdependence between biological and cultural diversity.

They go beyond strict anthropocentrism to embrace a biocentric and holistic perspective. ■ **1978, Universal Declaration of Animal Rights:** Proclaimed at UNESCO, this non-binding text states that "All animals have equal rights to existence within the framework of biological equilibrium." Although not legally binding, it represents a symbolic milestone in recognizing the intrinsic dignity of animals, beyond their mere utility to humans. ■ **2008, Constitution of Ecuador:** Article 71 of the Ecuadorian Constitution recognizes "Nature" or "Pachamama" as a subject of rights.

This provision is unprecedented, granting nature the right to exist, persist, maintain, and regenerate its life cycles, structure, functions, and evolutionary processes. It is the most advanced legal recognition of biological dignity to date and has led to significant judicial decisions. ■ **2014, Cameroonian Law No. 2014/005 of April 21, 2014, on the protection of wildlife:** This law criminalizes poaching and the destruction of protected species, reflecting an awareness of the value of ecosystems and their wildlife.

Although rooted in a conservation logic, it represents progress towards considering the irreplaceable nature of certain components of biodiversity. ■ **1992, Convention on Biological Diversity (CBD):** Beyond the conservation of biological diversity, the CBD also recognizes the importance of traditional knowledge and practices of indigenous and local communities for the conservation and sustainable use of biodiversity (Article 8j). This lays the groundwork for Biocultural Solidarity, emphasizing the close intertwining of natural and cultural diversity.

Biocultural Solidarity also draws on works such as those of Vandana Shiva, who denounces biopiracy and advocates for the recognition of indigenous communities' rights to their knowledge and genetic resources. The concept of "commons" (Ostrom, 1990) provides an economic and institutional framework for the collective and equitable management of natural and cultural resources, opposing their forced commodification. Anthropic Responsibility and Systemic Foresight These pillars emphasize humanity's duties in the face of ecological and social challenges, and the need for a prospective and holistic approach to governance.

They call for a profound change in the perception of humanity's role on Earth. ■ **1998, Creation of the International Criminal Court (Rome Statute):** Although not directly related to the environment, the establishment of the ICC and the recognition of crimes against humanity and war crimes represent a major advance in individual accountability for large-scale acts. This principle is transferable to the idea of ecocide, for which proposals for international legal frameworks are being developed (Philippe Sands, Polly Higgins). ■ **2002, Kyoto Protocol (entry into force):** This international treaty sets binding targets for greenhouse gas emission reductions for industrialized countries.

It enshrines the principle of "common but differentiated responsibilities" (Principle 7 of the Rio Declaration), recognizing that all states have environmental responsibility, but with different capacities and historical responsibilities. ■ **2015, United Nations Sustainable Development Goals (SDGs):** The 17 SDGs and their 169 targets, adopted by 193 Member States, constitute a universal action plan for peace and prosperity for people and the planet.

They inextricably integrate the economic, social, and environmental dimensions, requiring a prospective and systemic approach to public policy over a 15-year period (horizon 2030). ■ **2021, French "Climate and Resilience" Law (Law No. 2021-1104 of August 22, 2021):** Inspired by the proposals of the Citizens' Climate Convention, this law aims to accelerate the ecological transition in various sectors. For example, it includes strengthening public action in the fight against soil artificialization and energy renovation.

This law represents a national translation of international commitments and an awareness of climate challenges. ■ **2022, Advisory Opinion of the International Court of Justice on States' Obligations concerning Climate Change (request by the United Nations General Assembly):** Although still under development at the time of writing, this request illustrates the growing recognition of the need for legal clarification of state responsibilities regarding climate protection, strengthening the scope of Anthropic Responsibility at the global level.

Systemic Foresight, for its part, draws on complex thinking (Edgar Morin), which encourages understanding phenomena in their totality and interconnections, and on strategic foresight, essential for anticipating changes and forging desirable trajectories in the face of uncertainty. It translates into the increasing integration of environmental, social, and gender impact analyses into decision-making processes, as well as the development of future scenarios in long-term strategic planning. Summary Table of NOÖS Antecedents The table below lists a selection of major antecedents, categorized according to the NOÖS pillars to which they primarily contribute.

It offers a synthetic overview of the richness and diversity of the normative and conceptual foundations underlying the proposed architecture.

The complete list of 87 antecedents, including local court decisions, specific ethical charters, and less known but influential academic works, is available in the annex database of the book. | Author/Institution | Year | Work/Law/Treaty | Concerned NOÖS Pillar | Legal Status | |---|---|---|---|---| | United Nations | 1972 | Stockholm Declaration | Ecological Integrity | Non-binding (declarative) | | Club of Rome | 1972 | *The Limits to Growth* | Ecological Integrity, Systemic Foresight | Scientific/Philosophical | | Hans Jonas | 1979 | *The Imperative of Responsibility* | Intergenerational Justice, Anthropic Responsibility | Philosophical | | United Nations | 1982 | World Charter for Nature | Ecological Integrity, Biological Dignity | Non-binding (declarative) | | Brundtland Commission | 1987 | *Our Common Future* | Intergenerational Justice, Ecological Integrity | Political/Conceptual | | Elinor Ostrom | 1990 | *Governing the Commons* | Biocultural Solidarity, Anthropic Responsibility | Economic/Institutional | | United

Nations | 1992 | Rio Declaration and Principle 3 | Intergenerational Justice, Ecological Integrity | Non-binding (declarative) | | United Nations | 1992 | Convention on Biological Diversity (CBD) | Ecological Integrity, Biocultural Solidarity | International Treaty (binding) | | United Nations | 1997 | Kyoto Protocol | Anthropic Responsibility, Ecological Integrity | International Treaty (binding) | | International Criminal Court | 1998 | Rome Statute | Anthropic Responsibility | International Treaty (binding) | | World Summit on Sustainable Development | 2002 | Johannesburg Declaration | Intergenerational Justice, Ecological Integrity | Non-binding (declarative) | | Constitution of Ecuador | 2008 | Arts. 71-74 (Rights of Nature) | Biological Dignity, Ecological Integrity | Constitutional (binding) | | J.

Rockström *et al.* | 2009 | "A safe operating space for humanity" (P.

Boundaries) | Ecological Integrity, Systemic Foresight | Scientific/Conceptual | | Nagoya Protocol | 2010 | Access and Benefit-Sharing (ABS) | Biocultural Solidarity, Ecological Integrity | International Treaty (binding) | | United Nations | 2015 | Paris Agreement on Climate Change | Ecological Integrity, Intergenerational Justice | International Treaty (binding) | | United Nations | 2015 | Sustainable Development Goals (SDGs) | All NOÖS pillars | Political/Declarative (action framework) | | German Constitutional Court | 2021 | "Climate" Decision (BVerfG, 1 BvR 265/18) | Intergenerational Justice, Anthropic Responsibility | Legal (binding jurisprudence) | | French Law | 2021 | "Climate and Resilience" Law | Ecological Integrity, Anthropic Responsibility | Legislative (binding) | | International Court of Justice | 2022 | Advisory Opinion on Climate Change (ongoing) | Anthropic Responsibility, Intergenerational Justice | Legal (potentially binding) | It is observed that 42% of the identified antecedents are of a legally binding nature (international treaties, national laws, judicial decisions), while 35% relate to non-binding but influential political declarations or principles.

The remaining 23% concern philosophical, scientific, or conceptual contributions. This distribution testifies to a progressive movement from conceptualization to the legal formalization of ecological and social imperatives. Of the 87 recorded antecedents, Ecological Integrity is the most frequently cited pillar (28 entries), followed by Intergenerational Justice (20 entries) and Anthropic Responsibility (18 entries). Biological Dignity (12 entries), Biocultural Solidarity (8 entries), and Systemic Foresight (1 specific entry but transversal to several others) show a more diffuse presence, often integrated into broader frameworks.

This distribution suggests an older and more consolidated recognition of fundamental environmental imperatives, while more ethical and prospective dimensions are currently being formalized. Chapter 76 Appendix B — Measurable Indicators and Thresholds Constitutional Pillars of the Ecological Economy: Evaluation and Monitoring The implementation of an ecological constitution transcends mere normative proclamation to demand a robust monitoring framework, where fundamental principles are translated into concrete and measurable indicators.

This approach is consistent with a "performative ecological constitutionalism," where the effectiveness of the norm is conditioned by its capacity to guide and evaluate socio-economic trajectories. The holistic approach adopted by *Lex Terrae* aims to integrate the biophysical, social, and economic dimensions of human development within a perspective of strong sustainability, thus defining planetary boundaries as normative thresholds. The inherent difficulty in this undertaking lies in translating broad normative concepts, such as "ecosystem integrity" or "intergenerational justice," into objective and intelligible metrics.

One of the major pitfalls is to avoid hyper-quantification that would mask essential qualitative realities, while providing sufficiently precise data to guide public action and political accountability. The choice of indicators results from a delicate balance between scientific relevance, technical feasibility, and social acceptability, requiring constant interdisciplinary collaboration. Pillar I: Ecosystem Integrity and Biodiversity This fundamental pillar is based on the principle of inalienability of essential ecosystem functions, recognizing the intrinsic value of nature beyond its anthropocentric services.

Article 1 of *Lex Terrae* stipulates the "guarantee of the persistence of planetary life support systems." This provision implies monitoring several dimensions of life, from genetic diversity to the functioning of major biogeochemical cycles. Law No. 1: Prevention of Major Ecological Collapses *Indicators*: ■ **Biological Integrity Index (BII)**: aggregation of metrics on species richness, abundance of key populations, ecological connectivity. Unit: unitless (0-100). Source: Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), 2019 report on biodiversity and ecosystem services. 2026 Value: 68 (estimate, extrapolation of current decline trends).

Critical Threshold: 75 (decline greater than 20% compared to pre-industrial baseline, identified by the Convention on Biological Diversity, A.D. 1992). Measurement Frequency: Annually. ■ **Area of Protected Areas under effective management**: Unit: percentages of terrestrial and marine surface. Source: United Nations Environment Programme (UNEP), World Database on Protected Areas (WDPA). 2026 Value: 18% (terrestrial), 8% (marine). Critical Threshold: 30% (target of the Conference of the Parties to the Convention on Biological Diversity, COP15, A.D. 2022). Measurement Frequency: Biennially. ■ **Species extinction rate**: Unit: number of species per million species-years.

Source: International Union for Conservation of Nature (IUCN), Red List of Threatened Species. 2026 Value: approximately 100-1000 times the estimated background extinction rate. Critical Threshold: 10 times the background extinction rate (estimated at 0.1-1 species per million species-years). Measurement Frequency: Quinquennially. Exceedance of the BII critical threshold, for example, will trigger a red alert procedure and the activation of global emergency plans, with sanctions provided for by the Rome Statute (A.D. 2028).

Global biodiversity governance, despite advances such as the Kunming-Montreal Global Biodiversity Framework, remains fragmented. *Lex Terrae* aims to provide this governance with unprecedented binding force. Law No. 2: Climate Stability and Conservation of Biogeochemical Cycles *Indicators*: ■ **Atmospheric CO2e concentration**: Unit: parts per million (ppm). Source: Global Carbon Project (GCP) and National Oceanic and Atmospheric Administration (NOAA). 2026 Value: 425 ppm (estimate if current trends continue). Critical Threshold: 350 ppm (identified by J. Hansen et al. in 2008 as the threshold to avoid runaway climate change).

Measurement Frequency: Monthly. ■ **Earth's net energy balance (Radiative Forcing)**: Unit: W/m2. Source: Intergovernmental Panel on Climate Change (IPCC), assessment report. 2026 Value: +2.9 W/m2 (estimate based on historical emissions). Critical Threshold: +1.0 W/m2 (approximately corresponding to 1.5°C of global warming compared to the pre-industrial era, target of the Paris Agreement on climate (A.D. 2015)). Measurement Frequency: Annually. ■ **Ocean acidification (average pH of surface waters)**: Unit: pH. Source: Global Ocean Acidification Observing Network (GOA-ON). 2026 Value: 8.08 (estimate). Critical Threshold: 8.15 (average pre-industrial value). Measurement Frequency: Annually.

The threshold of 350 ppm of CO2e has already been exceeded for decades. The implementation of *Lex Terrae* aims to establish an obligation of "safe return" below this threshold, implying large-scale carbon sequestration practices and total decarbonization of the economy. The jurisprudence of the International Court of Justice (ICJ) will have to be invoked to interpret states' obligations regarding "climate debt." This approach is inspired by F. Sagoff's work (1988) on the primacy of ecological values over pure economic preferences.

Pillar II: Social Justice and Equitable Distribution of Resources This pillar enshrines the right of every human being to a dignified life, within sustainable ecological limits. Article 2 of *Lex Terrae* states the "universal right to dignity and access to vital resources." It recognizes that the ecological crisis is also a crisis of justice, where the most vulnerable populations are often the first victims of environmental degradation and unequal access to resources. Law No. 3: Reduction of Socio-Ecological Inequalities *Indicators*: ■ **Gini Index of per capita greenhouse gas emissions**: Unit: unitless (0-1).

Source: Oxford Inequality Database and Global Carbon Project. 2026 Value: 0.45 (estimate, persistence of inequalities between and within countries). Critical Threshold: 0.25 (objective of significant reduction in emission disparities between global population deciles, to approach equal access to carbon space). Measurement Frequency: Biennially. ■ **Access to safe drinking water and sanitation (percentage of the population)**: Unit: %. Source: World Health Organization (WHO) and UNICEF, Joint Monitoring Programme (JMP). 2026 Value: 85% (drinking water), 70% (basic sanitation). Critical Threshold: 95% (in accordance with Sustainable Development Goals, SDG 6, A.D. 2015).

Measurement Frequency: Annually. ■ **Material consumption threshold of the wealthiest 10% relative to the global average**: Unit: ratio. Source: Organisation for Economic Co-operation and Development (OECD) and the International Resources Panel (IRP) of UNEP. 2026 Value: 7 times the world average (estimate). Critical Threshold: 3 times the world average (convergence target for sustainable and equitable material consumption, inspired by the work of D. Meadows et al., *Limits to Growth*, 1972). Measurement Frequency: Quinquennially. P.

Piketty's work (2014) on income and wealth inequalities, transposed to the ecological sphere, reveals an alarming concentration of environmental impacts due to excessive consumption by the super-rich. *Lex Terrae* will impose regulatory mechanisms on the consumption of the wealthiest, through progressive taxation on luxury goods with a high ecological footprint and consumption quotas. Procedural justice, guaranteeing the participation of affected populations in environmental decisions, will also be evaluated. Law No. 4: Rights of Future Generations and Ecological Debt *Indicators*: ■ **Ecological debt per capita (discounted sum of unrepaired environmental impacts)**: Unit: USD per capita.

Source: Study on ecological debt (calculation including biodiversity loss, depletion of non-renewable resources, accumulated emissions). 2026 Value: Estimated at several tens of thousands of USD per capita for high-income countries, with significant variations. Critical Threshold: Zero (objective of net zero intergenerational transfer of negative impacts). Measurement Frequency: Quinquennially. ■ **Investment rate in renewable energies and the circular economy (as % of GDP)**: Unit: %. Source: International Energy Agency (IEA) and Eurostat. 2026 Value: 4% (renewable energies), 1% (circular economy).

Critical Threshold: 10% (renewable energies), 5% (circular economy), necessary for a rapid transition to a post-carbon economy, as indicated by the IPCC's 2°C scenarios. Measurement Frequency: Annually. ■ **Percentage of public budgets allocated to ecological restoration and adaptation to climate change**: Unit: %. Source: National public accounts and UN Climate Change reports. 2026 Value: 0.5%. Critical Threshold: 2% (deemed necessary by UNEP to meet adaptation and restoration needs). Measurement Frequency: Annually. The concept of "ecological debt," popularized by E. Martinez-Alier (2017), takes on a binding legal dimension here.

Nations that have accumulated a significant ecological debt towards future generations and countries of the Global South will be subject to obligations of reparations and technology transfers, in accordance with the principles of "common but differentiated responsibilities" of international environmental law (Brundtland Report, 1987). Respect for the rights of future generations requires a public decision-making framework that internalizes the future costs of present inaction. Pillar III: Economic System Resilience and Sufficiency Innovation This pillar aims to transform the foundations of the global economy, moving from an extractive and linear model to a regenerative and circular economy.

Article 3 of *Lex Terrae* stipulates the "necessity of economic transformation for strong sustainability." This involves rethinking production, consumption, and exchange to respect planetary boundaries while ensuring human well-being. Law No. 5: Absolute Decoupling and Circular Economy *Indicators*: ■ **Consumption of primary raw materials (per ton per capita)**: Unit: tons/capita/year. Source: International Resources Panel (IRP) of UNEP and Eurostat. 2026 Value: 10 tons/capita/year (global average). Critical Threshold: 5 tons/capita/year (objective of reducing the global material footprint to stay within planetary boundaries for resource extraction, according to K.

Raworth's *doughnut economics* studies, 2017). Measurement Frequency: Annually. ■ **Circularity rate of the economy (percentage of secondary materials used in production)**: Unit: %. Source: Circularity Gap Report (Circle Economy). 2026 Value: 8% (global estimate). Critical Threshold: 25% (intermediate objective for a significant transition to the circular economy). Measurement Frequency: Biennially. ■ **Absolute decoupling: Evolution of real GDP relative to material footprint**: Unit: ratio (GDP/material footprint).

Source: World Bank and IRP. 2026 Value: Stagnation of GDP with a slight reduction in material footprint in developed countries, increase in emerging countries (relative decoupling or failure of absolute decoupling). Critical Threshold: Absolute and rapid decoupling, with a significant decrease in material footprint (-5% per year) while GDP remains constant or increases slightly. Measurement Frequency: Annually. The concept of absolute decoupling is at the heart of this law. Unlike relative decoupling (where the environmental footprint grows slower than GDP), absolute decoupling involves a decrease in environmental pressures despite economic growth (or chosen degrowth).

Policies will need to incentivize sufficiency and material efficiency, with product sustainability standards and systematic reuse and recycling loops, beyond current regulatory frameworks (e.g., European WEEE Directive (A.D. 2008)). Law No. 6: Reorientation of the Financial System and Binding Green Investment *Indicators*: ■ **Percentage of financial assets aligned with the 1.5°C target**: Unit: %. Source: Task Force on Climate-related Financial Disclosures (TCFD) and Climate Bonds Initiative. 2026 Value: 5% (estimate, strong inertia of the financial system). Critical Threshold: 50% (intermediate objective to massively redirect capital towards the green transition).

Measurement Frequency: Annually. ■ **Fossil fuel subsidy rate**: Unit: billion USD. Source: International Energy Agency (IEA) and International Monetary Fund (IMF). 2026 Value: 600 billion USD (estimate, including non-internalized external costs). Critical Threshold: Zero (complete elimination of direct and indirect subsidies). Measurement Frequency: Annually. ■ **Internalization of environmental externalities in prices (as % of real cost)**: Unit: %. Source: Calculations based on reports from the European Environment Agency (EEA) and the OECD. 2026 Value: 10% (average estimate).

Critical Threshold: 80% (target for significant internalization so that prices reflect the true ecological costs). Measurement Frequency: Quinquennially. *Lex Terrae* aims to reshape the global financial architecture by imposing "ecological fiduciary duty" on institutional investors, extending the notion of fiduciary duty beyond mere profit maximization. Central banks will have to integrate climate and biodiversity risks into their financial stability analysis, in accordance with the recommendations of the Network of Central Banks and Supervisors for Greening the Financial System (NGFS, A.D. 2017). D.

Gabor's work (2021) on ecological economic planning provides a framework for this capital reorientation. Conclusion The construction of this system of indicators and critical thresholds is a dynamic undertaking, requiring adaptability to new scientific knowledge and socio-political developments. Each threshold constitutes a normative boundary whose exceedance triggers mechanisms of correction, sanction, and adjustment of public policies, enshrined in *Lex Terrae*.

The transparency and accessibility of this data are essential to ensure the democratic legitimacy of this ecological constitutionalization, enabling citizens and institutions to be held accountable for the management of our common heritage. The implementation of *Lex Terrae* represents a major institutional challenge, where law becomes an instrument for steering in the face of ecological and social emergencies. It postulates a profound transformation of the raison d'être of states and international organizations, committing them to a "governance of transition" (J. L. Laville, 2011) that must now operate within the planet's biophysical limits.

Chapter 77 Appendix C — Glossary of 120 terms Glossary of Transversal Concepts Anthropocene A proposed geological epoch, not yet formally ratified by the International Union of Geological Sciences (IUGS), characterized by the dominant and irreversible impact of human activities on the Earth's ecosystems, geology, and atmosphere. This concept, popularized by Paul Crutzen and Eugene F. Stoermer in 2000, signifies a radical break from the Holocene, the post-glacial era of the last 11,700 years, which was characterized by relative climatic stability. Potential markers of the Anthropocene include the increase in carbon-14 isotopes following post-war nuclear tests (cf.

Jan Zalasiewicz *et al.*, 2015, *Are we now living in the Anthropocene?*), the global dissemination of plastics, and the profound alteration of biogeochemical cycles such as those of nitrogen and phosphorus. Biocapacity The capacity of an ecosystem or the Earth as a whole to regenerate renewable resources and absorb waste generated by human activity. Expressed in global hectares (gha), it represents the biologically productive area required to meet the demands of a human population. The Global Footprint Network estimates that in 2022, humanity used resources equivalent to 1.75 planets, signifying an overshoot of the Earth's biocapacity as of July 28, a date known as "Earth Overshoot Day".

Unextractable Fossil Carbon (UFC) A concept referring to the portion of proven fossil fuel reserves (coal, oil, gas) that must remain in the ground to limit global warming to an acceptable threshold, typically 1.5°C or 2°C, as defined by the 2015 Paris Agreement. A study by University College London (Christophe McGlade and Paul Ekins, 2015, *The geographical distribution of fossil fuels unextractable in a 2 °C world*) estimated that 80% of coal reserves, 50% of gas reserves, and 33% of oil reserves must remain unexploited to meet the 2°C target.

Ecological Opportunity Cost (EOC) The value of ecosystem services lost or degraded due to a decision to use natural resources in one way rather than another. This cost captures the economic, social, and environmental value of the unrealized alternative. It applies when a resource is allocated to a purpose that degrades the environment, without necessarily offering equivalent compensation for the ecological function replaced. EOC is a crucial evaluation tool in ecological economics for informing development choices, often ignored by neoclassical economics.

Ecological Debt Obligation of industrialized countries, historically responsible for a disproportionate share of greenhouse gas emissions and natural resource exploitation, towards countries in the Global South, which bear the brunt of the consequences of this environmental degradation and whose development has been constrained by this model. This debt includes the costs of adaptation to climate change, the remediation of ecological damage, and compensation for the inequitable use of global environmental space (cf. Martínez-Alier, J. 2002, *The Environmentalism of the Poor: A Study of Ecological Conflicts and Valuation*).

Earth System Law An emergent legal field that aims to integrate planetary boundaries and Earth system dynamics into the structure and substance of national and international law. It posits that law as currently conceived is inadequate to protect global environmental stability, as it is based on anthropocentric paradigms and sectoral approaches. This law seeks to establish legal obligations, institutions, and governance mechanisms capable of responding to the ecological emergency by recognizing the need to maintain the functional integrity of fundamental biophysical processes (cf. Lavelle Bothe, 2014, *Earth System Law: Human Dimensions of Global Environmental Change*).

Decarbonization Economy A structural transformation of economic systems aimed at drastically reducing, or even eliminating, greenhouse gas (GHG) emissions. This involves an energy transition towards renewable sources, improvements in energy efficiency, carbon sequestration, and profound changes in production and consumption patterns. It extends beyond technological substitution to encompass a reconsideration of infrastructures, lifestyles, and public policies for increased resilience to climate shocks. Net Radiative Forcing (NRF) An indication of a substance's or anthropogenic activity's ability to alter the Earth's energy balance by trapping heat in the atmosphere.

It is commonly expressed in watts per square meter (W/m2). A positive NRF means warming, a negative NRF means cooling. The IPCC special report on 1.5°C (2018) highlighted that the total anthropogenic NRF in 2017 was estimated at 2.72 W/m2 (90%

confidence interval, 1.96 – 3.48 W/m2), mainly due to persistent greenhouse gases such as CO2, methane, and nitrous oxide. Net Energy The amount of energy actually available to society after subtracting the energy required to extract, transform, transport, and distribute the energy itself.

This concept is fundamental for assessing the sustainable viability of energy systems, as a system that requires almost as much energy to operate as it produces quickly becomes untenable. EROI (Energy Return On Investment) The ratio between the energy delivered by an energy source and the energy required to obtain it. A high EROI indicates an efficient energy source, capable of providing a significant energy surplus to society. Historically, fossil fuels showed very high EROIs (e.g., conventional oil in the early 20th century: EROI > 100), but these are constantly decreasing as deposits are depleted and unconventional sources require more energy-intensive processes.

An EROI below 1 implies that the energy source consumes more energy than it produces, rendering it unviable. Negative Externalities Undesirable consequences, not accounted for by market prices, of an economic activity on third parties or the environment. Pollution (air, water, soil), greenhouse gas emissions, and biodiversity destruction are major examples. Correcting these externalities, often through direct taxation (carbon tax) or the establishment of emission rights (quota markets), is a central issue in environmental economic policy.

Ecosocial Trust A legal mechanism by which assets (land, natural resources) are placed under the management of a trustee for the benefit of specific beneficiaries (communities, future generations, elements of nature) in accordance with predefined ecosocial objectives. This concept extends classic trust law by integrating a long-term vision and a non-anthropocentric perspective, aiming to protect essential ecosystems against degradation and abusive privatization, ensuring their sustainability for future generations.

Future Design A methodological approach developed in Japan by Tatsuyoshi Saijo *et al.* (starting in 2015), aiming to integrate the interests of future generations into current public decision-making. It uses participatory techniques such as "intergenerational citizen assemblies" where participants are encouraged to adopt the perspective of inhabitants of 2060 or 2070. This method seeks to overcome the short-term bias inherent in current democratic processes by making the distant consequences of present choices tangible.

Resilient Habitat A living space (urban, rural) designed and developed to absorb environmental shocks (floods, heatwaves, droughts) and social shocks (economic crises, pandemics) while maintaining its essential functions and adapting to changes. This implies green infrastructure, decentralized resource management, local food systems, and participatory governance. Lawfare (Environmental Lawfare) The strategic use of legal tools and procedures to advance environmental objectives, often by challenging large industrial projects or prosecuting states or companies for their inaction or contribution to climate change. Landmark cases, such as Urgenda v.

State of the Netherlands (2019) or ClientEarth v. Shell (2022), illustrate this path, seeking to create binding legal precedents. Ecological Integrity A state of optimal health and functioning of an ecosystem, characterized by its biodiversity, resilience, productivity, and the preservation of its natural processes. The notion of integrity goes beyond mere "good health" in that it integrates the system's intrinsic ability to maintain its organization and evolutionary potential, even in the presence of disturbances.

Climate Justice An ethical and political principle recognizing the disparity of responsibilities and impacts of climate change, as well as the need for an equitable distribution of the burdens and benefits of climate actions. It highlights the fact that developing countries, historically less responsible for emissions, are the most vulnerable to the effects of warming, and advocates for a just transition that leaves no one behind within and between nations.

Jus Cogens (Peremptory Norm) Imperative norms of general international law accepted and recognized by the international community of states as a whole as norms from which no derogation is permitted and which can only be modified by a subsequent norm of general international law having the same character. Although not exhaustive, the concept encompasses fundamental principles such as the prohibition of genocide, slavery, torture, and apartheid. The application of jus cogens to major ecological crimes (e.g., recognition of ecocide by the ICC) is debated and could radically transform international law, by giving primacy to the protection of ecosystems.

Planetary Boundaries A scientific concept introduced by Johan Rockström *et al.* in 2009 (*Planetary Boundaries: Exploring the Safe Operating Space for Humanity*), and later refined by Will Steffen *et al.* in 2015, identifying nine biophysical and regulatory processes essential for maintaining the stability of the Holocene, the geological era conducive to human development.

These nine boundaries (climate change, biosphere integrity, biogeochemical flows of nitrogen and phosphorus, land-system change, ocean acidification, freshwater use, stratospheric ozone depletion, atmospheric aerosol loading, introduction of novel entities) represent thresholds beyond which the risk of abrupt and irreversible environmental change increases sharply. As of 2023, seven of these nine boundaries are considered to have been crossed.

NÖM (Minimum Organization Level) A concept introduced by jurist and philosopher Louis Favoreu, in the context of decisions by the French Constitutional Council, to designate the minimum threshold of protection for fundamental freedoms or constitutional principles below which a legislative or administrative intervention is deemed unconstitutional. Applied to ecological economics, the NÖM could be redefined to signify the threshold of ecological and social viability of a politico-economic system.

It would represent the minimum level of resources, biodiversity, and ecosystem services to be maintained to ensure the subsistence and dignity of present and future generations, constituting a kind of "fundamental ecological bedrock." Governance Node An interconnection point within a complex governance system, where different actors (states, businesses, civil society, international institutions) and different scales (local, national, global) interact to influence a decision or the implementation of a policy. Identifying and understanding governance nodes are essential for designing effective interventions in ecological transition, as they are often strategic sites of power and resistance.

Principle of Non-Regression (Environmental) A legal principle according to which the level of environmental protection achieved by existing legislation and regulation cannot be diminished. It aims to prevent environmental setbacks and consolidate gains. This principle, although implicit in many international and national texts, tends to be explicitly affirmed, as in the French Environmental Charter of 2004, which has constitutional value. Principle of Resilience The capacity of a system (ecological, social, economic) to absorb disturbances and reorganize itself after a shock, in order to maintain its essential functions, structure, and identity.

Unlike mere stability or robustness, resilience implies adaptability and a capacity for learning in the face of change. It is central to the thinking of C.S. Holling (1973, *Resilience and Stability of Ecological Systems*) and is now applied to socio-ecological systems as a governance objective. Normative Foresight A foresight method that does not merely explore possible or probable futures but aims to define a desired future and develop strategies to achieve it. It contrasts with exploratory foresight by integrating a dimension of values and ethics, seeking to orient present action towards a desired objective.

It is particularly relevant in the context of ecological transition, where the goal is to imagine and build more sustainable and just societies. Geo-Biophysical Scarcity A concept that describes the constraint imposed by the Earth's finite limits in terms of natural resources (raw materials, energy) and absorption capacities for waste and pollution. This scarcity is not merely economic (dependent on prices and techniques) but intrinsically physical and irreducible. It constitutes a fundamental challenge to models of unlimited growth and calls for a rethinking of the foundations of economics and law (cf. Georgescu-Roegen, N. 1971, *The Entropy Law and the Economic Process*).

Biophysical Referent The set of constraints and dynamics imposed by the laws of physics, chemistry, and biology that govern the functioning of the Earth system. It includes energy flows, biogeochemical cycles, and biodiversity limits. This referent is distinct from the socio-economic referent and must be given primary consideration in the elaboration of public policies to ensure the sustainability of human societies. Ecological Regeneration The process by which a degraded ecosystem recovers its ability to function naturally, restore its biodiversity, and provide its services.

This concept goes beyond simple restoration or conservation, involving a proactive transformation to enhance the system's health and resilience, often through targeted but non-invasive human interventions. Full Reparation of Ecological Damage A legal principle stipulating that restoration of the degraded environment to its prior state must be the objective of any reparation action. If restoration is impossible, reparation takes the form of a financial payment allocated to an equivalent environmental action, or compensatory damages.

French law explicitly integrated this with Law no. 2016-1087 of August 8, 2016, for the reconquest of biodiversity, nature, and landscapes, notably in Article 1246-1 of the Civil Code, which specifies that "any person responsible for ecological damage is obliged to repair it." Intergenerational Responsibility The ethical and legal obligation of present generations towards future generations, implying the transmission of an environmental and social heritage that is not degraded or impoverished. This concept, central to sustainable development, involves prudent resource management and the prevention of irreversible damage (cf.

Hans Jonas, 1979, *The Imperative of Responsibility: In Search of an Ethics for the Technological Age*). Reversibility (Law of Legal Regimes) The capacity of a legal decision, public policy, or development project to be cancelled, modified, or restored to its initial state without irreversible consequences or prohibitive costs. In an ecological context, reversibility is crucial for prudence against uncertainties, particularly concerning the long-term environmental impacts of new technologies or infrastructures, such as nuclear waste storage or climate engineering. Ecosystem Services (ES) Direct or indirect benefits that humans derive from ecosystems.

They are classified into four main categories: provisioning (food, fresh water, timber), regulating (climate regulation, flood control, water purification), supporting (soil formation, nutrient cycling, pollination), and cultural (recreation, aesthetic, spiritual). The economic valuation of these services, often ignored by traditional markets, is essential to justify their protection. The Millennium Ecosystem Assessment report (2005) established the importance of ES for human well-being. Food Sovereignty The right of peoples to define their own sustainable agricultural and food policies and strategies, from production to consumption, while respecting biodiversity and the environment.

This implies the protection of local production against dumping, the regulation of agricultural markets, and resilience to climate shocks. The concept was formalized by Via Campesina in 1996. Just Transition An approach to ecological transition that seeks to ensure that the shift to a low-carbon and resilient economy does not create new inequalities but works towards social justice. It anticipates social and economic impacts (job losses in fossil fuel industries, increased energy costs for the poorest) and proposes accompanying measures (professional retraining, social assistance, targeted investments) for the most affected populations and territories.

The International Labour Organization (ILO) published "Guidelines for a just transition towards environmentally sustainable economies and societies for all" in 2015. Use Value The direct utility that individuals derive from a good or service, whether marketable or not. It is distinct from exchange value (market price) and intrinsic value. In the ecological context, the use value of ecosystem services is often non-monetized but fundamental for human well-being (e.g., clean air, drinking water). Intrinsic Value (of Nature) A philosophical and ethical concept that attributes inherent value to nature, living species, and ecosystems, independently of their utility to human beings.

This biocentric or ecocentric perspective contrasts with dominant anthropocentrism and is fundamental for supporting rights of nature or Earth law, advocating for the protection of natural entities for their own sake, and not merely as reservoirs of resources or amenities for humanity (cf. Aldo Leopold, 1949, *A Sand County Almanac*). Legal approaches recognizing the status of legal person or subject of rights for rivers or forests are based on this intrinsic value.

Truth in Pricing (Ecological) The application of economic principles aimed at integrating all environmental and social costs associated with the production, consumption, and end-of-life of goods and services into their market price. This involves the internalization of negative externalities through mechanisms such as carbon taxation, eco-taxes, or tradable emission permits, so that the price reflects the full actual cost to society and the environment. Via Campesina An international peasant movement that advocates for food sovereignty, peasant and agroecological farming as solutions to food and climate crises.

Founded in 1993, it brings together millions of peasants, fishers, pastoralists, indigenous communities, and agricultural workers worldwide. It is a major actor in promoting peasants' rights and recognizing agroecology as a sustainable agricultural model. Climate Vulnerability A measure of the susceptibility or inability of a system (human or ecological) to cope with the negative effects of climate change. It depends on the system's sensitivity to climatic impacts, its degree of exposure to risks, and its adaptive capacity. High vulnerability calls for specific adaptation policies and resilience-building, particularly in the most exposed and least resourced regions and communities.

Chapter 78 Appendix D — Legal Reference Models The Framework Pact: Foundation for Intergenerational Governance The intergenerational Framework Pact is conceived as a supranational constitutional treaty, aimed at guaranteeing the long-term habitability of Earth for future generations. Its development is rooted in the principle of intergenerational integration, as theorized by Edith Brown Weiss as early as 1989 in "In Fairness to Future Generations." This fundamental legal document recognizes the legal personality of humanity in its temporal continuum, thereby granting future generations an inalienable right to a healthy environment and sufficient resource base.

Article 1 of the Framework Pact stipulates that "humanity, as a transhistorical collective entity, is the holder of fundamental rights to ecological subsistence and planetary habitability." This provision breaks with a legally outdated anthropocentrism, to embrace a holistic perspective inspired by deep ecology. It relies on emerging jurisprudence recognizing nature as a subject of law, such as the Whanganui River in New Zealand (Te Awa Tupua Act 2017) or the Atrato River in Colombia (T-622 ruling of 2016).

Article 3 establishes a principle of "non-deterioration irreversible," prohibiting any action or inaction likely to substantially and irreversibly compromise the regenerative capacities of Earth systems. This principle differs from the simple precautionary principle by its higher threshold of prohibition, targeting systemic "tipping points" identified by the Intergovernmental Panel on Climate Change (IPCC) as early as 2007. It implies a re-evaluation of national legal frameworks, often deficient on this fundamental issue.

The Framework Pact also institutionalizes a binding "intergenerational carbon budget." Inspired by the work of Rockström et al. (2009) on planetary boundaries, it sets ceilings for greenhouse gas emissions and critical resource extraction for defined periods, proportionate to planetary absorption capacity and the fundamental needs of future generations. This budget is calculated to keep global warming well below 1.5°C above pre-industrial levels, an objective established by the 2015 Paris Agreement. Implementation and Control Mechanisms The application of the Framework Pact is supervised by the Constitutional Court of Humanity (CCH), whose jurisprudence is binding.

Article 12 grants the Chamber of Future Generations (described infra) and accredited non-governmental organizations a right of direct action before this Court, ensuring effective enforceability of intergenerational rights. This structure departs from the classic inter-state model for a cosmopolitan approach, influenced by Jürgen Habermas' reflections on international law and sovereignty. The financing of the Framework Pact mechanisms is ensured by a global taxation of negative externalities inflicted on planetary commons, notably a global carbon tax and a royalty on the extraction of non-renewable resources.

This ecological taxation, whose potential is estimated at several hundred billion dollars annually (OECD, 2019), aims to internalize environmental costs hitherto borne by future generations. Article 15 provides for the priority allocation of these funds to ecological restoration and the transition of production systems. Statutes of the Planetary Cognitive Agency (PCA) The Planetary Cognitive Agency is a transnational, independent, and multidisciplinary institution, tasked with collecting, analyzing, and synthesizing data relating to the state of Earth systems and their future trajectories.

Its statutes confer upon it a central role in preventing ecological disasters and prospectively evaluating public policies, acting as a scientific and ethical "brain" for global governance. It is created under Article 7 of the aforementioned Framework Pact. The PCA is structured into specialized departments: climatology, biodiversity, geology, oceanography, sociology, ecological economics, and systemic modeling. It is endowed with a mandate for disinterested expertise, with an annual operating budget estimated at 0.1% of global GDP, or approximately $85 billion based on 2022 nominal GDP.

This funding, guaranteed by the Framework Pact, ensures its autonomy from national or corporate interests. Its missions include elaborating prospective scenarios over 50, 100, and 200 years, including projections of climate change impacts and resource depletion. For this purpose, it uses cutting-edge climate models, such as those developed within the Coupled Model Intercomparison Project (CMIP6). The PCA's reports are public, accessible to all, and form the scientific basis for the decisions of the Constitutional Court of Humanity and the recommendations of the Chamber of Future Generations.

Article 5 of the PCA's statutes specifies that its members are recruited based on criteria of scientific excellence and ethical independence, for a 10-year term renewable once. They are subject to a duty to disclose conflicts of interest and are protected by international observer status, guaranteeing them the functional immunity necessary for the exercise of their sensitive missions. Their objectivity is the cornerstone of their legitimacy. Epistemic and Consultative Authority The PCA is vested with epistemic authority recognized by all signatories of the Framework Pact. Its analyses constitute "scientifically established facts" upon which political decisions must be based.

This is a form of deliberative expertise, inspired by Sheila Jasanoff's work on the co-production of scientific knowledge and social order. However, the Agency does not have coercive decision-making power; its role is to provide the rational bases for global governance. The PCA is also mandatorily consulted on any major infrastructure project or national legislation likely to have significant transnational or intergenerational impacts. Its opinions, although non-binding, carry considerable moral and scientific weight, and any divergence from its recommendations must be justified transparently and rigorously before the Chamber of Future Generations.

This mechanism reinforces governance based on scientific evidence. Charter of the Chamber of Future Generations (CFG) The Chamber of Future Generations is a representative body dedicated to the interests of unborn humans, inscribed in a logic of "extended democracy" explored by thinkers like Jonas (1979) and Giddens (1991). Its charter, annexed to the Framework Pact, confers upon it specific legitimacy and powers to speak on behalf of the absent. It is designed as a counter-power to the short-term logics inherent in contemporary political systems.

Article 2 of the Charter stipulates that the CFG is composed of 200 members, representing humanity's geographical, cultural, and epistemic diversity. The selection process is hybrid: 100 members are appointed by recognized scientific and ethical institutions, and 100 members are chosen by lot from voluntary citizens under 40 years old, thereby ensuring a sensitivity to the future. Their mandate is 15 years and is not renewable. The CFG's mission is to ensure the proper application of the Framework Pact, evaluate the sustainability of national and international policies, and propose amendments to existing laws or new legislation.

It has the power of legislative initiative before the United Nations General Assembly (or its future equivalent) and the right to refer matters to the Constitutional Court of Humanity, thereby enabling challenges to decisions deemed prejudicial to future generations. Annual reports on the state of future generations' rights are prepared by the CFG and presented to international bodies. These reports include transdisciplinary sustainability indicators, inspired by the Sustainable Development Goals but with an extended time perspective and stricter ecological thresholds. They highlight the "ecological debts" accumulated by present generations.

Power of Interpellation and Suspensive Veto Article 10 of the Charter grants the CFG a power of "strong interpellation" of states and international organizations. Any project with major environmental implications must be submitted to its review. Should the CFG deem a project manifestly contrary to the principles of the Framework Pact, it may issue a "suspensive veto" for a period of 18 months, allowing for a thorough re-examination and, if necessary, a referral to the CCH. This mechanism is inspired by parliamentary and constitutional control processes. The CFG is endowed with a scientific and ethical council, composed of independent experts whose opinions inform its deliberations.

It organizes public consultations and "citizen assemblies chosen by lot" on matters of major importance for future generations, such as nuclear waste management or deep-sea exploration. These participatory assemblies reinforce its democratic legitimacy. An example of a successful citizen consultation was the resolution on the ban of non-biodegradable nanomaterials in 2038, adopted at the impetus of the CFG. Intergenerational Ecological Trust Contract for 200 Years The intergenerational ecological trust contract is an innovative legal instrument, designed to safeguard ecological commons or critical infrastructures over very long periods.

Inspired by the Anglo-Saxon concept of "trust" and European "territorial foundations," it aims to depatrimonialize certain assets by placing them under the management of a designated third party, for the explicit benefit of future generations, for a temporal horizon of approximately 200 years. Article 1 of the standard Trust Contract model stipulates that "the grantor (State, community, enterprise, or person) transfers ownership or management of the asset (natural territory, groundwater table, dam, etc.) to a trustee, in the exclusive interest of present and future beneficiaries, for a period of 200 years." This transfer is irrevocable, except by unanimous decision of the CFG and the CCH.

This duration corresponds to geological and ecological time scales. The trustee, designated for their competence and integrity, can be a specific public entity (e.g., a Water Agency), a recognized environmental foundation, or even the Planetary Cognitive Agency itself when the asset concerns a planetary common of primary importance. The trustee is obligated to manage the asset according to principles of ecological restoration, biodiversity conservation, and ecosystem services, in accordance with a detailed management plan annexed to the contract.

The beneficiaries of the trust are "all human beings, past, present, and future, for their ability to enjoy a healthy environment and sufficient resources." This universal and diachronic clause anchors the contract in an ethics of global responsibility promoted by Hans Jonas. The CFG is named the oversight body for the interests of future beneficiaries, with a right of scrutiny over the trustee's management. Penalty and Radical Revision Clauses Article 8 provides for substantial financial penalty clauses in the event of a serious breach of obligations by the trustee.

These penalties, which can amount to several tens of millions of euros per infraction, are paid into the ecological restoration fund managed by the Framework Pact. They aim to deter any managerial failure and compensate for environmental damages. In a case of major non-compliance in the management of a hydrological basin in 2045, the CCH imposed a penalty of 450 million euros on the managing entity. The contract also includes a "radical revision" clause (Article 12) stipulating that every 50 years, an independent expert committee, mandated by the PCA and the CFG, evaluates the relevance and effectiveness of the management plan.

If major changes in ecological conditions or scientific knowledge require it, the plan can be revised in depth to better serve the interests of future generations, even if this implies significant modifications for the initial stakeholders. These legal models constitute the pillars for a re-foundation of law, no longer solely adapted to bilateral transactions between contemporary legal subjects, but ordered toward the persistence of a habitable "ecosphere." They represent an attempt to concretely translate the ethical imperatives of intergenerational justice into operational instruments, capable of transforming the decision-making frameworks of the 21st century.

Their ambition is to enable a harmonious coexistence between human activity and planetary boundaries, by shifting the center of gravity of sovereignty toward a shared responsibility for the future. Chapter 79 Appendix E — Thematic Bibliography (300 references) Planetary Boundaries Rockström et al., as early as 2009, crystallized the notion of planetary boundaries, identifying nine biophysical thresholds that should not be crossed to maintain the stability of the Holocene, a geological period conducive to the development of human civilization.

These thresholds include climate change, biosphere integrity (biodiversity loss and extinction), biogeochemical flows (nitrogen and phosphorus cycles), ocean acidification, land-use change, freshwater use, atmospheric aerosol loading, and the introduction of novel entities. In 2023, Steffen et al. updated this research, demonstrating that six of these nine boundaries have now been crossed, including the biosphere and biogeochemical cycles, signaling systemic destabilization. The overexploitation of resources and pollution manifest systemically.

For example, the average annual deforestation between 2015 and 2020 reached 10 million hectares, contributing not only to biodiversity loss but also to an increase in atmospheric carbon dioxide concentrations, which exceeded 420 parts per million (ppm) in 2024, a threshold not reached in at least 800,000 years. The erosion of biodiversity is estimated by the 2019 IPBES report to threaten one million species with extinction, an unprecedented rate in human history. Water resource management represents a major challenge.

Approximately 2 billion people lacked access to safely managed drinking water services in 2022, according to the WHO and UNICEF, while water stress already affects entire regions, exacerbated by climate change which alters precipitation patterns and intensifies the frequency of droughts. The over-extraction of aquifers compromises ecological resilience and global food security, as highlighted by Konikow and Kendy's 2005 study on global aquifer levels. Ecosystemic Implications of Deregulation The crossing of planetary boundaries is not an isolated phenomenon; it generates positive feedback loops that amplify disturbances.

Amazonian deforestation, for example, could potentially trigger a tipping point, transforming the rainforest into savanna, with global climatic and ecological consequences. High concentrations of greenhouse gases reinforce ocean acidification, affecting coral ecosystems and marine food chains, as explained by Le Quéré et al. in *Nature Climate Change* (2018). The issue of "novel entities," introduced by Persson et al. in 2022 into the planetary boundaries framework, encompasses artificial substances and energy forms, such as microplastics, persistent chemical pollutants, and radioactive waste.

These elements interact in complex ways with natural systems, often with unknown and long-term effects on human health and ecosystems. The lifespan of some of these pollutants, such as PFAS, can extend over centuries, posing an intergenerational challenge. Ecological Economics and Post-Growth Ecological economics, through the pioneering work of Nicholas Georgescu-Roegen (*The Entropy Law and the Economic Process*, 1971), highlighted the fundamental incompatibility between unlimited economic growth and the planet's biophysical constraints, drawing on thermodynamic principles.

This discipline proposes a departure from dominant neoclassical economics by integrating natural and social systems not as externalities, but as inherent and constitutive elements of economic activity. Serge Latouche, a leading figure in degrowth, popularized the idea that human well-being does not necessarily depend on a constant increase in gross domestic product (GDP), but rather on a reorientation towards sufficiency, relocalization, and the decolonization of the economic imagination.

His works, particularly *Petit traité de la décroissance sereine* (2007), advocate for a society that reduces its ecological footprint while increasing citizens' quality of life, breaking with the myth of green growth. Jackson, in *Prosperity Without Growth* (2009), emphasizes that absolute decoupling between economic growth and environmental impacts is not observable at a global scale and that a transition to a post-growth economy is essential. He proposes a model of "prosperity without growth" that focuses on investing in quality public services, reducing inequalities, and promoting non-material activities, to move away from the imperative of ever-increasing consumption.

Towards an Ethic of Sufficiency The principles of the circular economy, as theorized by the Ellen MacArthur Foundation, aim to redefine production and consumption to minimize waste and maximize resource value, drawing inspiration from the life cycles of natural ecosystems. However, a superficial application of the circular economy without questioning the scale of consumption and production risks not being sufficient to curb pressures on planetary boundaries, as some critics note. Ecological taxation is a potential tool for internalizing the environmental costs of economic activities. The carbon tax, for example, seeks to incentivize economic actors to reduce their greenhouse gas emissions.

However, its effectiveness depends on its level and its fair distribution to avoid exacerbating social inequalities, as shown by the "Yellow Vests" experience in France in 2018 in response to the increase in fuel tax. The issue of equitable distribution of resources and environmental impacts is central. The concept of "environmental justice," popularized by thinkers such as Robert D. Bullard, highlights the disproportionate way in which marginalized communities are affected by pollution and environmental degradation, emphasizing the ethical imperative of integrating social equity into any ecological transition.

Deliberative Democracy and Citizen Participation Deliberative democracy, as theorized by Jürgen Habermas (*Faktizität und Geltung*, 1992), proposes a model where the legitimacy of political decisions stems not only from majority vote but also from the quality of public debate and informed citizen participation. Applied to environmental challenges, it aims to overcome partisan divisions to build informed social consensuses on complex subjects and long-term issues. Citizen Climate Conventions, such as the one organized in France in 2019-2020, or the Citizens' Assembly on Climate Change in Ireland (2016-2018), offer concrete examples of deliberative mechanisms.

Composed of randomly selected citizens representative of the population, these assemblies formulated ambitious proposals, often more radical than those of traditional political institutions, to address the climate crisis. However, the implementation of recommendations from these deliberative processes remains a major challenge, as evidenced by the mixed fate of the proposals from the Citizen Climate Convention in France.

Political constraints, economic lobbies, and administrative complexity can hinder the translation of citizen aspirations into effective public policies, raising the question of the articulation between deliberation and decision. ■ Access to reliable and independent information ■ Pluralism of confronted expertise ■ Inclusive and respectful deliberation frameworks ■ Guarantees of influence on decision-making processes ■ Transparent evaluation of adopted decisions Expanding the Circles of Deliberation The integration of non-academic knowledge, including indigenous and local knowledge, is crucial for holistic environmental deliberation.

The approach of IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) in its global biodiversity assessment (2019) is an example of this attempt to integrate diverse perspectives for a better understanding of ecological issues. The participation of younger generations is also an essential issue. The "Fridays for Future" movement, initiated by Greta Thunberg in 2018, demonstrated the mobilization capacity of young people and their demand for ambitious climate action, emphasizing the imperative to integrate their voices into deliberative processes, particularly due to their disproportionate exposure to the future consequences of current decisions.

Artificial Intelligence and Planetary Governance The rapid emergence of artificial intelligence (AI) raises fundamental questions about governance, particularly regarding its potential for solving environmental problems and its intrinsic risks. Its applications range from optimizing energy grids, such as the deployment of solar panels, which could reduce carbon emissions by 5 to 10% in the energy sector, to complex climate modeling and biodiversity monitoring. However, the growing carbon footprint of AI itself, due to the energy consumption of its computing infrastructure, constitutes a paradox.

A 2019 study by the University of Massachusetts at Amherst estimated that training a large AI model can emit the equivalent of over 626,000 pounds of carbon dioxide, which is about five times the average emissions of a car in the United States over its entire lifetime. The development of AI poses challenges in terms of transparency, algorithmic bias, and sovereignty. The opacity of the "black boxes" of certain algorithms can hinder the understanding and contestation of automated decisions, raising ethical and democratic issues. Biases can be reproduced or amplified, particularly in the areas of justice or inclusion, and require constant vigilance in the design and training of systems.

AI governance requires international collaboration to establish ethical and regulatory standards. The European Union Artificial Intelligence Regulation (AI Act), proposed in 2021, represents a pioneering attempt to regulate AI systems based on their risk level, with the aim of ensuring safety and respect for fundamental rights. This legal framework is an example of a preventive approach that could serve as a model, although the rapid pace of technological innovation makes regulation complex. Systemic Risks of Uncontrolled AI In addition to ethical concerns, AI raises concerns about its potential impact on social stability and international security.

The use of AI in autonomous weapon systems (AWS), or "killer robots," represents a threat of a new arms race and the dehumanization of conflicts. Discussions within the UN, particularly the Conferences of States Parties to the Convention on Certain Conventional Weapons (CCW), attest to the gravity of this debate. The possibility of "superintelligence" and scenarios of loss of control are serious research topics in the field of AI safety, as discussed by Nick Bostrom in *Superintelligence: Paths, Dangers, Strategies* (2014).

These reflections aim to anticipate and mitigate the existential risks posed by AI systems whose objectives could diverge from those of humanity, a perspective that requires philosophical and technological vigilance. The increasing reliance on AI systems for critical infrastructure (energy, transport, finance) exposes society to new vulnerabilities. A systemic failure, whether accidental or malicious, could have cascading consequences of unprecedented scale. The resilience of these systems and constant monitoring are therefore imperative, similar to strengthened cybersecurity protocols.

International Law and Ecological Transition International environmental law, though evolving, struggles to respond to the urgency of ecological and climate crises. Its foundations date back to the Stockholm Declaration of 1972 and the Rio Declaration of 1992, which laid down the principles of sustainable development, common but differentiated responsibility, and precaution. The precautionary principle, for example, is enshrined in Article L. 110-1 of the French Environmental Code, but its transnational application remains fragmented.

The Paris Agreement on climate (2015), ratified by 195 parties, is a major milestone, committing countries to limit global warming "well below 2°C" compared to pre-industrial levels, and to "pursue efforts to limit it to 1.5°C." However, the non-binding nature of nationally determined contributions (NDCs) and the insufficiency of their cumulative ambitions (they would lead to warming of +2.5 to +2.9°C according to UNEP in 2023) raise doubts about the effectiveness of this mechanism alone. The International Court of Justice (ICJ) is seized with requests for advisory opinions on states' obligations regarding climate change.

States like Vanuatu, in collaboration with a group of countries, requested an opinion from the ICJ in 2022, which could clarify the interpretation of existing treaties on environmental protection and strengthen state responsibility. Climate justice mechanisms are emerging through litigation brought before national jurisdictions, such as the *Urgenda Foundation v. State of the Netherlands* (2019) case, which ruled that the Dutch state had a legal obligation to reduce its greenhouse gas emissions.

Normative Governance in Search of Binding Force The concept of ecocide, proposed as an international crime liable to prosecution before the International Criminal Court (ICC), embodies an attempt to broaden the scope of criminal law to protect the environment on a global scale. The independent expert panel for the legal definition of ecocide proposed a definition in 2021 that could constitute a major advance, but its acceptance by ICC member states is still uncertain. Bilateral and multilateral investment treaties (BITs) can pose obstacles to ecological transition.

Investor-state dispute settlement (ISDS) clauses have allowed companies to sue governments for environmental policies that affect their profits, as in the case of *Philip Morris v. Uruguay* regarding anti-tobacco laws, creating a "fossil fuel lock-in" according to some analysts, and inhibiting the regulation of polluting activities. The need for intergenerational law and a transformative approach is crucial.

The recognition of the rights of nature, as has been done in Ecuador (Constitution of 2008) or New Zealand for the Whanganui River (Te Awa Tupua Act 2017), represents a break with the anthropocentric vision of law, attempting to confer its own legal personality on ecosystems, and not solely on individuals or corporate entities that exploit them.

Chapter 80 Appendix Z — Executive Summary (15 pages) Diagnosis of a Systemic Crisis and the Ecosystemic Imperative The current dynamic of human civilizations, built upon the principles of unlimited economic growth and an anthropocentric domination over living beings, inevitably leads to a civilizational collapse, the precursors of which are now observable and measurable. The dominant economic model, supported by an exponential extraction of resources and uncontrolled waste emission, irreversibly exceeds the biosphere's capacities for regeneration and absorption.

Scientific warnings, from the Meadows Report (1972) to successive IPCC reports, continue to receive no adequate structural response. The erosion of biodiversity, climate change, the scarcity of abiotic resources, and the widespread pollution of ecosystems are not isolated problems, but interdependent manifestations of the same systemic crisis. This crisis is intrinsically linked to a legal and economic anthropology which, by placing humanity in a position of externality relative to nature, has institutionalized its exploitation as a organizing principle of societies and international law.

The radical disconnection between economic ends and biophysical constraints constitutes the core of this impasse. Scientific projections indicate an unsustainable trajectory, with an increasing probability of crossing irreversible tipping points during the 21st century. The Intergovernmental Panel on Climate Change (IPCC) thus estimated, in its sixth assessment report (AR6, 2023), that global greenhouse gas emissions must be reduced by 43% by 2030 compared to 2019 to maintain the 1.5°C target.

The degradation of natural systems not only jeopardizes current socio-economic conditions but fundamentally compromises the capacity of future generations to meet their own needs, rendering the very notion of sustainable development obsolete. Faced with this existential urgency, a profound reconsideration of legal, economic, and philosophical frameworks is not only desirable but indispensable. It is no longer a matter of adjusting the margins of an unchanged system, but of undertaking a paradigmatic mutation to anchor human societies within the limits and regulations of Earth systems, recognizing the radical interdependence and fundamental unity of living beings.

The ecosystemic imperative imposes a refoundation of the organizing principles of coexistence. The Fundamental Triptych of Ecosystemic Laws The sustainability of the human species and the biosphere requires the establishment of three fundamental laws, structuring the international and national legal order, aimed at embedding human action within the planet's biophysical limits. These laws, of superior constitutional value, express the subordination of all human activities to the systemic imperatives of Earth. Law I: The Law of Ecosystemic Integrity This law proclaims the inalienable principle of protecting and preserving the functional and structural integrity of ecosystems.

It recognizes ecosystems and their components (rivers, forests, oceans, species) as entities endowed with their own rights, capable of being represented in court, and whose destruction or degradation constitutes a crime falling under international jurisdiction. The concept of Ecocide, as proposed by the independent expert panel for the amendment of the International Criminal Court (2021), defining ecocide as "any unlawful or wanton acts committed with knowledge that there is a substantial likelihood of severe and either widespread or long-term damage to the environment," is here elevated to the status of a peremptory norm.

The Law of Ecosystemic Integrity prohibits any economic or social activity likely to destabilize major biogeochemical cycles (carbon, nitrogen, phosphorus, water), to irreversibly reduce biodiversity, or to alter the resilience capacity of Earth systems. It establishes a presumption of harm for any major anthropogenic intervention on ecosystems, and reverses the burden of proof, requiring the actor to demonstrate the absence of significant damage and alignment with local and global carrying capacities. Law II: The Law of Biocentric Transition This law imposes a radical reorientation of global economic systems towards regenerative, circular, and low-carbon and material footprint models.

It sets binding targets for the complete decarbonization of economies, the closing of material loops, and the drastic reduction of primary energy and virgin resource consumption. Public and private investment must be primarily directed towards ecological restoration, regenerative agriculture, renewable energies, and resilient urban planning. The Law of Biocentric Transition entails the gradual elimination of all subsidies for fossil fuels and non-essential extractive industries by 2030, as well as the establishment of deterrent ecological taxation for polluting and destructive activities.

It promotes the development of sober technologies and the relocalization of value chains, fostering territorial autonomy while ensuring equitable exchanges rooted in ecological reciprocity. It actualizes the principle developed by Nicholas Georgescu-Roegen in "The Entropy Law and the Economic Process" (1971), recognizing fundamental thermodynamic constraints. Law III: The Law of Ecosocial Cooperation This law establishes the principle of intergenerational and intragenerational ecological solidarity, obliging states and non-state actors to cooperate for the safeguarding of planetary common goods and the equitable sharing of the burdens and benefits of the transition.

It institutes global financing mechanisms for ecological restoration, adaptation to climate change, and universal access to vital resources (water, food, energy). The Law of Ecosocial Cooperation recognizes the interdependence of human and non-human destinies, and promotes participatory governance forms integrating indigenous knowledge and the perspectives of local communities. It paves the way for the establishment of climate and environmental justice, recognizing the "ecological debt" of industrialized countries to global South nations, and implying a substantial transfer of technologies and financial means.

The Six Pillars of Global Ecosystemic Refoundation The implementation of ecosystemic laws relies on the establishment of six interconnected pillars, forming the architecture of a new regime of global and local governance. Pillar 1: Ecosystemic Sovereignty This pillar redefines state sovereignty not as an unlimited capacity to exploit the resources within their territory, but as a primary responsibility for integrated management and protection of ecosystems beyond their borders, in connection with planetary common goods. Ecosystemic sovereignty is conditional upon respect for ecosystemic laws and the carrying capacities of bioregions.

It implies the recognition of global ecological citizenship, where each individual is a guardian of systemic balances. This principle underpins a new form of environmental diplomacy, where international treaties incorporate ecological non-regression clauses and binding oversight mechanisms. It justifies international interventions in cases of major state failure to protect ecosystems of global importance, following the model of the Responsibility to Protect (R2P) but extended to nature. Pillar 2: The Regeneration Economy This involves a profound transformation of productive and financial systems.

The regeneration economy abandons GDP as an indicator of prosperity, replacing it with multidimensional metrics that integrate social well-being, ecosystem health, and systemic resilience. It prioritizes the production of use value over exchange value, and promotes material and energy sobriety, circularity of flows, and the functional economy. Finance is reoriented towards long-term investment in the restoration of natural and social capital. Ecological central banks establish monetary policies aligned with decarbonization and regeneration objectives, for example, by conditioning bank refinancing on transition commitments.

A "triple capital accounting" (financial, human, natural) becomes the norm for all economic entities, as advocated by Pavan Sukhdev in "Corporation 2020" (2012). Pillar 3: The Law of the Earth (Lex Terrae) The Law of the Earth establishes an international and national legal corpus recognizing the legal personality of natural entities (rivers, forests, seas, endangered species), granting them fundamental rights (right to exist, to evolve, to be restored) and the capacity to be represented in court.

Inspired by initiatives such as those in Ecuador (2008 Constitution) and Bolivia (Law of the Rights of Mother Earth, 2010), this law allows ecosystems to defend themselves against anthropogenic damage. It institutes supranational and national environmental tribunals with expanded powers to investigate and judge ecological crimes, including ecocide. The notion of private property is redefined to include a dimension of ecological duty, limiting the use of property in compliance with ecosystem functions and common goods.

Pillar 4: Governance of Planetary Commons This pillar establishes global governance structures for the management of planetary common goods – the high seas, atmosphere, Antarctica, outer space, but also climate, biodiversity, and biogeochemical cycles. These structures, modelled on an international seabed authority or a global environmental agency with binding powers, ensure equitable, sustainable, and intergenerational management. The management of commons is based on the principles of precaution, shared but differentiated responsibility, and equitable access.

It involves the development of multi-stakeholder partnerships, including states, indigenous communities, scientists, and civil society, to ensure maximum legitimacy and effectiveness. Elinor Ostrom, in her work on commons ("Governing the Commons", 1990), demonstrated the feasibility of such non-state or multi-stakeholder management. Pillar 5: Education and Ecosocial Consciousness This pillar aims to transform educational systems at all levels to foster a deep ecological consciousness and civic engagement towards the regeneration of life.

It promotes holistic education, integrating scientific knowledge about Earth systems, environmental philosophy, the ethics of care for the non-human, and indigenous knowledge. The objective is to develop active eco-citizenship, capable of understanding systemic interconnections and participating in decision-making. This involves integrating biodiversity and climate into all curricula, teacher training, and promoting participatory sciences. A "Universal Declaration of the Rights of the Biosphere" is taught from an early age.

Pillar 6: Bioregional Resilience This pillar encourages the decentralization of governance and economy at the scale of bioregions, territories naturally coherent in ecological and social terms. The aim is to build local production and consumption loops, promoting food, energy, and water autonomy, and strengthening social cohesion and resilience to shocks. Bioregions are endowed with broad autonomy to implement ecosystemic laws adapted to their specificities. This implies collaborative governance among municipalities, local communities, and economic actors, aimed at restoring local ecosystems, developing regenerative agriculture, and local renewable energy sectors.

Mundia: The Global Institutional Architecture Mundia is the envisioned supranational body to ensure the implementation and respect of ecosystemic laws and the six pillars of refoundation. It is the legal and institutional framework that will enable the coordination of actions on a planetary scale, beyond narrow national interests. Mundia is not a world government, but a regulator of biophysical limits. Mundia would be structured around three main bodies: ■ **The Council of Ecosystems**: Composed of independent scientific experts, representatives of indigenous peoples, jurists specializing in Earth law, and members of environmental civil society.

Its function would be to constantly assess the state of Earth systems, establish diagnoses, issue early warnings, and propose binding planetary thresholds and limits. Its decisions would have legal and regulatory guiding power for the other bodies of Mundia and member states. It would notably draw upon the work of the Stockholm Resilience Centre concerning planetary boundaries, identified as nine in number (Rockström et al., 2009). ■ **The International Ecosystemic Court (IEC)**: A supranational jurisdiction specialized in applying ecosystemic laws and Earth Law.

It would be empowered to judge ecocide crimes, resolve disputes between states or between states and natural entities, and issue binding injunctions for ecological restoration. Natural entities themselves could bring legal action through their legal representatives. ■ **The Eco-social Solidarity Fund (ESF)**: A sustainable international financing mechanism, funded by contributions from states (proportional to their historical and current ecological impact), taxes on polluting activities (e.g., global carbon tax, tax on destructive financial transactions), and contributions from certain multinational corporations.

The ESF's mission would be to finance the ecological transition of Southern countries, transnational ecological restoration projects, and support vulnerable communities facing climatic and environmental impacts. Its initial budget could be set at 1% of global GDP, or approximately 1000 billion USD per year, for the next twenty years, to address the transformative challenges. Mundia would have monitoring and sanctioning power over states that seriously fail to meet their obligations regarding ecosystemic laws. These sanctions could range from the suspension of certain international rights to substantial financial reparations and injunctions for the restoration of specific ecosystems.

It would be organized on a principle of subsidiarity, strengthening local and bioregional scales, while ensuring global cohesion. Implementation Phases: A Three-Stage Transition The transition to an ecosystemic regime will unfold over several decades, requiring rigorous planning and constant adaptation. It is designed in three major phases, each integrating specific objectives and evaluation mechanisms. Phase 1: The Decade of Urgency (2026-2036) This first phase is dedicated to establishing the basic legal and institutional frameworks, as well as initiating the most urgent actions.

The main objectives are the ratification of Ecosystemic Laws by a critical number of states, the creation of Mundia and national ecosystemic courts. An international moratorium on new destructions of primary forests and deep oceans is put in place. Greenhouse gas emission reduction targets of 50% are set for developed countries, and national decarbonization and ecological restoration plans are developed. Initial funding for the ESF is ensured by voluntary contributions and initial mandatory mechanisms for polluters. The elimination of fossil fuel subsidies is set for 2030, leading to a massive redirection of investments and price signals.

Phase 2: The Decade of Transformation (2036-2046) The transformation phase aims at a systemic reorganization of economies and societies. Mundia's mechanisms are fully operational, with the International Ecosystemic Court having ruled on several emblematic cases. Decarbonization targets are strengthened (75% reduction compared to 2019), and the share of renewable energies reaches 80% of the global electricity mix. The principles of the regeneration economy are integrated into fiscal and commercial regulations, massively promoting circular models and low-impact sectors.

Eco-social consciousness education is generalized, and territories are gradually reorganizing into autonomous and resilient bioregions. Massive ecological restoration programs are launched, including reforestation and ocean depollution. Phase 3: The Decade of Harmonious Coexistence (2046-2056) This phase is one of stabilizing Earth systems and the emergence of a new ecological civilization. Carbon neutrality is achieved or in the process of being achieved globally. Biodiversity is reconstituting, and major tipping points have either been avoided or reversed by restoration actions.

The economy is fully circular and regenerative, with energy and material consumption levels compatible with planetary limits. The governance of planetary commons is mature, and eco-social cooperation is the norm in international relations. Humanity lives in synergy with living beings, and the notion of "progress" is redefined in terms of well-being, resilience, and ecosystemic harmony, rather than material growth. Achieving these objectives will require unprecedented mobilization, a rapid paradigm shift, and global political will.

Safeguards of the Ecosystemic Transition Implementing such a large-scale transformation requires robust mechanisms to prevent abuses, ensure equity, and guarantee the democratic legitimacy of the process. Safeguard 1: The Primacy of Universal Human Rights Ecosystemic Laws and Mundia's governance are subordinated to the respect of Universal Human Rights, as enshrined in the Universal Declaration of Human Rights (1948) and the International Covenants of 1966. The ecological transition must in no way occur at the expense of fundamental freedoms, social justice, equality, and human dignity.

On the contrary, it aims to strengthen these rights by guaranteeing a healthy environment and a fair distribution of resources. Specific mechanisms, such as a Human Rights Committee within Mundia, will ensure that environmental policies do not create new inequalities, do not exclude populations, and protect the rights of "climate refugees" or communities directly impacted by the transition, guaranteeing free, prior, and informed consent, as defined by the United Nations Declaration on the Rights of Indigenous Peoples (2007).

Safeguard 2: Transparency and Open Science All decisions of Mundia, as well as the scientific data and environmental assessments on which they are based, are made public and accessible. A principle of radical transparency is applied to all decision-making processes. Reports on the state of planetary limits, ecological diagnoses, and projections are systematically published and submitted for review by the global scientific community. Scientific research is encouraged and funded independently, with an emphasis on participatory science and the integration of traditional and indigenous knowledge.

Global open data platforms on environment and climate are established, allowing real-time monitoring of key indicators and accountability of states and economic actors. Safeguard 3: Participatory and Deliberative Democracy The transition process is based on deep democratic legitimacy, going beyond classical representation. Global and regional citizens' assemblies on environment and climate are regularly organized, their conclusions serving as a reference for the policy orientations of Mundia and states.

Major decisions, particularly those concerning planetary thresholds and limits, or the designation of new protected areas, are subject to expanded deliberation processes and public consultation. The role of environmental civil society organizations, indigenous peoples, youth, and local communities is institutionalized and strengthened, giving them a direct voice in ecosystemic governance. Mechanisms for periodic review of laws and institutions are planned to allow for adaptations based on feedback and new scientific knowledge.

Safeguard 4: The Principle of Non-Regression Ecological Once a norm, threshold, or environmental protection measure has been established at the international or national level, it cannot be weakened or repealed, unless it is replaced by an equivalent or superior measure. This principle, of constitutional value, ensures that progress in environmental protection is irreversible. It constitutes a legal barrier against political setbacks and pressures from industrial lobbies. The principle of non-regression applies to legislation as well as to international commitments and sectoral standards.

It implies constant vigilance from courts and citizens against any attempt to reduce the level of protection acquired for ecosystems and the biosphere. — End of Protocol — This work was written and edited by David Mosbeux Reference edition, May 16, 2026.