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TECHNOLOGICAL FORESIGHT:
A CRITICAL POLICYMAKING TOOL FOR THE 21ST CENTURY

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JULY 2022

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Reference to this paper should be made as follows:
Loesekrug-Pietri, A. (2022) "Technological Foresight: A Critical Policymaking Tool for the 21st Century", The Digital Revolution and the New Social Contract series, Center for the Governance of Change, IE University, July.

"To shape the future, and not be shaped by it."

ACKNOWLEDGEMENTS

The author would like to thank the Advisory Board and IE's CGC team for their constructive feedback. Special acknowledgement to Paula Oliver for her useful critique and advice in writing this piece, and to Nicole Wadley for her copy editing support.

ABSTRACT

Technology has become an essential part of our economies, societies and democracies, with a central role in every societal and geopolitical issue. Emerging technologies are disrupting every sector. They are proving to be double-edged swords: they have an immensely beneficial potential, while some technologies can severely disrupt the way our world and societies work. Technologies open up new opportunities, uncover new risks, and reshuffle the cards at a global level. This is a major battleground in big power competition and allows authoritarian states, rogue states, global platforms, and terrorist groups to achieve strategic relevance and project their respective power and values.

Anticipation is of paramount importance to leading strategically, though the acceleration of technological advancement makes this increasingly challenging. The pace of technological evolution and, even more importantly, the interconnections between different technologies make it even more difficult for leaders to understand new, disruptive technologies and their consequences. Misunderstandings of key enabling technologies can lead to strategic surprise, political confusion, and tensions.

The major crises of the 2020s thus far (health crisis, energy crisis, demographic transition, defense of democracies, etc.) have demonstrated the crucial importance of long-term thinking and the importance of science and technology in our societies. Public policies focused on individual branches or industries, and short-term thinking due to electoral considerations, increasingly fail to grasp the profoundly cross-sectoral and interdisciplinary origin of disruptions and breakthroughs. Leaders and societies without a long-term, agile, and holistic vision are increasingly reacting to unfolding events instead of shaping them around their own values and strategic goals. This is extremely costly both financially and politically.

Technology foresight is therefore a major political and societal endeavor for our democracies. With this paper we urge democratic societies to have an agile and powerful

foresight capability so that the State can fulfill its primary mission: to defend the general interest of its people and not be left at a disadvantage vis-à-vis authoritarian systems.

Further, we demonstrate the relevance of technology foresight through six breakthrough technologies and their potential economic, societal and geopolitical impacts: cognitive manipulation, nuclear fusion, immersive technologies, Quantum Positioning Systems (QPS), nanotechnologies, hypersonics and neuromorphic computing.

Based on our experience, our key recommendation for policymakers is to make foresight and technology foresight in particular a key pillar of their policymaking exercises. Societies need to be actively (rather than reactively) involved in shaping their own future. Thus, foresight capabilities should be incorporated into the state architecture and properly articulated. Foresight knowledge should not be static, but constantly reviewed and updated. For foresight to be effective, it should be coordinated throughout the administrative levels, institutions and organizations that produce it. It is important that there is an independent entity in charge of articulating the foresight knowledge that is disseminated across institutions, who can leverage those insights for proper policy design and decision making.

TECHNOLOGICAL FORESIGHT IS CRITICAL IN THE 21ST CENTURY

The many crises that democracies have had to (and continue to) face in the past 20 years have demonstrated the crucial importance of long-term thinking. Challenges such as the pandemic, the energy crisis, the demographic transition, and the defense of democracy—in the context of the war in Ukraine—position foresight and strategic planning as a core function to be carried out or, at least, encouraged, by our institutional framework. However, the necessary foresight capabilities are not currently sufficiently or correctly integrated into our societies to address these events and trends. Therefore, this paper aims to reflect on the shortcomings of the existing foresight capabilities and institutional frameworks in which they operate and provide specific policy recommendations to be fit for current and upcoming challenges. The aim is to better prepare the State and policymakers to perform their primary mission: to defend the general interest, today and in the future.

Currently, foresight capabilities are insufficient. European foresight faces six key problems, which undermine the effectiveness of said efforts:

1. Predominance of short-term perspectives, even though the major issues faced require a long-term vision.

2. Lack of a generalized mechanism that preserves long-term investment budgets.

3. Crisis of representation and trust by a growing part of the population towards the political leaders and the State. This lack of trust and perceived legitimacy is also fueled by the difficulty in measuring and communicating the level of understanding by political leaders and decision-makers of major contemporary issues.

4. Division of foresight tools are divided into multiple institutions that are not connected, which hinders the adequate definition of clear and coherent objectives.

5. High difficulty in thinking in a holistic, interdisciplinary way that involves all stakeholders across different sectors. Most of these challenges and potential solutions are cross-topical.

6. Passive position towards technological foresight from Europe, which struggles to draw the contours of a desirable future for itself and for the rest of the world.

Based on our experience at the Joint European Disruptive Initiative, the European ARPA, foresight capabilities need to be built around two characteristics: scenario planning and agile coordination. They will impact the content of the work and the way in which foresight is generated.

CONTENT: STRENGTHEN FORESIGHT CAPACITY THROUGH SCENARIO PLANNING

Foresight development is a complex effort. It is significantly different from the somewhat unhelpful exercise of extrapolation of current trends. Accurate and effective foresight requires the definition of scenarios for desired outcomes and for undesired futures to be avoided.

Foresight should not simply serve as an exercise in abstract futurology, far removed from the aspirations of citizens. On the contrary, foresight must be conceived *ab ovo* as an instrument for building a desirable future, democratically imagined (if not precisely defined), according to the assets and constraints of the present time. In other words, the primary data that futurists must take into account when building their different scenarios are the political objectives of their societies. Therefore, preferred options and objectives should be defined and prioritized in advance.

The different scenarios must then be developed and prioritized according to the dual requirements of (1) probability of realization and (2) "desirability". The priority scenario will thus provide a general picture of Europe in 2030, 2040 or 2050, summarizing the

various elements necessary and sufficient for its realization *in concreto* and the probability of these various key elements coming together (access to liquidity, geopolitical stability, technological breakthroughs, growth greater than x%, etc.).

Following an inverse pattern, and in the context of scientific and technological acceleration and growing convergence, back-planning capabilities from desirable futures or from dystopian scenarios also need to be developed. This is particularly important for topics like climate change or General Human Intelligence to take two examples. Back planning allows us to think about the conditions for the country's resilience in the event of catastrophic events (environmental, health, industrial, geopolitical, etc.) and build on those conditions to mitigate or prevent the impact of those events. To do this, different scenarios must be built according to the degree of probability of occurrence (e.g. scenario 1 = coronavirus type pandemic; scenario 439 = collision with a comet). Worst-case scenarios are a major component of back planning, as they allow us to combat the traditional cognitive biases which have been at play during and before the pandemic (not wanting to really prepare for this crisis) or are ongoing for climate change (knowing what will happen but not incorporating those learnings fully into policymaking). These are the cases where the preferred options are impossible to achieve and would require a "plan B" in order to attain the next "most acceptable" outcome for society.

WAYS OF WORKING: AGILE COORDINATION OF FORESIGHT INSTITUTIONS TO ENSURE COHERENT ANTICIPATION AND STRATEGY DEVELOPMENT

France is a useful example to illustrate the relevance of coordination among the institutions involved in foresight development. France has a large number of institutions that include the development of prospective studies as part of their mission (with varying levels of relevance). Some of them include the Haut-Commissariat au Plan, France Stratégie (both within the Prime Minister's office), Centre d'Analyse, Prévision et Stratégie of the Foreign Ministry, the Directorate General for International Relations and Strategy and the Institute for Strategic Research (both within the Ministry of Defense), and the Statistics and Foresight Service of the Ministry of Agriculture. Their task is complemented by the many think tanks and private companies that engage in foresight activities, such as Axa, Total and Amundi. However, these organizations and departments do not provide a unified and comprehensive vision supported by clear and coherent objectives that cut across public action.

European Union institutions face a similar situation. There are several bodies with foresight capabilities within the EU framework, but they do not necessarily coordinate or complement their views. For example, Maroš Šefčovič, the Vice President in charge of Interinstitutional Relations and Foresight, is also in charge of many other topics (most recently, his agenda has been significantly dedicated to the EU-UK relationships following Brexit). Some of the actions he has enacted are a good start for the structured coordination and sharing of foresight analyses and conclusions, but they are not enough. For instance, he has launched the EU Foresight Network, an informal meeting of the "Ministers for the Future" of each Member State, who meet at least once a year. This initiative, despite being valuable, is by itself insufficient when new crises arise, particularly when they can play out in a matter of weeks.

Another EU body with a foresight mandate is the EU's Joint Research Centre (JRC), which is under the authority of Commissioner Mariya Gabriel (Commissioner for Innovation, Research, Culture, Education and Youth). The JRC "anticipat[es] emerging issues that need to be addressed at EU level" as one of its responsibilities. Additionally, some DGs or Commissioners have their own de-facto foresight expertise, many EU research bodies (European Innovation Council, European Research Council…) develop their foresight as well in order to identify the technologies they decide to invest in in the context of Horizon Europe, and even the European Parliament has some foresight and knowledge generation capabilities, which are sometimes disseminated between the ITRE (Industry, Research and Energy) Committee and the STOA (Future of Science and Technology) Commissions.

The proliferation of state and European foresight institutions is an asset that must be made to bear fruit with effective foresight generation. The solution does not necessarily involve the merger of the myriad of institutions into a single entity, which could turn into a simplistic mistake that hinders the production, creativity, and dissemination of foresight knowledge among key policymaking bodies. Rather, the intellectual production that emerges from them deserves to be enhanced and, in so doing, to be better-oriented *ab initio* to achieve a panoramic vision of the issues and needs of each sector.

Still, a central body – not necessarily a new one – is needed to gather this work and facilitate the coherence of the whole. This body would have three main missions: to leverage all inputs and anticipate a desirable future; to foster a coherent strategy for the State and society; and to democratize and test the sustainability of public action. It would act as an expert pool, tapping into the various foresight bodies, drafting reports and opinions for referral to the executive and legislative bodies or for self-referral. Foresight production would be in different formats. Firstly, through an annual report that would act as a strategic white paper, built around scenarios that reflect short-, medium- and long-term strategic planning. The white paper and the contained scenarios would build

on all the creative input generated by public and private foresight entities. Secondly, through normative work that will inject consistency into policymaking and regulation. The foresight coordinating body would act as a watchdog in charge of policymaking coherence. Thirdly, it would promote citizen participation in foresight development to take advantage of the benefits of collective intelligence exercises and to get buy-in on possible scenarios. Its organization would allow it to be represented in all ministries of the executive, to directly report to the Head of State, and to be linked to civil society through the composition of its board of directors and its working groups.

A SPECIAL FOCUS TO TECHNOLOGICAL FORESIGHT, AS TECH & SCIENCE ACCELERATION ARRE AMONG THE GREATEST SOURCES OF DISRUPTION – AND SOLUTIONS – IN THE 21ST CENTURY

No matter which policies and institutions are developed and used to enhance the foresight capabilities of the State, they will all have to take into account disruptive technologies. Scientific and technological breakthroughs have the potential to solve some of our world's most pressing problems, while three of the biggest challenges globally are closely related to technology (1) life sciences (with a global focus on healthcare, on rising threats such as fast-changing diets and pandemic risks due to biodiversity loss) (2) the environment (due to the acceleration and increasing impact of climate change) and (3) the digitalization of our economies and human relations (the megatrend of our society).

Science and technology are developed at an ever-increasing speed. Change is accelerated by the increase in scientific and technological resources, network effects at a global scale, the technological race between big powers, the growth of the startup economy, and the convergence of many of these topics.

Disruptive technologies are of even greater relevance since they are part of the solutions for crises just as much as they can sometimes fuel new crises. For instance, the quick development of vaccines was the most important variable that supported democracies to get out of the Covid-19 crisis (although it did not eliminate the virus). Covid-19 containment was mostly fueled by the application of mRNA vaccines, which were an emerging technology and a technological breakthrough at the time. Simultaneously, social media played an unexpected role in the spread of vaccine misinformation and skepticism to the surprise of many policymakers and parts of society. This was mostly because of the large disruptive character of social media, and because the dynamics they facilitate in our democracies, societies, and economies were not sufficiently understood.

As part of the efforts that should be conducted in our societies, both from public institutions and private sector initiatives, there are seven emerging technologies that should be further studied and taken into account for their disruptive potential.[1]

IDENTIFIED BREAKTHROUGH TECHNOLOGIES

Cognitive manipulation technologies

Cognitive manipulation was used to influence democratic outcomes during the 2016 United States Presidential elections and the Brexit referendum. The main tool used in both of these instances was social media, and the phenomenon caught public attention. Politicians and public officials became more aware and sensitive to the risks of social media because of foreign (and domestic) electoral intervention. However, as illustrated by the Covid-19 crisis, the regulations put in place have barely caught up and the impact of cognitive manipulation is still present in Covid-19 and climate change denial efforts, for example. The Digital Services Act, currently in its final approval steps in the EU legislative process, might be a gamechanger — but questions remain on whether it will be able to tackle new challenges and opportunities brought by future social networks. Cognitive manipulation opens up new fronts for hybrid warfare, which could be accentuated through the rise of "deep texts" generated by GPT-3 and other large AI models.

Nuclear fusion

Nuclear fusion could be a gamechanger in energy. It uses almost illimited fuel (deuterium and tritium) and does not produce radioactive waste nor CO2 emissions. Even though fusion was for long considered an energy unavailable before the 22nd century, recent breakthroughs like hot superconductors, simulation of plasma through AI, etc. have massively increased the probability of fusion becoming a reality, and on a scale that would make it nuclear fusion energy accessible globally.

Energy is the global critical strategic topic, particularly in the context of climate change, energy transition to ensure the sustainability of our planet, and rising energy prices driven by the Russian invasion of Ukraine. Nuclear fusion offers great advantages

[1] A detailed review of these technologies is provided in Appendix I. Additionally, the first three of them (cognitive manipulation, nuclear fusion and immersive tech), are detailed in Appendix II, with a focus on the potential societal and geopolitical impact of these technologies, future scenarios, possible policy options and open questions
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compared to other alternatives, since it uses deuterium and tritium (isotopes of hydrogen), which are virtually illimited resources in nature. Additionally, it is unique in that nuclear fusion does not produce radioactive waste or greenhouse gas emissions.

Most investments in nuclear fusion are made via massive international projects (ITER, JET) or, more recently, through startups. The latter are mostly US companies. Since the first working prototypes are expected for the 2030s and the first scaling-ups are optimistically scheduled for the 2040s, policymakers need to safeguard investments in nuclear fusion, in order to avoid any temptation to make easy budget savings on it.

Immersive tech

Immersive tech (which includes the metaverse) will revolutionize digital interfaces and the way we interact. It has the potential to become a complete game-changer in terms of trust relationships, Command & Control, scenario planning, and confidentiality management.

Immersive tech seems for now to be mostly a "software" technology made of private ecosystems and whose infrastructure is controlled by private actors (Meta, Roblox…). Since immersive tech will probably become mainstream by the late 2020s/early 2030s, it is yet unclear how it will be regulated — which has led policymakers to underanalyze at immersive tech.

Quantum Positioning System (QPS)

The Global Positioning System (GPS) is both increasingly critical in all sectors of our society and increasingly at risk of being jammed or disrupted – be it in contested aerial zones, exo-atmospheric space, or underwater environments. GPS is strategically important, because it has an impact on the sovereignty of states, and its many applications imply the alternatives are dual-use technologies appropriate for both civil and military use cases. Meanwhile, Quantum Positioning System develops with immensely increased precision and reliability. QPS will prove critical in the context of European strategic autonomy, which implies that moving faster on this topic is of strategic importance for Europe.

Nanotechnologies

Nanotechnologies have a wide range of applications in many sectors: from microelectronics, to robotics, healthcare, and power storage/autonomous systems. Some topics related to nanotechnologies have gained increasing public attention and are now more closely followed by public officials as a result of recent events. For example, microelectronics due to the microchips shortage, and nanotechnologies in healthcare due to the Covid-19 pandemic. However, no comprehensive strategy encompassing the whole potential of these technologies has been put in place.

Hypersonics

Hypersonics and nonballistical trajectories create an entire new set of vulnerabilities that we will need to be prepared to face. The current debate is on whether they are gamechangers or not. The vulnerabilities they create are in the speed of decision-making processes, the anticipation of impact, and the potential disruption of long-established military doctrines such as nuclear deterrence. Hypersonics have been actively developed by Russian and Chinese militaries, precisely for their disruptive potential. The US itself does not have operative hypersonic technologies so far – even if developments are in full motion - nor do the Europeans.

Neuromorphic

Lastly, neuromorphic computing can be a gamechanger in terms of computing power and memory access speed, as well as collective intelligence. Most leaders in Western countries are now well-aware of the strategic importance of semiconductors, as illustrated by the US Chips Act and its EU equivalent. Yet, they too often focus entirely on policies to catch up on existing silicium-based chip capabilities and on always smaller nodes (for instance chips under 5 nm) instead of including strategies to explore new architecture systems such as neuromorphic or optical computing.

CONCLUSIONS AND KEY RECOMMENDATIONS

The last two years and a half have demonstrated how important it is to be prepared for future events. There are economic, social, political, and geopolitical reasons that substantiate why governments and institutions, particularly in democratic societies, should shift their vision from electoral and partisan short-term policymaking to longer-

term informed policies. This requires a collective institutional and societal effort to look into the newest trends, their potential impact, and the coordination of insights to develop coherent strategies and shape the future according to democratically-defined values.

Based on the previous analysis and the relevance of foresight knowledge and planning, particularly on disruptive technologies, in our societies, we develop the following policy recommendations to both demonstrate the need for technological foresight due to the central role of science and technology and give foresight a more prominent place in policymaking.

While it is not possible to force public officials to buy in on the benefits of foresight, the credibility of an institution in charge of it will grow incrementally through a track record of identifying and executing upon the right priorities.

RECOMMENDATIONS FOR A SUCCESSFUL IMPLEMENTATION

In order to successfully incorporate foresight into national and European policymaking, we recommend the following measures:

1. Making foresight central but not centralized: There should be a specific institution in charge of coordinating the foresight produced within all the institutions of both the EU and national levels.

2. Making foresight independent and flexible: Such entities should be agile and economically independent through specific and guaranteed long-term funding. They should not be subject to the pressures of any administration to justify discretionary or partisan policymaking.

3. Making foresight matter: The coordinating authority should directly report to a leading national or European figure (i.e. at Member State level, it should report to a President or Prime Minister, and at EU level, the authority should actively be part of the portfolio of a specific Commissioner, but serve the interests and investigate on the topics of the whole Comission).

4. Planning the unplanned: In order to deliver foresight with an action plan, it is necessary to not only have a "topic" approach, but also a "scenario" perspective — meaning that the question to be asked is not "what if there were a pandemic?" but rather "what if there were a pandemic with a much deadlier virus than Covid-19 (for instance, a 20% death rate)?" or "what if there were a pandemic with a much longer incubation period?".

5. Involving civil society and leveraging diversity to anticipate major risks: For the success of foresight, it is essential to actively listen to the various stakeholders involved in a future crisis. Many scientists were already ringing alarm bells before the pandemic, and many Eastern European countries were insisting on a possible Russian threat that might lead to war. This shows that most often, the problem does not lie in identifying the issue itself, but to hear the person or institution that has identified it.

6. Agile foresight and frequent updates: Good foresight delivers clear policymaking insights and actions that need to be rolled out. However, foresight is also prone to major shifts and needs to be updated. The same should go for the policies enacted in anticipation to major crises or topics: they need to be regularly amended to consider the new tools available (especially when it comes to technological anticipation and regulations) and new situations.

7. Foresight and experimentation: In times of great uncertainty and volatility, we need to experiment with new solutions to counter new problems and frameworks. Foresight should in some cases lead to "pop up policies", i.e. policies that are put in place for a limited amount of time (a few months) and act as a "sandbox" where new regulations can be temporarily enacted to see which policy option is the most effective.

KEY PERFORMANCE INDICATORS FOR A SUCCESSFUL FORESIGHT STRATEGY

The previous recommendations referred to how should foresight be developed within national and supranational entities. This next set of recommendations refer to how foresight should be utilized:

1. Foresight as a societal tool and a renewed democratic instrument: The coordinating foresight entity must actively engage in dialogues with various ministries/DGs, the central administration, and different stakeholders (private companies, NGOs, trade unions…) to catalyze a unified and accepted vision for the future of the society.

2. Foresight as an instrument for more effective policies: Foresight should also adopt a public policy evaluation role, which is critical to assess the quality of policies and the planning process. Metrics defined by foresight may be useful tools for evaluation.

3. Foresight as a tool to accelerate diversity and truly leverage European strengths: Using foresight to increase diversity and rotation among civil servants would increase public capabilities, understanding of its fast-changing environment, and resilience.

4. Foresight as a metric for consistent policies: Foresight is a unique tool to evaluate whether different, sometimes apparently unrelated policies, converge at a later point with positive or negative impacts.

5. Foresight to focus on topics that are often overlooked: Foresight offers the ability to raise awareness on issues that policymakers cannot pay enough attention to under the current administrative structure. In theory, a foresight institution should have allowed policymakers to actively discuss pandemics or hybrid/conventional wars before they occur. Now, it would allow policymakers to put the issues of future pandemics (including antimicrobial resistance) on the agenda.

6. Foresight to spread benefits to other economic actors: While foresight is of paramount importance for policymakers, it can also have numerous benefits for private companies, from startups to large corporations. These organizations can obtain direct benefits through the use of foresight information to develop better products and technologies Indirectly, they would benefit from having a clearer political vision of society and a better understanding of the policies and signals that can drive innovation.

APPENDIX I

Disruptive technology	Potential impact	Specific technologies involved (non-exhaustive)
Cognitive manipulation technologies	Cognitive manipulation through social networks is putting democracies – and organizations– under attack, and opening an entire new front of hybrid warfare – the trend will accelerate with the rise of "deep texts" generated by GPT-3 and other AI	Deep text Neural implants Reinforcement algorithms
Nuclear fusion	Potential gamechanger in energy. Nuclear fusion requires deuterium and tritium as fuel, which are almost illimited natural resources. Furthermore, fusion does not produce radioactive waste nor releases CO2 emissions. Recent breakthroughs increase the probability of fusion becoming reality in the future, and on a scale that would make it accessible globally	Deuterium production Hot supraconductors High-power magnets
Immersive tech	Immersive tech will revolutionize digital interfaces and the way we interact. It could be a complete game-changer in terms of trust relationships, Command & Control, scenario planning and confidentiality management.	Artificial vision Sensors Motion simulation Neural implants Parallel Computing
Quantum positioning systems (QPS)	QPS may render GPS obsolete, and change the paradigm in contested aerial zones, exo-atmospheric space or underwater environments.	Quantum sensors New generation inertial measurement systems
Nanotechnologies	Their applications span the industries of microelectronics, robotics, healthcare (potentially minimizing invasive surgery), power storage and autonomous systems.	Nano controllers Nanotubes
Hypersonics	Hypersonics are raising new vulnerabilities in the decision process, geographical positioning, early detection capabilities, balance of power considerations, etc.	Heat resistant materials Guidance systems Reentry components Propulsion (including nuclear)
Neuromorphic computing	Potential game-changer in terms of computing power and memory access speed, as well as collective intelligence	Spintronics Photonics Synthetic biology

APPENDIX II

COGNITIVE MANIPULATION				
Basic information	Scenarios and possible impact	Interconnection of these technologies	Policy options	Open questions
Cognitive manipulation involves the idea of manipulating or tricking someone into believing a certain thing or acting a certain way. The lines between what cognitive manipulation is exactly are blurred. With social networks, cognitive manipulation can reach unprecedented scales. Rogue states using cognitive manipulation are usually more technically advanced in these technologies, since they use them quite often for domestic purposes and can benefit from reinforcement algorithms (they train their models against different	Impact on elections Electronic votes may be a false good idea. It may be easier to manipulate a digital vote than a paper vote. More importantly, it is essential that the process can be held equally accountable by citizens. New approaches using blockchain can be put in place, but only as a complementary tool to more classical checks. Similarly, international organizations (OSCE, UN, Council of Europe) are in charge of election monitoring. A global framework should be implemented by Western	Handle switching: as using AI-generated profile pictures do not work well anymore, individuals use handle switching, a technique that consists of changing name, bio and handles of a social media account and shifting to a new target, while maintaining the number of followers. Automated accounts: these are accounts known as bots and they are usually used for political purposes like amplifying certain narratives while drowning out others.	Need for states to have policies/frameworks adapted to the velocity of digital tools. In France, there is a 48 hour ban on media before elections. But a false rumor or some fake news could very well start being disseminated 50-60 hours before the start of the election. Need to develop detection capacities against deepfakes and "deeptexts" (texts generated by AI, including large AI-models such as GPT-3), in very limited time/real time.	How integrated will cognitive manipulation become with hardware (eg. Neuralink) and software (eg. social networks)? Will cognitive manipulation become more data-driven in the future, or will it base itself on only a sample of data (so far, cognitive manipulation has been focused on large groups without much customization)?

actors); this is usually not the case of Western actors. All happening while public debate in Western democracies is becoming much more polarized. The key players are mostly authoritarian regimes (with Western democracies sparsely involved), para-governmental institutions (e.g. Russian troll farms), state-funded media, social media intelligence companies (e.g. Graphika, PGI), and some data-mining/exploiting companies (e.g. Cambridge Analytica).	democracies to prevent and detect election manipulation. Hybrid warfare is cheaper than "hard" warfare and cognitive manipulation is one of the most cost-effective aspects of a hybrid warfare. Passive and active impact The impact for now of technology is mostly passive (it consists of information/propaganda that is "consumed" by citizens). In the future, it might be "active" with potential neural implant hacking.	Human-curated accounts: these accounts use low levels of automation but also engage in conversations by posting comments or tweets. Impersonation accounts: These accounts are less common, and they include hacked, stolen, or fake accounts used to impersonate influential people. Creation of disinformation or manipulated media: this includes creation of fake news, websites, memes, images, videos and any other form of deceptive online content. Data-driven strategies: this strategy allows actors to profile and target specific segments of the population with political	Western democracies should use "deeptexts" as an opportunity to analyze the weak signals/messages relayed by authoritarian regimes. They should significantly enhance their mapping of deepfake/deeptexts through graph-based detection. Current research in neural implants should ensure these implants (and the AI backing it) take into account ethical issues — since a ban on such implants would only promote the use of neural implants unable to make appropriate judgments in the long term.	

		advertisements in order to spread disinformation and false narratives. Trolling, doxing, and online harassment Content or account filtering: state-backed cyber-troop accounts can report posts by activists, political dissidents etc. to flag, demote, or take down inappropriate content.		

NUCLEAR FUSION				
Basic information	Scenarios and possible impact	Interconnection of these technologies	Policy options	Open questions
Nuclear *fusion* is the process by which energy is emitted through the combination of one nucleus or different nuclei. So far, all attempts at nuclear fusion have required more energy to stimulate the fusion reaction than energy created. Indeed, massive amounts of energy are needed to heat a gas, so that it transforms into a plasma — and only within that plasma can the nuclear fusion happen (with high enough temperature, the ions involved in the reaction can be close enough and produce a fusion of their nucleus). Therefore, the real breakthrough will happen once more energy can be produced than consumed through nuclear fusion (what is called reaching the "scientific breakeven"). Nuclear fusion paves the way towards a much safer energy landscape than	Change in actors Nuclear energy, which was usually led by state-controlled consortia, might become disrupted by startups. Geography of nuclear energy So far, nuclear energy (fission) has been mostly dominated by Europeans, but Europeans do not have this advantage in fusion. The lack of a common learning curve between nuclear fusion and fission implies that Europe might not	There are currently two main pathways explored in energy fusion: magnetic confinements, which has gathered increased attention, and inertial confinement. Magnetic confinement fusion (MCF): the deuterium-thorium fuel is heated (10 million degrees Celcius in the case of tokamaks) in order to reach fusion level, while being within a "magnetic confinement". This magnetic field helps keep the plasma under control. Inertial confinement fusion (ICF): a "target" (containing the	Need for states to have a "portfolio" approach: not betting too big on a single project, but also looking at different ones. Policymakers might decide to ban nuclear fission (this is not a scientific, but a social and political choice); however, they need to keep investing in nuclear fusion research. Making no clear mention of fusion energy, EU Commissioner Breton estimated that the EU would need to invest about 500 billion Euros by 2050 in "new generation nuclear plants" (without taking into account the ~50 billion euros	What is the terrorism risk linked with nuclear fusion plants? How linked are civil and military R&D in nuclear fusion technology? Will key players in nuclear fusion assist other countries in mastering it? Will there be technology sharing/exporting? How long would the scaling up of a working prototype take? Once a country is able to master nuclear fusion, how long until this country deploys it to have a cheap and

nuclear fission: fusion does not produce chain reactions (eliminating the possibilities of nuclear accidents as we know them); fusion produces significantly less nuclear waste (it would not entirely eliminate radioactive waste), since it produces helium (a common gas), and radioactive elements (such as tritium) whose average life is much shorter; the radioactive waste from fusion is expected to remain radioactive for hundreds of years (compared to about millions of years for nuclear fusion). Key actors: JET (Joint European Torus), K-DEMO, ITER (multinational initiative based in France), EAST (Experimental Advanced Superconducting Tokamak, based in China), Commonwealth Fusion Systems, TAE Technologies, National Ignition Facility, Laser Mégajoule, some private funders (Bill Gates, Jeff Bezos and Peter Thiel are all funding fusion energy startups).	maintain its centrality in nuclear energy. <u>Timeline</u> ITER and CFS plan to deliver their first plasma by 2025; while the British startup Tokamak aiming at having a commercial reactor by 2030s. This timeline means that ongoing efforts to decarbonize energy (through new breakthroughs in renewable energy, energy storage, nuclear fission, etc.) should be actively supported — although fusion energy alone will not be enough to tackle climate change.	thermonuclear fuel) is heated through lasers or beams. This produces physical reactions and conditions such that the target is hot enough that fusion can occur within it. Other methods investigated to produce fusion energy are actually either a mix of fusion, fission, or of the two approaches quoted above. So far, both have delivered few tested results.	to invest in current plants up to 2030) . The figure was estimated to be closer to 400 billion euros by energy Commissioner Kadri Simson.	clean energy across all its territory?

IMMERSIVE TECHNOLOGIES				
Basic information	Scenarios and possible impact	Interconnection of these technologies	Policy options	Open questions
Immersive technology might augment the impact of cognitive manipulation, through more personalization and the tailoring of immersive content to specific consumers, users, and citizens. This means that specific groups of users could be contacted privately through immersive tech to be influenced. Many companies (Meta, formerly Facebook, being the most prominent example) are focusing massively on immersive tech, with a winner-take-all approach: one company might control whole segments of immersive tech (or of the metaverse) The customization of immersive tech will make moderation even more difficult compared to social networks (since social networks focus on usually on public spheres/social	Immersive tech can be decentralized and interoperable (especially if immersive tech becomes blockchain-based), fragmented and oligopolistic (different private actors controlling around 15-20% market shares), or monopolistic (one company controlling most of the metaverse). Policymakers should focus their attention on the constitution of today's large ecosystem and should proactively avoid any monopolistic attempt from private companies. Geographic fragmentation: immersive tech could be global or regional (with a	Persistent: there is no way to stop, pause or end immersive tech (even if one might disconnect) Synchronous and live: immersive tech is providing live experience that exists consistently for everyone and in real-time Unlimited: in terms of users and must provide a sense of presence through a critical mass. Providing a fully functioning economy: individuals and businesses can create, sell, own, invest and be rewarded for anything that is recognized by others as "work" or "value" — meaning that blockchain and cryptocurrencies will likely play an important role in immersive tech	Need to identify the building blocks of the metaverse/immersive tech and leave them open to allow free and fair competition — thereby preventing any forced linkage like between Oculus and Metaverse, for instance. Competition rules should be much more proactive, in order to avoid previous mistakes and prevent only a handful of actors from having monopolistic tendencies in the 2030s, and whose monopolies could not be broken.	Might immersive tech be only a hype, and might consumers or citizens barely use it? Will immersive tech reshuffle the cards and will lead to new global companies able to compute with GAFAM or with BATX? What will be the value proposition and target user?: Will immersive tech be mostly leisure, will it boost

groups; while immersive tech might be much more individual). Legislators/regulators will likely have to play a much more proactive role. Key actors: for now, most GAFAM (especially Meta) and Big Tech companies, especially the ones who are focusing on the metaverse; few European actors; in China, especially Tencent, Huawei, and Alibaba.	Western/American ecosystem, a Chinese ecosystem, and a Russian ecosystem for instance). Generational fragmentation Immersive tech might only be embraced by younger generations or different segments of population, which will also depend on how immersive tech is used in the workplace.	Hybrid experience, which mixes digital and physical world. Interoperable (except in case of oligopolistic/monopolistic immersive tech): it might be possible to move data (including content, items bought…) from one platform to another. But this might only happen in case of full cooperation between platforms and companies which for economic and competitive reasons may not be willing to accept these kinds of proposals. Populated by content and experiences: everyone can contribute to the creation of content and experiences from independent individuals to companies.		productivity, will it be an interface connecting different daily habits?