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ESIR

Embedding Anticipatory Governance in Europe's Transitions

Independent Expert Report

Research and Innovation

Embedding Anticipatory Governance in Europe's Transitions

ESIR Policy Brief

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Embedding Anticipatory Technology Governance in Europe's Transitions

A policy brief by the Expert Group on the Economic and Societal Impact of Research and Innovation (ESIR)

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EXECUTIVE SUMMARY

The current century is marked by unprecedented technology developments. While leading on some of them, the EU is struggling to keep pace on others. Attempting to revive its global position in the 2024-2029 policy cycle, the EU will need to remain cognizant of the fact that **technology is an integral part of the broader societal transitions, and it must respect the overarching planetary boundaries**. These are some of the reasons why technology governance is needed to orchestrate developments in line with European values.

In the context of the overwhelming pace and scale of technology development, **a proactive framework** is needed for addressing its ethical, social, environmental and economic implications. Ensuring accountability and public trust requires restoring citizens' and consumers' sense of agency, which is ever more difficult in the face of the steady progress of the big tech companies. This is the logic behind the recent EU legislation which aims to create **a new digital social contract** and replaces *ex post* enforcement with *ex ante* regulation.

In the meantime, **research and innovation policy has evolved to be increasingly focused on the larger, transformative change**, recognising the complexity of innovation and **need for a systems-approach**. Openness and transparent sharing of information about how technologies are developed and deployed are important foundational principles of responsible innovation and governance. Governments and international institutions cannot stand still but require greater knowledge and capacity to deal with complex problems. Understanding the rate of technological change and its underlying logic is a prerequisite of effective governance. This is particularly true in the current period of technology convergence, where developments in different disciplines are often combined.

Decisions about the **choice of a governance method need to reflect the technology's maturity as well as its intrinsic characteristics, including the risks** it poses. Available options range from "doing nothing", to self-regulation, awareness-raising, labelling, nudging, co-regulation, all the way to prescriptive regulatory measures. An integrated approach needs to acknowledge that policy development is a multi-stakeholder effort, not limited to governments. Due to the complexity and global scope of modern technologies like AI, genetic engineering, and quantum computing, **governance frameworks need to be both comprehensive and flexible**. They should address present challenges while also anticipating future advancements.

In the new EU cycle, with much centrality attached to technology development, **alternative futures, rather than a single future, need to be examined** to enhance policy resilience. A complete spectrum of policy options needs to be considered, including "by design" approaches. Adequate space ought to be preserved for uncertainty and adaptation when choosing among policy options. Experimentation needs to be a permanent part of the toolbox, as well as regulatory sandboxes and greenhouses. Appropriate protocols, regular audits and compliance mechanisms are helpful to ensure safety. Protecting data and infrastructure from security threats is of essence. A high degree of transparency is needed for public trust. Finally, international cooperation brings additional value and should be the default position, unless outweighed by risks.

Investing in technology revival and ensuring that technology has a sound governance framework are not only mutually compatible, but also reinforcing objectives. They should become EU priorities in the forthcoming term on an equal part.

1. Introduction

We live in an age of exponential change and systemic risk: continued, albeit unevenly distributed population growth, technology development, including the rise of computational power, and climate change, all produce planetary feedback loops which are making themselves mercilessly felt. **Diverse types of technology have driven significant improvements in human living conditions**. Thanks to advancements technology offers, in many parts of the world we now live longer, enjoy greater freedom and equality, leverage knowledge and collective intelligence within seconds, and have the largest middle class in history. However, **technology has also enabled exploitative habits and practices** that have led to biodiversity loss and ecosystem collapse as well as widespread and irreversible waste, air, and water pollution, and acceleration in atmospheric warming. It has now set us on course for at least 2 degrees of average global temperature rise above pre-industrial levels, no matter how quickly and effectively we act, with catastrophic implications for continuity and quality of life around the world.

In addition, technology developments over the last century have led to activities that have annihilated multiple species on Earth as well as violated individual and collective rights on an unprecedented scale. Emerging technologies such as artificial intelligence (AI), genetic engineering and synthetic biology, nanotechnology, the digitally interconnected world, and quantum technologies - referred to as "**next technologies**" by the Millennium Project[1] - **are anticipated to bring further profound changes to human civilization and to our material impact on our planet.**

There are multiple possible developments the 'next technologies' can bring, raising crucial questions about how we will address their consequences for climate and the environment, for the social contract, and for dealing with new challenges they create. **The open nature of what is coming necessitates a more central role assigned to foresight**, including through horizon scanning and exploration of alternative scenarios. While holding enormous promise, technological developments **raise ethical questions and challenge our ability to control and design technological progress**. What is more, the future of geopolitical dynamics and relationships will likely centre on access to critical enabling technologies and associated capabilities to enable societies to survive, adapt, build resilience and maximise societal value. The Earth's limited natural resources must be deployed for this purpose in ways that minimise environmental and social costs.

The new EU political cycle 2024-2029 is starting amidst an intensified debate on the revival of Europe's socio-economic model, prompted by the report of Mario Draghi on "The Future of European Competitiveness", with particular attention devoted to scenarios for Europe's technological revival. Continuing the pathway towards climate responsibility and an effective social model are seen as a function of Europe's ability to

[1] Millennium Project is a global think tank and research initiative focused on identifying, analysing, and addressing emerging trends and technologies that impact humanity's future.

improve its productivity and reignite sustainable growth. With Mario Draghi's diagnosis that "the EU's regulatory stance towards tech companies hampers innovation"[2], and conviction that the EU needs to profoundly refocus its "**collective efforts on closing the innovation gap with the US and China, especially in advanced technologies**", his call has given a new impetus to technology development as the first and most important pillar of action proposed for the period 2024-2029[3].

In the uncertain and volatile conditions of poly-crisis over the next decades, and most importantly in the context of bio-physical limits of the Earth system ("planetary boundaries"[4]) which set hard limits for human development, **competition for materials, access to critical resources, and governance of technologies will determine how the delicate balance of people, planet and prosperity will play ou**t and with what implications for societal values, norms and freedoms.[5]

In this light, what approach to technology governance should the European Union adopt to navigate these unprecedented changes? This policy paper explores how to govern key emerging technologies in a geopolitical context of increasing competition for scarce resources, sustainable development and adaptation capabilities, respect for planetary boundaries, as well as significant unknowns in the long-term development of exponential "next technologies". It advocates **a proactive, multilayered strategic framework** for addressing the ethical, social, environmental and economic implications of technological advancement, in the most anticipatory way possible and in line with European values.

2. Restoring Accountability and Public Trust in Emerging Technologies

Since the industrial revolution, **the question of agency has closely accompanied the rise of technology**. Two broad approaches have been practiced in the past: the first one is to let technology run its course and step in only when problems become apparent, while the other to prevent challenges from occurring by defining the rules they need to obey at the earliest possible stage.

With the advent of digital technologies, and particularly the Internet, a new phenomenon has emerged. As observed by Lawrence Lessig in the mid-1990s, **in cyberspace technology defines and shapes societal dynamics, not the other way around**. "Always in principle, and increasingly in practice, there is a code (as in software) to assure what the code (as in law) demands, which means always in principle and

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[2] See Mario Draghi, The Future of European Competitiveness, 2024, Part A, p. 26.
[3] See Mario Draghi, The Future of European Competitiveness, Part A, p. 2.
[4] See: "A safe operating space for humanity", Rockström et al, Nature, 23 September 2009.
[5] European Commission: Directorate-General for Research and Innovation, Dixson-Declève, S., Dunlop, K., Renda, A., Charveriat, C. et al., *Research and innovation to thrive in the poly-crisis age*, Publications Office of the European Union, 2023, https://data.europa.eu/doi/10.2777/92915.

increasingly in practice, law is inscribed in the code"[6], he wrote. With the benefit of hindsight, it would have been useful to start defining the "minimum viable product" already at that time, to obtain immediate feedback on the workings of an innovation that is put onto the market, to guide future development.

In 2011, in their book "The New Global Rulers", Tim Büthe and Walter Mattli explained the relevance of technology corporations such as Microsoft in setting global standards, often embedded in technological specifications such as Application Programming Interfaces: software intermediaries that allow different applications, systems, or components to communicate with each other. Since then, the **tech companies developing and selling these technologies have captured increasing shares of the value generated by the real economy, and amassed more political capital**.

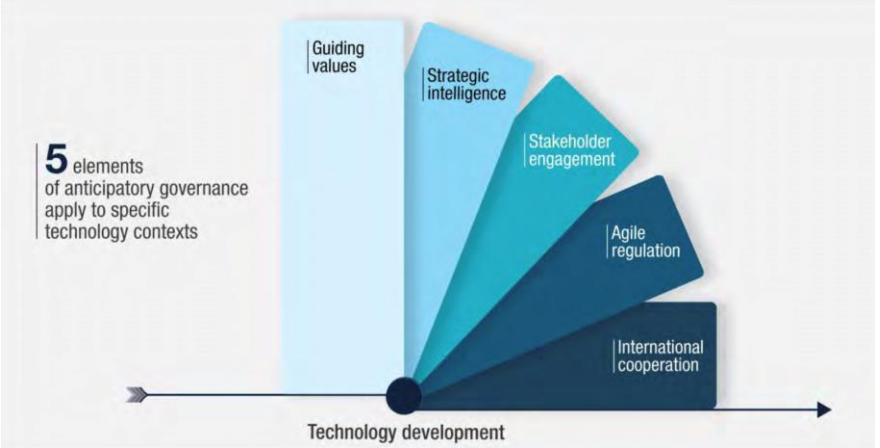
The rise of technology as a key shaper of modern society, and **the increasingly private control over its development, has prompted governments to take action to restore control and trigger directionality** in the way technology is developed. Specifications for technological development are increasingly shaped by non-neutral considerations, such as the socio-technical performance of artifacts in meeting green standards (e.g., carbon footprint) or the ethical alignment of technological systems (e.g., AI frameworks).

The imperative of strengthening public governance of technologies has become stronger than ever over the past few years. And nowhere has this become more visible than in the digital space. On its part, the EU has reacted to the almost-entirely unregulated and privatised nature of the internet with the General Data Protection Regulation (GDPR), and later with a flurry of legislative initiatives such as the Digital Markets Act, the Digital Services Act, the Data Act, the Data Governance Act, the AI Act, the Cyber Resilience Act, and many more. There has been a long list of policy objectives that has accompanied this realisation: repatriating data, achieving technological sovereignty, ensuring trustworthiness of AI, promoting Business-to-Business data exchanges, increasing the contestability of gatekeeper positions in cyberspace, introducing responsibility of large intermediaries for online harms, ensuring user control over data, and much more.

At its heart, EU technology governance aims **to restore agency** to democratic societies in the digital age. It is about **ensuring that the rules and norms that govern the development of technology are anchored in societal values** and that these values in turn are determined through meaningful democratic engagement. It is also about designing effective de-risking strategies, given that technology development comes to pose significant, often existential challenges to humanity.

In this effort, **the EU has been an early adopter of the OECD Framework for Anticipatory Governance of Emerging Technologies**, with its **five interconnected elements**: guiding values, strategic intelligence, stakeholder engagement, agile regulation and international cooperation.

[6] See Lessig, Lawrence, "The Zones of Cyberspace", Stanford Law Review, May 1996.



Source: OECD

There is no doubt that the EU **has aimed to anchor technological development in foundational and technology-specific values** although it could have been better at debating these values in "particular technology contexts" and integrating them throughout the entire process, from agenda-setting to deployment. Some of the mechanisms for public consultation in the EU have become excessively routine to reflect the nuanced ways in which technology affects citizens in the workplace and in everyday life.

The EU needs to radically improve its apparatus for strategic intelligence, enabling early analysis of the technology's potential and impact. While foresight has made strong inroads into the EU's policymaking, it often remains a stand-alone process, that is not fully integrated into the design of technology-related initiatives. Ensuring that tools such as horizon scanning, scenario analysis, and technology assessment are at the disposal of all EU institutions is necessary to make sure there will be sufficient anticipation of future challenges, with the relevant impact on the development of roadmaps and strategic visions.

The EU needs to make further progress in the field of **stakeholder engagement** and ensure that it becomes a genuinely two-way process, allowing for crowdsourcing of valuable ideas and insights. Multi-stakeholder efforts need to be based on trusted relationships. One framework that could be useful for understanding the role of each stakeholder is **orchestration**, **a form of partnership in which one leading institution leverages the specialised knowledge** and information of other stakeholders to reach a desired result. Popularised in social science by Kenneth Abbott at Arizona State University, orchestration has so far mostly been applied to the pursuit of global public goods through multi-stakeholder partnerships such as Gavi or COVAX[7]. In technology governance, it may take different forms, but in principle **it should leverage end users, civil society and the private sector to enable greater situational awareness**, stronger auditing of technologies, monitoring of the interplay between technology and

[7] See Kenneth W. Abbott, Philipp Genschel, Duncan Snidal, Berhard Zangl, "Orchestration: Global Governance through Intermediaries", August 2012, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2125452.

society, and *ex ante* and *ex post* evaluation of technology trends and possible needs for reform.

As regards the fourth element of the OECD's framework, **agile regulation**, the EU has been a frontrunner globally, putting its elaborate legislative machinery to active use, albeit with the risk of overregulation in certain areas. It has acted forcefully where the rules and responsibilities needed to be enshrined in the law, especially as regards the functioning of the digital single market. In the process, **it has tended not to give sufficient weight to non-binding approaches** such as codes of conduct. **It has also sacrificed adaptability**; given the politically charged compromises it has needed to strike, which are inevitably difficult to revisit.

Finally, the EU has been a champion of **international co-operation**, aiming to promote dialogue and hence coordinate approaches to technology governance.

3. Frontloading Technology Governance

Already during the Industrial Revolution of the late 18th and 19th centuries, **rapid technological advancements prompted the need for formal regulation and oversight**. As mechanised production and the steam engine transformed industries, governments began implementing basic labour laws, factory regulations, and safety standards, exemplified by the UK Factory Acts. The subsequent rise of electrical infrastructure, telecommunications, and transportation required more organised governance and saw the advent of organisations like the International Electrotechnical Commission, set up in 1906, and later the International Organisation for Standardisation, founded in 1947.

Today, **technology[8] governance should be understood as the ensemble of measures** applied to ensure that technology development follows a path which is **in line with societal values**.

Governance can be achieved through explicit rules, incentive schemes, social norms, guidelines, standards, policies, ethical principles or command structures. It typically goes beyond government, and includes other stakeholders, such as the private sector, civil society, domain experts, and individuals. Technology governance encapsulates the process, timing, scope, actors and the outcome of decisions concerning the development and diffusion of technology.

The aim of technology governance is to **stimulate support for science and innovation, enabling social well-being within planetary boundaries**, facilitating broad collaboration at multiple scales, maximizing sustainability, resilience and environmental regeneration, attracting financial and human capital, and building anticipatory or dynamic capabilities. Governance frameworks should serve as **enablers for the development and responsible use of technology**, removing unnecessary hurdles, within an appropriate time horizon.

[8] For the discussion of the definition of technology, see Annex I.

The evolving framework of technology governance should not overlook the governance of **research and knowledge generation**. The latter is often seen as an inherently free and unregulated domain, distinct from technological deployment. However, certain fields of research highlight the **urgent need for a governance framework even at the pre-technology stage**. One notable example is **climate engineering**, specifically technologies aimed at altering the Earth's radiation balance to reduce global temperatures. While such technologies might be considered a "last resort" if global greenhouse gas (GHG) reduction efforts fail, they come with profound risks. Deploying such systems would alter the climate globally, with uneven and largely unpredictable impacts. These risks are so severe that scientific consensus, as noted in IPCC reports, and prominent voices in the scientific community argue for restricting research beyond laboratory experiments.

Similar concerns arise in other contexts, such as **deep-sea mining**, where the extraction of valuable resources could lead to irreversible environmental damage and inequitable exploitation of global commons. These examples underscore **the need to extend governance considerations beyond technology to the research phase**, particularly for domains with potentially irreversible or global-scale impacts. Incorporating principles of **proportionate and adaptive governance** at the research stage can prevent risks from escalating and ensure that innovation aligns with societal, ethical, and environmental values.

An early diagnosis is also needed regarding the societal aspects of technology governance, so that technological innovation aligns with public values, avoids resistance, and achieves sustained societal benefits. The concept of **"societal readiness levels"**(SRLs) is a way to gauge the acceptance and preparedness of society to engage with and adopt new technologies. Societal readiness should inform the early stages of research and innovation agendas, ensuring that societal needs, values, and potential concerns are integrated into the conceptualization of technologies. Governance frameworks should actively assess and adapt to societal readiness during the policy formulation process, particularly in contexts where resistance or fluctuating acceptance is likely. Ongoing evaluation is necessary, given that societal readiness can shift over time and even regress, necessitating continuous monitoring and engagement. In this context, **governance should be framed as a co-evolutionary process** that engages society actively.

4. Technology Governance as an Enabler of Transformative Change

Research and innovation policy has evolved **from focusing primarily on market failures to addressing broader systemic issues known as transformation failures**. The market failure perspective addresses issues such as externalities, information asymmetries and underinvestment since firms cannot fully capture investment benefits. Policies aimed at correcting these failures include funding research and innovation, providing tax incentives, and protecting intellectual property rights. The reform agenda in this area is wide-ranging. As Mario Draghi has pointed out, Europe must refocus its research and innovation spending on a smaller number of priorities. It should allocate more resources to breakthrough innovation, make the process more outcome-based and

efficient, and put in charge more project managers and "people with proven track record at the frontier of innovation"[9].

On the other hand, **transformation failures** address broader systemic issues that hinder the transition to new, more sustainable technological and societal systems. **Transformation failures recognize that innovation systems are complex**. They involve and require collaboration and orchestration of many different actors and institutions. Transformation failures are also a matter of systemic issues, such as **lock-in effects** where existing technologies, user practices, and regulatory frameworks, create barriers to new innovations. The policy shift from tackling market failures to transformation failures reflects a deeper understanding of the complexity of innovation and the need for policies that can guide transformative change. It is a recognition that **innovation** is not just about creating new products or services, but about **transforming entire systems of production and consumption to meet societal challenges**[10]. Consequently, the policy mix targeting transformation failures typically needs to be broader than the policy portfolios aimed at market failures.

In many cases, it is the **rollout phase that falls short of transformative ambitions**, due to a combination of several factors such as: excessively narrow framing of initiatives, under-involvement of key stakeholders, lack of policy coordination and joint action between innovation ministries, agencies and implementing bodies on the EU, national and regional level. The sheer spectrum of actors to be involved, and the fact that transformative change emerges from decentralised, bottom-up initiatives that may even be external to the system is in itself a challenge to policy coordination and alignment. Other factors include path dependencies in the research and innovation (R&I) support system and overreliance on existing instruments, logics and governance structures.

It is important to acknowledge that **both top-down and bottom-up approaches to defining the direction of transformative change have their limitations**. Transformative third generation research and innovation policies are often introduced in a context where more traditional first- and second-generation policies persist[11]. This may create frictions and require management of trade-offs although first-generation instruments like R&I subsidies can remain part of the policy mix for transformative change unless they support legacy policy, as is the case with subsidies for fossil fuel R&I. In such a context, transformative policy mixes need not only to stimulate change in the "new" direction but also actively phase out instruments that support the "old", undesirable direction.

Several initiatives proposed in the Political Guidelines of President Ursula von der Leyen as well as in Mario Draghi's report on the Future of European Competitiveness have the characteristics of **projects aiming at transformative change**. This is the case with

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[9] See Mario Draghi, The Future of European Competitiveness, Part A, p. 29.
[10] Raven & Walrave, 2020. Overcoming transformational failures through policy mixes in the dynamics of technological innovation systems; Weber and Rohracher, 2012. Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework.
[11] Diercks 2019, Janssen et al 2021.

Mario Draghi's suggestion to build "computing capital" by scaling up the EU's computing infrastructure and AI capabilities and connecting private and public computing nodes[12]. Under this concept, an EU-wide framework would be created with a relevant legal, financial and operational model, including revised state aid rules, to allow the "computing capital" of public institutions to support innovative SMEs in exchange for equity options, royalties or dividends to be reinvested in capacity and maintenance. A proposal of this nature reflects the fact that the state and the public sector at large retain a crucial role in the activation and design of the innovation process. While this has been true from the beginning of the current phase of technological advancement, as demonstrated in the work of Mariana Mazzucato[13], the geopolitical competition as well as greater expectations placed on innovation in the context of the ongoing transitions, points towards continued case for state involvement.

Technology Governance in the Context of the EU Mission 100 Climate Neutral and Smart Cities

In European and global contexts, transforming cities and regions is the leading edge of climate action. Cities hold 80% of the human population and produce 70% of global emissions. How cities transform will determine the survival and the future shape of human civilisation in all its diversity. In these contexts, the **role of technology is critical** – to raise awareness, shape knowledge and understanding, determine choices and relevance, and enable climate-safe and climate positive infrastructure, materials and logistics, agile decision making and governance.

Technology governance plays a pivotal role in the transformation of cities, given the importance of issues of ownership and control, which are relevant to ensure that infrastructure and data are used in public interest, lead to equitable outcomes and prevent monopoly control. Urban utilities rely on vast amounts of data, including sensitive personal information. Clear rules are needed to address data ownership, privacy, security, and usage rights. In addition, data generated in cities needs to remain accessible for public benefit.

Place-based, spatially organised transformation of energy and resource systems, processes and infrastructure require integrated and interoperable technology architecture, systemic solutions and responsive analytics to coordinate and sequence different interventions, drive behaviour change, and unlock co-benefits to achieve **whole systems change**. For example, the digital and information infrastructure needed for energy and resource efficient buildings is the same digital infrastructure needed for in-home health care for ageing populations and for climate resilient protection mechanisms. Climate-related events will need real-time resource mobilisation, climate resilient materials and constructions, accessible and reliable information, and demand-side reduction and sustainable lifestyles. Financial markets will need new information

[12] See Mario Draghi, The Future of European Competitiveness, Part B, p. 82.
[13] See Mariana Mazzucato, "The Entrepreneurial State: Debunking Public vs. Private Sector Myths", 2013.

architectures to support new classes of assets, key indicators and rapidly evolving risk assessments.

Algorithmic governance is emerging as an enabler for action and potentially a means of fair distribution of resources. At the same time, it raises the risk of bias and unequal access if not properly designed. It needs to be accompanied by robust oversight and accountability mechanisms to not exacerbate existing social inequalities or create new ones. Effective and intelligent urban and regional transformation is fast becoming a highly competitive market as public authorities, businesses and communities reach for answers and support and will constitute one of the most significant technology development, deployment and accelerated test and learn contexts for the next 50 years.

Within the mandate of the European Green Deal and the Fit for 55 legislative package, the Commission's Horizon Europe, has launched five 'Missions' designed to create the conditions for exponential social, economic and infrastructural transformation for people, planet and prosperity. **One of these Missions is focused on accelerated decarbonisation of 100+ cities to reach net-zero by 2030**. This is intended to test, learn, build capability and demonstrate how to achieve a just and sustainable transition amongst cohorts of cities, so that thousands of other cities can follow as quickly as possible, leveraging the knowledge, information and decision support assets created by the NetZeroCities platform. The Cities Mission is supported by a raft of enabling policy measures, public procurement measures, new indicators, permitting procedures and incentives. It comes with an unusually structured approach, clear directional signal and agreed timeframes for implementing solutions and achieving outcomes which creates ideal 'pull' conditions for rapid technology acceleration and implementation at scale.

The fundamental question is: who should own, use, learn and benefit from the application of 'next' technologies in these cities to achieve the ambitious commitments they are making, and how should such technologies be governed, so as to facilitate the Single Market in Europe, protect and strengthen the social contract and the commons that cities represent and aggregate. The pressure to deliver is extreme, compounded by the intensified onset of climate change effects; transformation of urban environments implicates personal data, ownership rights, individual and collective responsibilities and benefits as well as questions of corporate citizenship for businesses operating in cities. **There is currently no governance framework in place for cities to use to insist on technology deployment that is holistic and systemic**, effective in recognising and honouring the interweaving of public and private value creation entailed in green transformation, designed for just resource distribution and transparency, or 'made in Europe', so that Europe, and the residents of these cities, can benefit from the 'training data' and competitive edge that this mission will provide.

5. Equipping Governments with Anticipatory Skills

The pace of technological development is challenging traditional working methods, structures, roles, and regulation in society. Challenges related to geopolitical security, pandemics, demographic development, migration, climate change and energy supply, can be multifaceted and complex. They emerge suddenly and grow rapidly. In some

cases, part of the answer to tackling these challenges could be the use of innovation, including applying existing or new technologies in new ways or on a new scale[14].

Governments and public administrations need increased knowledge related to new technologies and **a greater capacity** to deal with complex solutions. They need to develop governance that anticipates and supports technology development and at the same time prevents negative impacts on people and society. **Anticipatory intelligence is needed to establish which technologies are critical**, how significant is their potential impact and to what extent the EU develops a technological dependence on other countries and regions. One example of an instrument which supports anticipatory governance is the Critical Technology Tracker developed by the Australian Strategic Policy Institute. What it shows is not only that China is now the leader in 57 out of 64 critical technology areas but also that it has developed a near-monopoly position in 24 of those areas, most significantly in synthetic biology, where its scientists currently publish five times more high-impact research than the US[15].

The Multi-Level Perspective (MLP) model provides a valuable framework for informing innovation policy, emphasizing that while supporting niche innovation remains important, **policy should prioritize interventions at the landscape level and engage with stakeholders across the socio-technical space**. Mechanisms such as regulatory test beds and experimentation platforms can facilitate systemic change through targeted and careful questioning of entrenched assumptions. Policies that aim to shift entire regimes rather than solely nurturing niches can enhance the likelihood of transformative and sustained impacts.

In addition, **innovation policy should be complemented by exnovation strategies that guide the deliberate phasing out of technologies no longer aligned with desired societal and environmental outcomes**. Governance frameworks need to include structured approaches to manage technological obsolescence, ensuring a transition away from outdated practices without causing significant disruption. Rapid transitions often generate social conflict, particularly when changes challenge established norms, practices, or livelihoods. Policy frameworks must proactively address these dynamics by anticipating resistance and designing measures to mitigate new barriers to change. Enhancing social readiness is essential for fostering acceptance and cooperation. This requires a deeper understanding of what determines readiness within different social groups and contexts[16].

Understanding the rate of technological change in each industry or field is a prerequisite for identifying the speed and strength of technological transformations[17]. It

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[14] See: Swedish Government Committee for Technological Innovation and Ethics, SOU 2022:68.

[15] See: https://www.aspi.org.au/report/aspis-two-decade-critical-technology-tracker .

[16] These insights strongly align with the impact logic of Horizon Europe, which emphasizes the need to identify innovation opportunities and address the specific needs of non-technical and non-scientific actors within socio-technical systems. This approach aims to accelerate and smoothen transition processes, ensuring that technological and social innovation proceed in tandem to achieve sustainable and inclusive outcomes.

[17] See: P Parraguez et al, Quantifying technological change as a combinatorial process, 2020.

is also a prerequisite for supporting the management of interventions that seek to modify trajectories and speed-up or control the degree of technological change[18]. As a driving force for societal progress, technological change has been widely understood as **a process of combination and recombination[19]**, where different new and already existing technologies are integrated, resulting in a technological novelty.

Innovation in the coming decades will be driven primarily by **technology convergence, combining developments in different fields in new ways**. This phenomenon has recently been described as "superconvergence" by Jamie Metzl, who argues that artificial intelligence, genome sequencing, gene editing, and other technologies are increasingly interconnected, with potential for both leapfrogging in health, food security and climate protection, but also for doing significant harm[20].

The potential impact of billions of connected people, new quantum and biotechnology as well as increasingly powerful networked and AI driven devices, all with access to breakthroughs in emerging technologies, is hard to conceive. **The combined effect delivered by multiple emerging and disruptive technologies is multiplicative.** The impact for innovation and the transformative effect of a combination of emerging technologies is far more profound than what a single technology can provide alone. Emerging technologies have thus become core to business and societal innovation[21]. **Dynamic capabilities** are necessary to adapt to the rapid pace of technological change and demands on technology solutions for existential, systemic risks.

6. Choice of a Governance Method: the Staircase Approach

There are several types of policy approaches to the "agile regulation" element of technology governance. They range from "doing nothing" to adopting strongly prescriptive regulation. Decisions about the adoption of formal, legally based regulation should be taken in relation to the actual and anticipated levels of technological maturity, when there is a clearer grasp of the technology's capabilities, applications, benefits, and risks, and hence its regulatory requirements.

Up to that point, effective governance of the technology can be assured through the adoption of standards and guidelines that are easier to adapt than legally based regulations, as the understanding of appropriate solutions becomes clearer. The decision should be about the need for legally based regulation or whether the continued reliance on standards and guidance would be sufficient to control future development of the product or service in the public interest.

Technology governance is a holistic process that encompasses both rule-setting and enforcement as essential components of ensuring the effective, ethical, and equitable use of technology. Rule-setting defines the norms and expectations, while enforcement ensures compliance and operationalises these rules to achieve intended

[18] See: Guan and Liu, 2016.
[19] See: Fleming and Sorenson, 2001; Schumpeter, 1934.
[20] See Jamie Metzl, "Superconvergence", 2024, https://superconvergencebook.com .
[21] EY, The combinatorial effect of emerging technologies, 2018.

outcomes. Both are essential to maintaining the balance between fostering innovation and safeguarding public interests.

A sliding scale of governance tools can be outlined as follows:

1. **“Zero option, or "do nothing" option**: consists of not intervening, since the evolution of the technology is likely to bring solutions to possible concerns identified by the regulators today; or it seems to be too early to fully understand the problem and devise solutions; or there are no better alternatives on the horizon.

2. **Improving the application/implementation of current rules**: means implementing tech-driven solutions for the implementation of current rules, without changing the main basis of the legislation and/or its scope.

3. **Applying international standards (public or private)**: reliance on existing international standards, such as ISO/IEC or IEEE standards, avoids the possible addition of new rules, with associated compliance costs. However, relying on international standards is often not fully satisfactory, as it typically waters down the ambition to protect end users’ fundamental rights, as well as guarantee the alignment of technological developments with EU values. It is also increasingly challenging in the global text dominated by fierce technological competition. More proactive approaches to actively negotiate and set the standards that align with EU values are often necessary. Private transnational standards are also difficult to endorse in many cases, as the governance of transnational private regulators is often lacking sufficient stringency.

4. **Self-regulation**: this is normally not a policy option, but a development that policymakers can trigger by defining a policy problem, or even threatening to take action (as in the case of sunrise clauses). Self-regulation has the advantage of being tailored to the needs of the group of stakeholders in question, but it requires a good degree of trust and even internal governance and enforcement mechanisms, depending on the case, to ensure alignment with policymaker’s goals.

5. **Awareness-raising campaigns, or labelling**: this is the lightest form of intervention. At the same time, it is only effective in specific circumstances, such as when end user behaviour is affected by specific biases or lack of information and the campaign can restore more rational decision-making.

6. **Nudging**: drawing on the findings of behavioural law and economics, as well as the work of cognitive scientists such as Dan Kahneman and Amos Tversky, nudging technique has been popularised by the work of Cass Sunstein and Richard Thaler, and has later come to the attention of policymakers, who even relied on dedicated behavioural insights units in several countries, starting with the UK, Denmark and the U.S. The idea behind nudging is to use choice

architecture to induce decisions that are more in line with the public interest, or even more sustainable for the same individual that takes the decision, by removing behavioural or cognitive biases. The converse is also true in that 'dark patterns' or 'sludge' can harm consumers by leading them astray.

7. **Co-Regulation**: compared to self-regulation, co-regulation typically entails a legal backstop. Co-regulation can be broadly defined as a mechanism in which a regulation entrusts the attainment of the objectives defined by the legislator to parties which are recognized in the field (such as economic operators, social partners, non-governmental organizations, or associations). Co-regulation combines the advantages of the binding nature of legislation with a flexible approach to implementation that encourages innovation and draws on the experience of the parties concerned. A drawback is the need to set up monitoring arrangements, which are needed to avoid that the entities in charge of implementing regulatory measures abuse their position of informational advantage (as occurred, for example, in the famous Volkswagen emission scandal).

8. **Prescriptive Regulatory Measures**: this is the most common and well-known approach to regulation: many governments, especially the ones that have not gone through a thorough reform of their regulatory process, tend to focus on this as the only way to intervene in markets. Prescriptive regulation normally relies on very detailed rules, which specify the behaviour that will be considered as complying with the regulation (for example, mandating that a fire-proof door be made of a specified combination of wood, steel, fiberglass and fire-rated glass). However, regulation can also adopt a more innovation-friendly approach and specify the overall performance that a product must comply with (for example, a fire-proof door must be able to sustain very high temperatures for at least 60 minutes). Along similar lines, the European Commission guidance distinguishes between:

    - ***Traditional 'command and control' policies***. these specify the use of certain practices, technologies, or designs. The advantage is relative ease of monitoring and enforcement. The disadvantages are that they are likely to be less cost-effective and they do not encourage technological innovation or to go beyond standards.
    - ***Performance-oriented (or outcome-based) rules***. performance-oriented standards, which are essential for democratic rather than technocratic governance, specify the required performance of the target product or service. They do not detail the exact mechanisms by which compliance is obtained, but rather specify the criteria to be followed to achieve such compliance. They are often preferred to engineering or design standards, since they increase flexibility to achieve the regulatory standard. Standards should be flexible allowing aggregation or offsetting between different plants

or agents, even regionally or nationally provided this does not unacceptably affect the overall outcome.

Governance approaches should be talored to the degree of advancement of a given technology. Given the dynamic of technology development, potential risks need to be identified from the early stages in the process, including the pre-release (or beta-testing) phase of products before use. Generally, the purpose of assessing readiness of a specific technology for a given application, and hence governance mode, is well served by Technology Readiness Levels (TRLs)[22]. TRLs can inform policy decisions about the **relevance or timeliness of different regulatory interventions**[23]. However, governance approaches need to take account of the fact that many decisive developments are shaped in the closed, proprietary phase, when companies build technological advantage before opening up their products and services via APIs or platforms to capture network effects.

It must be noted as well that TRLs are not a relevant dimension of industrial innovation activities in some sectors, notably in software and services. There, the **'minimum viable product' is a concept and innovation management strategy that put a new services design / software product to the market** (in software beta-version) to collect customer / user feedback as guidance for further development.

[22] While identifying the TRLs applicable to different technology domains, the OECD has proposed categorisation of the nine-point TRL scale into four levels: basic research (TRL 1-3); technology development (TRL 4-5); technology demonstration (TRL 6-7); and early deployment (TRL 8-9). Given the widespread adoption of TRLs as an aid to technology policy decision-making, the concept of 'readiness' is increasingly being advocated in other innovation-related contexts: regulatory readiness, investment readiness, market readiness and innovation readiness[22]. Technological innovations also require to be accompanied by organisational and social innovations. Therefore, social and societal readiness levels should be considered.

[23] See: UK Regulatory Horizon Council, 2024, Regulating Quantum Technology Applications.

In the context of the technology such as quantum, the UK Regulatory Horizons Council has recently proposed the following regulatory journey[24]:

• Basic research (TRL 1-3) **Pre-regulatory Standards** with focus on consensus standards, underpinning an understanding of the quantum technology's properties, identifying potential benefits and risks and determining future optimal development and management strategies (the caveat should be that early-stage standards have the advantage of providing directionality and interoperability between different RDI actors, but may also be skewed towards picking "winners" too early).

• Technology development (TRL 4-5) **Pre-regulatory Guidelines**, building upon the initial standards, and laying the groundwork for a future regulatory system, if guidelines do not suffice in ensuring the safety, quality, and efficacy of the quantum product or process.

• Technology demonstration (TRL 6-7) **Regulations,** either on the basis of existing regulatory systems, or contemplating a fresh regulatory approach. Legally based regulations should be articulated in broad terms, focusing on desired outcomes, ensuring proportionality towards quantum-related products and processes and adaptability in the face of future changes.

• Early deployment (TRL 8-9) **Post-regulatory Standards and Guidelines,** crafted to facilitate compliance with regulatory systems by those engaged in quantum product development.

7. Towards Comprehensive and Adaptable Technology Governance

Establishing a robust framework for technology governance requires an **integrated and multifaceted approach**. Government is only one of many entities that can engage in technology governance. Independent regulatory agencies are also very active regulators in many countries, as are international institutions (for example, International Standards Organizations). Private businesses (alone or in trade associations) often set the rules for the area in which they are active through self-governance mechanisms.

It is for this reason that the World Economic Forum has defined agile governance as "**adaptive, human-centred, inclusive and sustainable policymaking**, which acknowledges that policy development is no longer limited to governments but rather is

[24] See: UK Regulatory Horizon Council, 2024, Regulating Quantum Technology Applications, https://assets.publishing.service.gov.uk/media/65ddc83bcf7eb10015f57f9f/RHC_regulation_of_quantum_technology_applications.pdf .

an increasingly multi stakeholder effort."[25] It involves flexible, iterative assessments, cooperative government approaches, outcome-based regulations, and responsive, compliance-promoting methods focusing on outcomes and risk proportionality. Similarly, G7's "Governance Principles for a Society Based on Cyber-Physical Systems" emphasize proactive governance, expert involvement, digital tools, agile regulation, certification mechanisms, effective enforcement, and tailored liability systems.

Agility alone does not ensure regulatory stability or citizen rights' protection. **Stability and transparency in governance processes are essential** to prevent exploitation by stakeholders with informational advantages. In addition, **monitoring plays a foundational in navigating the opportunities and risks of a technology**. When it comes to generative AI, to ensure accountability, transparency, and trust, monitoring frameworks must strike a balance between agility and stability, incorporate multi-stakeholder perspectives, and embed safety and ethical principles into the technology's lifecycle. One example is the G7's Hiroshima AI process, which led to the establishment of AI Safety Institutes and monitoring principles for generative AI.

As a result, **an effective technology governance framework encompasses a diverse range of measures**: regulation, technical safeguards, new governance models, funding and mechanisms for transparency, accountability and participation. It can also include voluntary commitments, or behavioural approaches, which end up "nudging" consumers or businesses towards specific conducts. **Technical safeguards especially are critical for mitigating the risks** associated with powerful technologies.

Given the complex and global nature of modern technologies, such as AI, genetic engineering, and quantum computing, the **governance framework must be comprehensive on the one hand, and adaptable on the other**, addressing both current challenges and anticipating future developments. **Governments must be agile, capable of updating regulations as technologies evolve.**

New Digital Social Contract

One example of a comprehensive and adaptable approach to technology governance is the recent EU digital legislation, which, if fully implemented, will usher in a fully-fledged new digital social contract. The Digital Services Act makes a U-turn on a principle that governed the internet for over three decades (namely, no liability for online intermediaries). The Digital Markets Act breaks the deadlock of clumsy antitrust enforcement in fast-changing markets, replacing ex post enforcement with *ex-ante* (yet still *post-hoc*) regulation.

The AI Act proposes the world's first-ever comprehensive AI regulatory framework, imposing design and deployment discipline to high-risk applications, centralising the

[25] See: "Agile Governance. Reimagining Policy-making in the Fourth Industrial Revolution", World Economic Forum, White Paper, 2018: https://www3.weforum.org/docs/WEF_Agile_Governance_Reimagining_Policy-making_4IR_report.pdf

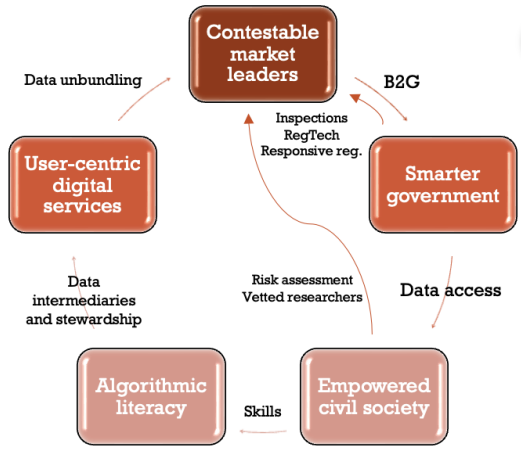
monitoring and inspection of general-purpose AI systems, and even prohibiting certain AI uses. The Data Act seeks to enhance data flows without giving up on end user protection and the fairness of exchanges, in conjunction with data spaces and the Data Governance Act.

Among the **brand-new dynamics and mechanisms** introduced by recent legislation around digital markets and AI, **some stand out as truly ground-breaking**. For example, the idea that no hardware product should be designed under the assumption that user data will be collected, stored and managed by the same company that markets the device (Data Act, and DMA); or the idea that large online platforms and search engines open up their AI systems to "vetted researchers" as well as third party auditors for the purposes of risk assessment (DSA); the idea that governments should be allowed to use data in the possession of the private sector to generate public services and act in the public interest, remunerating them at fair conditions (Data Act); and the idea that value is (more) fairly distributed across value chains, for example through fairer B2B data exchanges (Data Act) and the availability of data intermediaries that are independent of private data-driven businesses (Data Governance Act).

That said, **many other pieces are missing** before a comprehensive technology governance framework can be achieved. Among them, the **upskilling of citizens and workers** in dealing with new technologies; **the promotion of data stewardship skills** and the **interoperability between public and private data** to enable the safe and secure reuse of data for public interest purposes (a first step being made possible by the Interoperable Europe Act); **the creation of a pan-European, open and secure digital identity and wallet**, which lays the foundations for new trustworthy AI-driven applications; and investing in new forms of regulatory and design-based interventions, which would compose a brand-new mix of tools for governments to steer and monitor the evolution of general-purpose technologies.

Figure below offers a stylised version of a future digital social contract.

A multi-stakeholder future social contract



8. Recommendations for the EU 2024-2029: Embedding Anticipatory Technology Governance at the Heart of Europe's Socio-Economic Revival

Europe's future prospects are **inextricably linked to its technological revival**. Mario Draghi could not have been clearer about the importance of putting technology at the forefront of Europe's future competitiveness in his flagship report. The high-tech sector redirects labor, capital, and resources toward more productive and innovative domains, resulting in higher economic output and efficiency. As such, technology is a driver of economic transformation. Technological advancements spill over into adjacent sectors, amplifying productivity across the value chain. For instance, advancements in 5G connectivity are enabling smart manufacturing, autonomous vehicles, and precision agriculture.

As emerging technologies are a key element of economic development and prosperity and create growing risks due to their unforeseen consequences and knock-on effects, the EU needs to place technology governance at the centre of its reinvention efforts. Fields like AI, biotechnology, and renewable energy are converging, creating opportunities for synergies but also heightening risk exposures.

The following **elements** are essential in this context:

8.1. Capacity to Anticipate

- Equipping EU institutions and regulatory bodies with the **best possible understanding of emerging technologies** and their potential impacts. At the **agenda-setting level**, policymakers should mainstream foresight, namely horizon scanning, mapping the emergence and possible interaction of new technologies, and the opportunities and risks that this may entail. They should also leverage experts and civil society, to increase their situational awareness.

- **Accounting for uncertainty and adaptation when choosing among policy options.** Some options are less resilient to shocks than others, both when it comes to the poly-crisis and more specifically to technological development. Defining and comparing options not only based on the efficiency but also their resilience to change and the possibility to course-correct policy action over time, based on agreed criteria, can increase the agility and fitness-for-purpose of chosen policies.

8.2. Adaptive Instinct

- Defining **principle-based rather than excessively prescriptive regulatory frameworks**, allowing for flexibility in application as new technologies emerge and new challenges present. During the **ex-ante phase** of regulation, consideration should be given to **alternative futures instead of a single future** (as currently done in EU better regulation) to enhance policy resilience. Alternative policy options should remain viable also in worst-case scenarios.

- **Broadening the spectrum of policy options and alternatives** by including, when possible and appropriate, RegTech (Regulatory Technology) and SupTech (Supervisory Technology) options aimed at improving compliance with regulations and enhancing the supervisory processes of regulatory authorities, "rules as code" options, third-party ongoing technology auditing options, as well as other innovative approaches that guarantee more effective monitoring of compliance and alignment. More generally, alternative policy options may include "by design" approaches, as well as more traditional, outcome-based regulatory approaches.

- Creating mechanisms for **regular review of the regulatory framework to ensure they remain relevant and effective**. Establishing dedicated entities to assess new technologies can help in timely understanding their implications. They can provide insights and recommendations on regulatory adjustments needed to accommodate new technologies or mitigate associated risks.

- During the **implementation phase** of regulation,

    - Implementing *stress-testing and evaluations* for entire policy domains (akin to fitness checks), based on data management plans and data-driven inspections.

    - Implementing *AI-driven scans of the regulatory stock* to find inconsistencies, room for codification and simplification that do not compromise the overall objectives of the legislation.

- **Seeking 360° public engagement,** vital for building trust and ensuring that technology development aligns with public interests. This involves open communication about the benefits and risks of new technologies, as well as involving the public in decision-making processes. Movements and initiatives that educate and engage the broader population on technological issues can drive more democratic and inclusive governance. Furthermore, transparency in the development and deployment of technologies can prevent misuse and ensure accountability, fostering a culture of responsible innovation. Open

access to data, supported by open data initiatives, is needed to encourage collaborative development.

- Elaborating new **corporate models** to manage the rapid and widespread impact of emerging technologies, including by achieving a more inclusive balance between profit and social responsibility. In the case of the B Corporation model or Fairhold standard, they have managed to successfully emphasize stewardship of value over time and align business practices with broader societal goals. Similar objectives can be achieved by encouraging corporate ownership through foundations with philanthropic objectives, as is the case with NovoNordisk and other Nordic companies.

8.3. Space for Testing and Experimentation

- Mainstreaming **constant experimentation**, an iterative process that constantly tests new solutions and improvements to the regulatory framework by enabling new instruments such as regulatory sandboxes, innovation hubs and testbeds. Regulatory sandboxes for example often operate under an experimentation or derogation clause, which distinguishes them from other forms of experimentation. The JRC EU Policy Lab is a place of experimentation that can provide knowledge and testbeds for policy ideas.

- Encouraging use of **regulatory sandboxes** for the testing of innovative products and services in a controlled environment under regulatory oversight. As a result, regulators can obtain data on the effects of new technologies and consider necessary changes without reducing capacity to innovate. In all cases, high adaptive potential requires ongoing dialogue with all stakeholders, including market actors, academia and civil society.

First tested in the fintech sector in 2015, **regulatory sandboxes** are increasingly used by regulatory agencies in other areas, including the health sector with the objective of developing safe and high-quality innovative health technologies. Their value lies in enabling the testing of alternative regulatory approaches for disruptive new medicinal products, or combinations of medical and digital tools, leading to shared learning for innovators and regulators. At the same time, simpler instruments such as **innovation hubs and testbeds**, or **programmes initiated by regulators** (such as the UK regulatory pioneer's fund) can prove superior, and easier to implement.

8.4. Addressing Risks Proactively

- Developing **safety protocols, conducting regular audits, and ensuring compliance with established standards**. An "Apollo-type program" for AI and biosafety, could spearhead efforts to prioritize and fund technical safety research. Creating and experimenting with systems that can independently verify the safety and integrity of technological implementation is essential. For instance, in synthetic biology, initiatives like SecureDNA[26] aim to prevent the synthesis of hazardous DNA sequences, showcasing the importance of proactive and comprehensive safety measures.

- **Adhering to principles of responsible innovation**, ensuring that technological advancements respect human rights, privacy, and equity. Ethical governance involves establishing clear **ethical guidelines and standards for new technologies**. This might involve ethical review boards, robust privacy protections, and mechanisms to ensure that technologies are developed and used in ways that are consistent with societal values.

- As technology permeates every aspect of life, **ensuring the security of the emerging systems is paramount**, by safeguarding data and infrastructure from cyber threats, ensuring the resilience of critical technology systems, and protecting against misuse of technology. Security governance requires robust cybersecurity laws, regulations, and standards that evolve alongside technological advancements.

8.5. Systems Approach as the Baseline

- **Addressing transformation failures in a holistic and systemic way**, considering the broader context of socio-technical and economic systems in which innovation occurs. This might involve policy mixes combining different instruments to address various aspects of the status quo, direct interventions in some cases directly challenging incumbent systems by removing their resources or support, and indirect interventions supporting emerging technologies until they can compete with incumbent systems on their own merits.

- **Using a portfolio approach to anticipate and engage effectively with emergent, complex adaptive dynamics** that are particularly characteristic of General Purpose Technologies (GPTs). Systems innovation portfolio approaches entail implementation of multiple interventions or solutions

[26] See: https://securedna.org

simultaneously to test and drive connections, relationships and combinations among them. Portfolio design and construction to actively encourage different and/or complementary initiatives to combine and achieve multi-dimensional solutions together should be a structural requirement of technology policy, funding instruments and governance, including collaborations amongst competitors addressing related problems.

- **Creating decentralised and distributed governance frameworks for technology development and deployment to enable systemic effects**, anticipating and mitigating risks of lock-ins, inadvertent dependencies, value capture. Increasing buy-in from stakeholders combined with monitoring of process and impact frames rather than outputs, will require a greater emphasis on multi-level governance.

8.6. Collaborative International Frameworks

- **Seeking international agreements to ensure consistency and effectiveness across borders**. The global, multilateral dimension of technology governance is relevant from the point of view of ensuring a level playing field, reducing barriers to entry for technology companies aiming to operate internationally, anticipating the pressures of limited resources and competition for them, but also to enabling ongoing learning on a global scale.

- **Developing and harmonizing international standards** is important for managing global technologies, such as AI, or biotechnology. Collaboration through international bodies like the International Organization for Standardization (ISO), the International Telecommunication Union (ITU), or sector-specific entities helps create common frameworks that facilitate interoperability, security, and compliance[27].

- **An international scientific authority should guide the regulation of research and development in high-risk areas**, while incorporating diverse perspectives from moral philosophers, political scientists, planetary science experts and cultural anthropologists into technology organizations is required in parallel to enhance ethical considerations.

- In some areas, exemplified by the Stratospheric Aerosol Injection (SAI), **since the technology would have a global impact, governance also needs to be**

[27] At the same time, one could also envision a future where international standards are aligned but not fully harmonised. For example, certain forms of hydrogen production that are considered green in the EU may also be considered green outside of the EU, but not the other way around. Depending on the attractiveness of the market, companies may decide to adhere to the strictest standards in all or some markets.

global, based on a broad alignment between governments and societies. At this point in time, there is no readiness for a global, science-based and well-governed deployment of such a climate intervention technology[28]. The international community would need to be able to make well-informed decisions on how to phase-in, monitor and provide options for phasing-out again if deployment needed to be halted.

9. Conclusions

The age of technological acceleration demands new forms of effective governance to protect people and the planet. They need to consider a broad range of technology developments. Relevance of technology governance is particularly pronounced with respect to platform technologies, given their horizontal significance for a range of technological developments. **Pervasiveness of technology means that governance frameworks need to exert their impact at all levels**, from that of the product or service, all the way to the delivery processes. Given that many of the emerging technologies have winner-takes-all characteristics, the intervention window may be quite small and decisions regarding the potential take-up of the regulatory pathway have to be taken promptly.

As the EU embarks on a project of technological revival, driven by the growing realisation of the pressing need to improve its productivity, understood as resource and material productivity, enabling the maximisation of sustainability and well-being[29], technology governance will have to be **both comprehensive and adaptable**. To achieve the former, the full spectrum of means, including evidence-based regulation, co-regulation and non-regulatory approaches such as voluntary codes or standards, will have to be used. In addition, effective collaboration across levels of government will be needed to ensure joined-up approaches. To accomplish the latter, use of flexible, iterative and adaptive *ex ante* and *ex post* assessments[30] will need to be pursued. In addition, focus will need to be placed on outcome-based regulations and risk-proportionality, as exemplified by the AI Act.

Given the growing size and influence of the technology sector, establishing governance frameworks in a timely fashion is increasingly challenging. Regulation is part-and-parcel

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[28] See: "Policymakers' FAQ. Climate Interventions", International Center for Future Generations, April 2024, https://icfg.eu/wp-content/uploads/2024/04/ICFG_7679_-_CLIMATE_INTERVENTIONS_-_FAQ_DOCUMENT_-_FINAL.pdf

[29] ESIR Report on "Why Europe needs a systemic R&I policy: Redefining competitiveness for long-term sustainability", 13 June 2024, https://research-and-innovation.ec.europa.eu/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/esir_en .

[30] See: "Recommendation of the Council for Agile Regulatory Governance to Harness Innovation", OECD, 6 October 2021, https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0464 .

of the democratic process, which involves lengthy deliberation and compromises. Rather than installing a sense of determinism, which presupposes an inevitable advantage of technology companies, **this realisation should encourage greater efforts at *ex ante* formulation** of the rules and norms for the world of technology, **coupled with the ability of the governance framework to evolve in line with the changes in technology**, as well as effective enforcement[31]. The normative dimension and the legal foundation are equally important in ensuring sufficient resonance of such a framework.

Given the acceleration and sophistication of technological developments, the role of anticipation will grow in an exponential way, with the corresponding need to equip policymakers with comprehensive insights about the projected opportunities and risks. From being a pillar of preparedness for the future, foresight will become an integral part of successfully navigating Europe's transitions.

Annex I

Technology Definition

Technology can be defined as the practical application of scientific knowledge with the purpose of creating tools, machines, and systems to solve problems and achieve specific goals. A special type of technology is the so-called **General Purpose Technologies** (GPTs). GPTs are technologies that have **broad applications across multiple sectors and profoundly impact the economy and society**. Examples of GPTs include the steam engine, electricity, and the internet. These technologies drive innovation, productivity, and economic growth, transforming industries and creating new opportunities. However, the widespread applicability and profound impact of GPTs also make them particularly challenging to control and regulate.

The difficulty in the governance of GPTs arises from their complex and dynamic nature. Unlike specialized technologies, GPTs integrate into various aspects of society, leading to direct and indirect impacts that are often unpredictable. Effective governance of GPTs requires a multifaceted approach, encompassing regulation, technical safety measures, new governance models, and increased transparency and accountability. Establishing such a comprehensive framework is challenging due to the interconnected and global nature of these technologies, which often transcend national borders and regulatory jurisdictions.

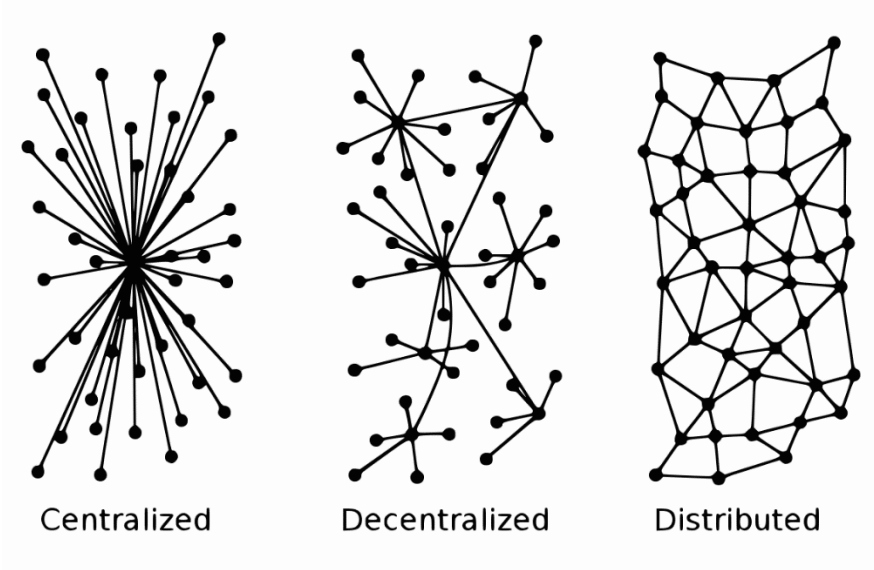
[31] For an overview of effective enforcement needs, see: Koomen, Maria and MacDonald Raegan, "Enforcement is crucial for EU's tech policy success", ICFG, July 2024, https://icfg.eu/op-ed-enforcement-is-crucial-for-eus-tech-policy-success/ .

Annex II

Centralisation Versus Decentralisation in Governance

Modern digital technologies offer diverse approaches to problem-solving. Governance takes more centralised forms, more decentralised or even fully distributed forms.

Figure 1. Alternatives in governance: decentralisation



Examples of alternative approaches to technology governance are manifold in EU legislation. The EIDAS 2.0 framework for digital identity is one of the most interesting, as it relies on a decentralised, self-sovereign system in which users retain of their data.

This will be increasingly important as both the scale and granularity of data increases. The growth of consumer neurotechnologies illustrates this particularly well, as companies increasingly aim to harvest and sell brain data to tailor marketing campaigns and social media feeds, and as mental surveillance and neuropolicing becomes possible[32].

Decentralised or even distributed systems can, of course, be made interoperable, consistent and even centrally coordinated. Examples of decentralised architectures are found also in the current work of DG GROW on data spaces, all the way to the proposed creation of data spaces governed by DAOs (decentralised autonomous organisations). The plasticity of digital technology is so powerful that it is possible to imagine systems that are self-sovereign, yet completely synchronised and scaled up to the EU level. In order to enhance the effectiveness of future solutions, the EU has even organised large-

[32] See: Mahieu, Virginia, “Navigating the Neurotechnology Frontier”, July 2024, https://icfg.eu/navigating-the-neurotechnology-frontier/ .

scale pilots run by four different consortia (DC4EU, NOBID, POTENTIAL and EWC), another interesting feature in the *ex-ante* selection of alternative policy options.

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The EU faces challenges in keeping pace with the rapid technological developments of the 21st century while striving to align them with societal transitions and planetary boundaries. This Policy Brief argues that a proactive governance framework is essential to address the ethical, social, environmental, and economic implications of technology, emphasising accountability, public trust, and a new digital social contract. Effective governance requires understanding the complexity of innovation and the convergence of disciplines, balancing flexible and comprehensive regulatory approaches tailored to technologies' risks and maturity. Moving forward, the EU must explore diverse futures, adopt adaptive and transparent policies, and prioritise international cooperation alongside robust safeguards to ensure security, trust, and transformative progress.

Research and Innovation policy

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