Future technology for prosperity

Horizon scanning by Europe's technology leaders

[Julian Müller and Lesley Potters]
[*August – 2019*]

Research and Innovation

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Manuscript completed in September 2019

Luxembourg: Publications Office of the European Union, 2019

PDF	ISBN 978-92-76-09509-5	doi: 10.2777/187237	KI-03-19-551-EN-N

EUROPEAN COMMISSION

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2019

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FOREWORD

In spring 2019, when the EU agreed on the principles of Horizon Europe, the new EU Framework Programme for Research and Innovation, we realised that we had the same intriguing question: "What is the next 'big' technology which we should have 'on our radar', one as important as artificial intelligence or quantum technology?' Something that will be a game changer for industry and society at large? However, we could not come up with a clear answer.

By looking into many different "Horizon Scanning" reports, we found many which highlight in particular digital and biotechnologies as key to future markets and competitiveness, however none provides a silver bullet solution.

We wanted to test therefore what answer we would get when thinking about emerging technologies that were orientated towards 'prosperity', building on the strengths and values of European science and research, which so often discovers the game changers of the future. We also wondered if we were in good time to ensure that European industry is at the forefront of capitalising on the potential of emerging technologies, in particular of 'other than digital only' technologies and capacities, on which so many discussions are already taking place.

We invited therefore the Directors of research and technology organisations and funding bodies, one per country, to a workshop in Oslo on 2-3 July 2019, hosted by the Research Council of Norway. This report is a summary of the workshop that brought together high-level representatives of 20 different organisations from 18 European countries.

We do not claim that it offers the complete answer, and again we should repeat that there is no single answer to the question of what 'the next game changer technology' will be. A variety and broad range of technologies were presented. However, common factors were the convergence of technologies and interdisciplinary cooperation as a breakthrough factor. We also looked beyond technologies, but instead of 'applications' we identified 'purpose' as the driver of creative and market relevant new solutions to sustainability challenges. We distinguished between 'needs' and 'demand' and discussed the task of policy makers to lay down the right framework conditions for successful business which itself respects inclusiveness and acts within environmental (planetary) boundaries.

We hope that you enjoy this report, which aims to inspire further discussion, in particular on priority setting at European level and on Horizon Europe.

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EXECUTIVE SUMMARY

Technology-driven companies and research organisations scan and monitor continuously their environments in order to maintain leadership in their field. Technology funders face similar challenges, as it is important to offer opportunities ahead of the established knowledge.

This report is the outcome of a workshop – the first of its kind - that took place in Oslo in July 2019, bringing together leading figures from European research and technology organisations and funders to explore emerging technologies that would be most promising for prosperity.

Five technological frameworks (outside ICT) were identified with a particularly strong potential:

1. **Biological transformation** including gene technology, neuro technologies, human-machine interaction and smart farming.
   Biological transformation is the systematic application of knowledge from nature, i.e. the integration of biological and bio-inspired principles, materials, functions, structures and resources.

2. **Smart materials** including renewable plastics, smart nanomaterials and additive manufacturing.
   Smart materials build on technologies for materials that give them additional functionalities, capacities, and features in bulk and/or at the interface, including adaptability and the capacity to be not only sensors but also actuators, or to create new structures even on very small scales.

3. **Low energy data transmission**, including smart dust and coherent optics.
   A wide variety of health, food, mobility and environmental applications require sensors in order to provide the necessary data to improve sustainability outcomes. Making them energy-autonomous and biodegradable increases their spread and enables their widespread application and environmental compatibility. Also, through more efficient low-distance communication based on coherent optics, the overall energy consumption of digitisation and data transmission can be reduced.

4. **Power to X** technologies including hydrogen and carbon capture and storage.
   Power to X allows much more efficient processes than existing ones in the chemical industry through direct power conversion. It is also closely aligned with carbon capture and storage technologies. CO2 emissions from process industries can be captured, allowing, for instance, zero emission cement (first results only indicate a 2% increase in costs), zero emission waste incineration, absorbing carbon from bio process industry or supporting the scale up of hydrogen or renewable energy.

5. **Marine technologies** including digital fish and fresh water under sea.
   Overall, technologies can be used to create a holistic understanding of the ocean ecosystem, predicting hazards, stress factors, monitor production and reduce environmental footprint.

As general framework conditions for all technological frameworks, participants stressed the creation of high-skilled jobs, the establishment of robust innovation ecosystems and sustainable value chains across Europe, which are particularly important for ensuring scale-up in Europe. In addition, methods for horizon scanning, especially technology identification and evaluation, and methods for collaboration and technology transfer were discussed. Participants also shared good-practice on engaging actively with civil society and citizens from the very start of technology development. Policy conclusions include creating conditions for scale-up investments in the EU, stronger inclusion of social sciences and arts in technology development, using innovative public procurement to pioneer innovative solutions and achieving leadership through ambitious goals and scale.

REPORT

The workshop *'Future technology for prosperity - Horizon scanning by Europe's technology leaders'* was born from the idea of setting the investment priorities for the next Horizon Europe Framework Programme. At present, investment priorities for the first work programme 2021-2024 are being shaped. The main goal for Horizon Europe is a higher impact for society. In order to reach this, a co-creation process has been set up to define priorities. The workshop is part of this process that includes a wide global public consultation on the draft strategic plan.

Leading figures from the main European research institutes, national research councils and the European Commission gathered on 2-3 July in Oslo to share their insights on the mid to long-term challenges that surround the overarching objective. That objective is to make Horizon Europe a success by identifying future technologies that will contribute to the priorities and that will reshape our future. In view of other ongoing work on future technologies, the workshop also explored technologies outside the currently predominant discussion on information and communication technologies (ICT), such as Digital Transformation or Industry 4.0.

Why future technology for prosperity? There is a widespread emphasis on GDP growth, but an alternative focus on other aspects of life is needed. Prosperity, from the Latin prosperous or 'good fortune' deals with things that significantly improve the quality of life. Living within the boundaries of the planet and with equal opportunities for all. Prosperity is also very much linked with the next Commission – there will be more action centred on sustainability. Prosperity is one element in this. Therefore, the workshop also aimed to contribute to a fair and just transition towards sustainability by investing in and using several technologies discussed in this report.

1 Political and economic context: towards value creation

The keynote speeches by entrepreneurs at the opening session aimed at setting the political and economic context for the workshop. Human society struggles to address less apparent 'slow' risks which build up over time and tends to focus on the more apparent and immediate ones. However, the 'slow' risks must be considered and tackled equally, if not given even more attention, because they affect the sustainability of our development model. Norway, the host of this workshop and full partner in Horizon 2020, is a perfect example in Europe for addressing the main societal challenges: an economy that is very advanced in making the transition from a resource-based economy (oil, gas, fishery, metals and other mining) to a sustainable and research- and knowledge-based economy.

This move was not made overnight. It takes time to build a competitive company, and it takes many decades to build a successful and competitive industry. European industry, policymakers and research institutes play an important role in this transition. Ambitious EU regulation can steer industry to make bigger steps towards more sustainable production processes but also as a provider for more sustainable products and services, for example by setting clear emission reduction goals for the car manufacturing industry. Free rider problems can be fought by setting up the right barriers and limit the access to a public good. This might also require creating viable competition in the internet/data industry, where measures such as the breaking up of Standard Oil in the early 20th century can serve as an example.

At the same time, research institutes, entrepreneurs, venture capitalists and funding agencies should focus more on investing in innovative businesses that address the main societal challenges. There are good opportunities in technologies where Europe has a strong position compared to its main competitors in the US and Asia. These opportunities involve completely new and innovative products and new processes – where Europe can be competitive due to its strong industrial and research foundations – but also services around these new products and processes. In many ways, things will change as we know them. Innovation will lead to fundamental changes in society, the perspectives range from new energy sources and new forms of energy storage (especially in batteries where Europe is in a non-favourable position compared to the US and Asia on the availability of resources), to new materials, processes and systems for circular construction (e.g. cement has a big impact on the environment). They also concern challenges on health, access to resources (e.g. water) and food related issues (where the EU is at the forefront of development).

Unfortunately, there is still only a small minority of entrepreneurs and venture capitalists in the business of sustainability. The right framework conditions should make it possible to grow our own companies instead of selling off start-ups. Through this, we could cope with the societal challenges ahead and turn technological research into value creation. We could transform our needs into direct customer demand rather than satisfying a demand that might not represent an actual need.

China has shown that it is capable of setting up a goal-oriented and top-down approach to address big societal challenges: creating a critical mass including human resources, education programmes, venture capitalist funds, steering research efforts in specific applied fields and creating value for society out of it, such as reducing air pollution in cities. Technological research in the EU traditionally seems to be born out of curiosity, leaving application and scale-up to others, with the effect that scaling up is often done outside the EU.

However, it is also important not to underestimate the societal dimension involved in this transition. With today's increased complexity in scientific disciplines, it will be more difficult for people to understand the real impact and applications of technologies. There is a need to show the benefits these technologies have on society. Introducing social sciences upfront in the technology research process and an open innovation process where society can participate are necessary conditions to increase the readiness of society to accept these new technologies. Sharing knowledge and communication can help to build this capability and to support a shift where today's needs become tomorrow's demands. Open access to science-based information is key while at the same time we should continue to build on the variety of cultures and traditions that exist in Europe. Collaboration, co-creation and collective intelligence in this multidisciplinary world will create trust and can have a huge positive impact on society.

In a world of fake news, we also need to address new ways of communication while building upon the trust that European research institutions have gained with the public. It is important to continue to build on European values and to develop technologies, while at the same time having profound and open discussions within society, while competing countries such as China have a different approach. European research institutions can play a pivotal role in this new way of communicating.

2 Technological frameworks

The workshop was organised around biology, climate, materials and other fields. Participating leaders from Europe's research and technology institutes were asked to prepare a short presentation pitching 'the next big technology trends' associated with high expectations in terms of development and impact within their organisation.

Each of the participating institutions' representatives was asked to present a specific technology outside ICT, Digital Transformation and Industry 4.0 'only'. Still, many of the technologies are largely dependent on ICT and require ICT to untap their full benefits, also in combination with further technologies described. The technologies that were presented do not constitute an exhaustive list.

The presentations outlined the technologies by describing them briefly, presenting issues related with the technology, also outside the technological perspective, and their expected impact on society and sustainability.

However, the workshop was not about just one technology per institute. This is just one part of a bigger picture where modesty should prevail: we do not try to predict the future but rather to build the technologies of the future.

Moreover, the workshop dealt not only with 'cathedrals' (main missions), such as the carbon neutral economy, demographics and resources, but also with the 'stones' to build those 'cathedrals': technologies that help to reach these goals. The discussion also addressed bridging between 'stones' and 'cathedrals': ensuring a competitive market with reliable and effective legislation and applying the correct methods of horizon scanning to be prepared for the future, ideally in order to be able to anticipate and not just react to change.

The two-day workshop related all technological frameworks and technologies presented in the following, to the creation of high-skilled jobs, the establishment of robust innovation ecosystems and sustainable value chains across Europe, the stimulation of with new business creation, and the strengthening of international technology leadership in key strategic domains for the EU.

Figure 1 gives an overview of the presented technologies in the five technological frameworks that have been identified in this report.

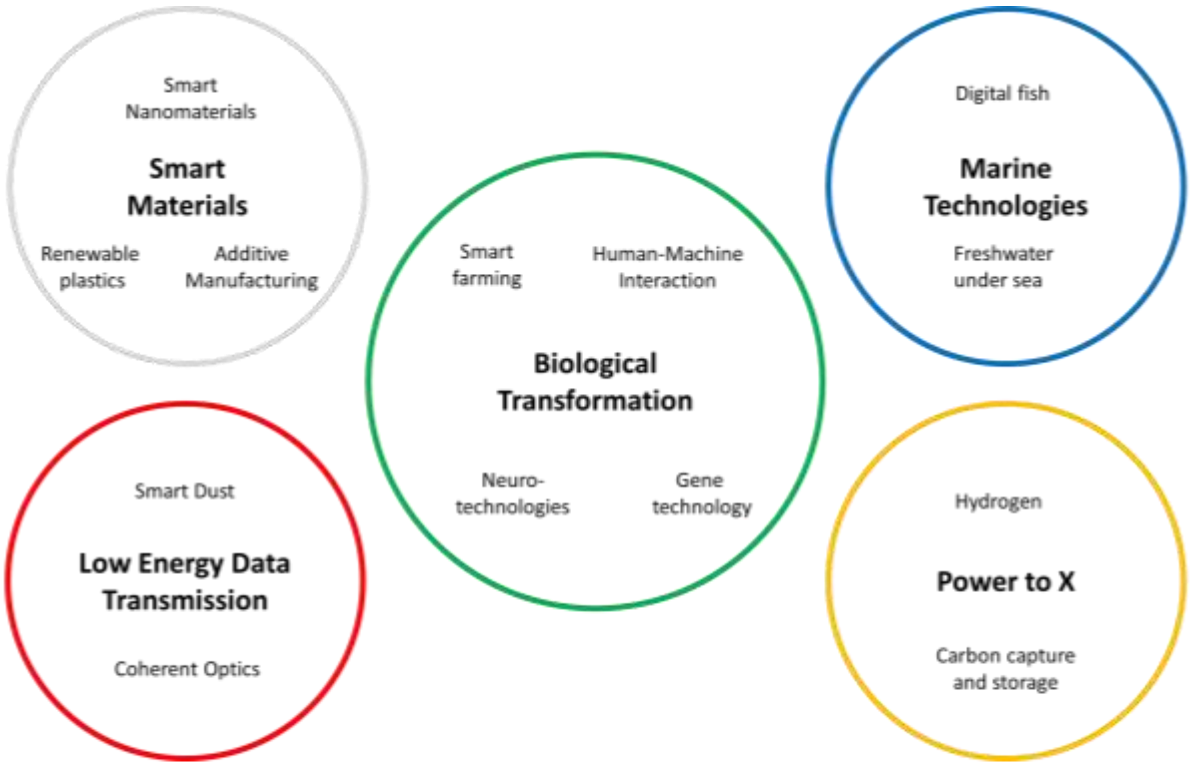

Figure 1. Overview of technology frameworks and technologies

Each technology is briefly described below and the impact on society and sustainability is explained.

2.1 Biological transformation

Biological transformation brings together the basic disciplines of biotechnology, engineering and information technology. Methods of adaptive data processing (self-learning algorithms) are just as important as biotechnological production processes. Their combination and intelligent networking, including biological components and principles for their optimisation, is the key to a bio-intelligent economy that enables prosperity and healthy and sustainable (qualitative rather than quantitative) growth.

Biological transformation in general

- Description: biological transformation is the systematic application of knowledge from nature, i.e. the integration of biological and bio-inspired principles, materials, functions, structures and resources. Bio-Intelligence is the convergence of the digital transformation with the biological transformation. In fact, many technologies, such as artificial intelligence, swarm intelligence or additive manufacturing are derived from nature.

- Technology issues: bionic principles are studied and utilised since decades. The biological transformation builds on distributed, parallel computing and artificial intelligence, and their convergence, and also with biotech, material and engineering (manufacturing) developments. A large-scale rollout of bio-intelligent technologies associated with biological transformation is expected as of 2030. The combination of isolated fields requires interdisciplinary research approaches.

- Society and sustainability: a future resource shortage could cause bottlenecks, since some resources are already becoming scarce, such as rare earths, silver and lithium. Biological transformation has a high potential for disrupting products and processes, replacing scarce resources and thereby reducing import dependencies. Further, more sustainable products and processes are expected that reduce the demand for fossil fuels and feedstock, and allow upcycling and biodegradable, circular industrial processes with less emissions. Further, improving working conditions and safety at work by replacing hazardous chemicals in work processes is expected.

Gene technology

- Description: modulation of genetic materials. Gene technology is a way to reprogramme life: for the first time in history we are able to read, write and edit DNA through technologies such as CRISPR.

- Technology issues: gene technology has ethical, medical and biological considerations, for instance the desirability of modifying living organisms, the impact of gene modification on health, changes to the environment and protection of privacy. In China, regulatory barriers are considerably lower, allowing gene technologies to develop more quickly, but also in a riskier way that neglects, amongst others, possible ethical concerns, and biological and medical hazards. Further considerations are high costs for gene technology-based medicine, the acceptance for consumers (especially in the EU) and the legislative environment in the EU driving companies outside Europe.

- Society and sustainability: gene technology could have a profound impact on many aspects of a more sustainable future. With a long list of applications, such as in green industry (new, sustainable materials, measures against antibiotic-resistant bacteria, biodegradable plastic, more efficient fuels), food production (healthier food while reducing emissions and waste), energy efficiency (e.g. through improved photosynthesis) and healthcare (new forms of medical diagnostics and gene therapies, or resistance to diseases also for livestock).

Neurotechnology

- Description: neurotechnology describes developing our understanding of the nervous system and systems capable of restoring or enhancing functions in people affected by different types of neuronal disability. Neurotechnology integrates fields such as Neuroprosthetics, neuromodulation, neurosurgery, neurosoftware and neuroimaging.

- Technology issues: neurotechnology requires specialists that are rare since it combines engineering, micro and nanotechnology, electrical and mechanical systems, computer science, molecular and cognitive neuroscience. As neurotechnologies represent an example of 'unknown territories of known interfaces', high risks are expected that require long funding mechanisms.

- Society and sustainability: neurotechnology enables several possibilities for cures and treatments against diseases such as strokes, migraines and Alzheimer. Those illnesses are increasing, in part because the global population is getting older, and those diseases are more likely to occur with old age.

Smart farming

- Description: smart farming encompasses a technology-enabled approach to farming management that observes, measures, and analyses the needs of individual fields and crops. It is driven by technologies as big-data and advanced-analytics capabilities (for instance artificial intelligence), robotics-remote sensing and imagery (drones, planes, satellites), and sophisticated local weather forecasts. It is then coupled with autonomous farming machines that create an intelligent farming ecosystem.

- Technology issues: the market lacks comprehensive services in precision agriculture and forestry. Also the acquisition of reliable, homogeneous and comparable data through sensors and actuators with low energy consumption, data availability and accessibility is required. Farmers must be involved from early on in technology development in order to accept the technology, as they require data evaluation that can be translated into actionable knowledge and precise recommendations.

- Society and sustainability: less chemicals, fertilizers, and pesticides as well as low energy and water consumption are required to make farming sustainable. More efficient farming allows feeding more humans within a growing world population at lower costs and environmental impact. Further, the food supply chain can be improved (traceability and food security). The technology is also applicable for land monitoring (fields, forests and natural disaster monitoring).

Human-machine interaction

- Description: human-machine interaction includes a set of technologies for the collaboration of automated and digitised systems with humans in order to combine the strengths of both. It therefore does not aim to replace humans with robots and digitised systems, but to complement humans in terms of cognitive and manual capabilities and reduce hazardous and harmful manual work.

- Technology issues: so far, there is still little awareness in industry, which requires research and fieldwork at production plants and with workers on the shop floor in order to increase the acceptance and highlight the difference to fully automated systems. Thus, cross-disciplinary research, including psychology, computer science, social and organisational sciences, must improve the usability of the different technologies and the impact on human-to-human interaction.

- Society and sustainability: collaborative systems can serve as a way to increase technology acceptance, allowing to digitise production in an inclusive way for workers. Also, correct instructions and assistance of humans in production processes leads to higher quality, efficiency and employee satisfaction. It is able to improve decision-making processes and combine artificial and cognitive capabilities, also outside industrial and manufacturing processes.

2.2 Smart materials

Smart materials build on technologies for materials that allow them to have additional functionalities, capacities, and features in bulk and/or at the interface, including adaptability and the capacity to be not only sensors but also actuators, or to create new structures even on very small scales.

Renewable plastics

- Description: under the term renewable plastics, we can include the use of raw materials other than fossil-based materials for the production of plastics (replace), redesigning of products, and recycling of plastics. For the latter, either recycling using mechanical or chemical technologies are possible avenues to produce different grades of raw materials for further production.

- Technology issues: the homogeneity of plastic waste materials depends on the suitability of recycling methods. So far, mechanical recycling is economically viable in most cases, while chemical recycling is required to produce higher grade raw materials usable for example in food packaging. Further, a regulatory framework for the recycling of plastics should be established that would create incentives for different actors to build both collection of plastic waste as well as invest into new recycling technologies.

- Society and sustainability: today, 60% of plastic waste comes from packaging, while two thirds of packaging waste is food packaging, but only a small percentage is recycled. Encouraging the use of renewable plastics in packaging can reduce the CO2 footprint, reduce the requirement of crude oil for plastics production and reduce the overall environmental impact of packaging.

Smart nanomaterials

- Description: moving materials on small-scale (nano or quantum), for instance by lasers, enables to create new materials, that can be found throughout all industries. For medical applications, optical imaging, medical imaging, sensors for health analysis or new medicine can be named. Through nanotechnology, properties and functionalities that are not possible otherwise can be achieved. Nanosensors and nano delivery systems can have a great impact also in food safety and security.

- Technology issues: so far, mainly US companies were interested in buying the technology. Therefore, while the research and development activities might be present in Europe, the technologies are exploited and commercialised outside of Europe. Evaluation of the impact of nanomaterials on health and the environment should also be considered ('safe by design' developments). Further, research is needed on embedding data or information in materials.

- Society and sustainability: smart nanomaterials can be used in a multitude of medical applications that allow better treatment of patients and new forms of therapy. Other applications outside the medical sector, also can serve as enablers for further smart materials technologies by adding capabilities and materials properties on a nano level. Developing complex new products, or second-generation commodity products, can have a significant impact on more sustainable products and processes, enabling new ways of materials properties, recycling, repair and self-healing or sensing.

Additive manufacturing

- Description: additive manufacturing (also known as 3D printing), is based on adding materials layer-by-layer, in contrast to subtracting ('cutting') materials from semi-finished products. This allows new production processes, geometric shapes and material properties.

- Technology issues: additive manufacturing is well known by now, but there are still few viable applications outside low volume production (customised parts, prototyping, product designing, and concept modelling). Further research and development activities are needed for pre-treatment and post-treatment aside of the additive manufacturing process itself to reach its full potential.

- Society and sustainability: additive manufacturing allows energy and raw material savings through more efficient production processes and reduction of logistics and delivery processes. Further, new material properties and geometric shapes can be used in the medical industry, for instance as implants.

2.3 Low energy data transmission

For the requirements of interconnection in the Internet of Things among products, production facilities, humans, and sensors, low energy data transmission technologies will be needed in order to decrease the energy requirements.

Smart Dust

- Description: Smart Dust combines systems for ubiquitous Internet of Things (IoT) needs with ultra-low power consumption or energy autonomy. It encompasses intelligent sensors that are able to communicate among each other and that are degradable.

- Technology issues: only first test applications have been established so far and require further developments in energy-autonomous systems, materials science, and microelectronics.

- Society and sustainability: a large variety of health, food, mobility and environmental applications require sensors in order to provide the required data to improve sustainability outcomes. Making them energy-autonomous and biodegradable increases their widespread application and environmental compatibility.

Coherent optics

- Description: low-distance communication in data centres is energy-inefficient due to old technology, this is why the Internet (of Things) communication is still energy-hungry. Low energy data transmission encompasses the use of coherent optics and the full spectrum of light within the short communication of data centres. This means replacing electrical transistors, still widely present in data centres and data hubs, through optical transceivers.

- Technology issues: coherent optics are well-developed in long-range communication, but underdeveloped in short-range communication and therefore require further implementation in data centres.

- Society and sustainability: through more efficient low-distance communication based on coherent optics, the overall energy consumption of digitisation and data transmission can be reduced.

2.4 Power to X

Power to X technologies aim for the production, conversion, or storage of chemicals, fuels or CO2, preferably directly from renewable energy sources.

Power to X in general

- Description: Power to X is also termed as the electrification of the chemical industry. The long-term vision is to turn natural sources of energy, for instance sunlight, directly into heat, fuels, or further chemical products.
- Technology issues: besides Europe's role as a user of Power to X technologies, it should attempt to become the provider of the technologies worldwide in order to benefit from Power to X.
- Society and sustainability: Power to X allows much more efficient processes than existing ones in the chemical industry through direct power conversion. It is also closely aligned with carbon capture and storage technologies.

Hydrogen

- Description: for hydrogen, technologies for the production, conversion and storage are required in order to be able to serve as an alternative fuel and energy storage.
- Technology issues: the storage (weight and size of storage tanks for vehicles, flammability of hydrogen) and efficient conversion of hydrogen remain challenging. Further, adequate infrastructures must be ensured across Europe, while a further coupling with Power to X processes is required.
- Society and sustainability: hydrogen as an alternative fuel and form of energy storage allows cycle processes where water is turned into hydrogen and oxygen with zero emissions, when using renewable energy sources. Also, renewable energies can be stored and the components required are mostly available across Europe.

Carbon capture and storage

- Description: carbon capture and storage describes storing CO2 underground in cavities in order to reduce CO2 levels in the atmosphere or store CO2 directly from industrial processes.
- Technology issues: carbon capture and storage is still at an early development stage, discussions regarding safety of underground cavities are currently ongoing.
- Society and sustainability: CO2 emissions from process industries can be captured, allowing, for instance, zero emission cement (first results only indicate a 2% increase in costs), zero emission waste incineration, absorbing carbon from bio process industry or supporting the scale up of hydrogen or renewable energy.

2.5 Marine technologies

Marine technologies are closely related to biological transformation, but highlight underwater resources and oceans as a future field of technologies.

Digital fish

- Description: the monitoring of fish via sensors allows to create a digital twin of fish. In using this technology, hunger, disease stress and further stress factors can be tracked and mitigated to decrease diseases and improve fish mortality, and to optimise the feeding process and its well-being.
- Technology issues: the ecosystem under water must still be better understood in order to generate a valid digital twin of it.

- Society and sustainability: understanding and digitally monitoring fish enables production control and management of aquaculture systems to reduce environmental footprint and to boost farming performance. Hence, the sustainability of entire maritime ecosystems can be improved.

Freshwater under sea

- Description: large amounts of fresh water can be found below the ocean surface, often hidden in caves. This water could be used to irrigate regions with low precipitation, for instance for farming or for providing fresh water to settlements.

- Technology issues: the known main risk is not so much a decrease in fresh water resources, but to safeguard and benefit from them in the long-term. Therefore, it must be better understood how new fresh water reaches the reservoirs and how those can be exploited without cutting the fresh water supply. Also cross-disciplinary research among physics, chemistry, biology, geology and ecology is required.

- Society and sustainability: access to fresh water provides opportunities for farming and settlements and improves overall living conditions and prosperity. The Mediterranean Sea has many European shores that could be used here, as well as regions in North Africa that are close to Europe. Overall, the technology can be used to create a holistic understanding of the ocean ecosystem, predicting hazards, stress factors and sustainable strategies.

2.6 Further technologies on the horizon

Quantum technologies

Quantum computing technology might be another game changer and will revolutionise the way we perform calculations. The EU has recently started a quantum flagship initiative covering quantum communication, quantum simulation, quantum computing, quantum metrology and sensing as well as the basic science behind quantum technologies. The long-term vision of the flagship initiative is to develop a quantum web in Europe, where quantum computers, simulators and sensors are interconnected via quantum communication networks.

3 Methods

Some presentations were dedicated to good-practice, methods and processes for technology foresight scanning to identify breakthrough technologies and their application in the economy and society. These methods do not try to predict the future, but to capture early signals of emerging technologies that address societal challenges[1].

An important aspect of the proposed methods was the co-creation and collaboration between all actors. To deal with the societal challenges, collaboration and co-creation of all main actors is needed, with industry taking a leading role in this. This approach demands the presence of a strong innovation ecosystem where all actors of the innovation process are connected and can create value.

Public authorities also can fulfil an important role in these ecosystems by creating critical mass to tackle strategic economic and societal domains, to deploy favourable regulation and financial instruments as an impetus for the collective innovation. An important distinction here is the degree of centralisation vs. decentralisation of the proposed method. While China's targeted approach may be effective in changing society, other more decentralised network methods reflecting European values and principles are proposed to identify breakthrough innovation on the horizon, to shorten the time-to-market of these innovations and to generate a critical mass.

Sandboxes – or pilot facilities – can help start-ups and SMEs by facilitating the testing of new technologies with adapted regulations and at reduced costs. This drastically shortens time to market and helps to generate a critical mass in which technologies can thrive, which can be reached in a much earlier stage. Through this, a systematic approach towards innovation can be taken in order to connect the different scientific disciplines together with a sound set of policies and regulations.

In addition, systemic innovation can help to ensure that innovative policies, regulations and innovation related to societal aspects keep pace with the sustainable and competitive transformation of industry and society. Test piloting this will strengthen the possibilities of making a long-term sustainable difference for Europe.

European research institutes play an important role in reaching this scale and obtaining efficiency gains by bridging knowledge creation activities with industry through a combination of strategic collaborations and partnerships. They can also offer scanning and foresight activities, e.g. by sharing information on emerging technologies that are identified through a process of scoring based on their potential innovation, societal and market potential.

Collaboration is imperative and finding common goals and road maps, and further down the road - understanding data and intermediate results – are crucial. Efforts to create a collaborative network that can facilitate such cooperation need to grow even further. During the workshop, ideas emerged for collaboration also between the participating research institutes.

[1] See also the 2019 foresight report « 100 Radical Innovation Breakthroughs for the future" https://ec.europa.eu/info/sites/info/files/research_and_innovation/knowledge_publications_tools_and_data/documents/ec_rtd_radical-innovation-breakthrough_052019.pdf

4 Policy conclusions

4.1 Investments from non-EU countries

The workshop stressed the importance of creating the right conditions in which European start-up companies can grow and scale up without being bought out by large US or Asian companies. Especially the US and China are very determined to invest strategically in technologies that entail higher risks and are still very far from application in industries but do show future potential for maintaining or obtaining global leadership in strategic industries and economic sectors, while Europe is much more prudent. Although first round capital funding is picking up in the EU, we lack second and third round funding that scale up companies and technologies to market scale – with the increased likelihood of being bought out by US or Asian capital at those later stages. How should we create the right conditions in which this type of funding efforts can emerge? Horizon Europe is an opportunity to create a competitive environment that would attract financial instruments and potential investors to scale up small innovative companies and technologies to the market scale.

That said, certain technologies (especially deep tech) do not leave the country, because of the skills that are difficult to transfer. Proposals for smart money, or a financial ecosystem, were made where investments and relationships go hand-in-hand. This is currently available in the US, where the biggest technology markets and ecosystems are located. This will be dealt with under the Capital Market Union, the Europe Innovation Council and InvestEU.

4.2 Inclusion of social sciences

Interdisciplinarity and convergence of technologies is a well-known phenomenon in ground-breaking technological research, although biology might be a relative newcomer in this game, besides IT, engineering and other scientific fields. However, training and education will be crucial to train the next generation of scientists and the upskilling and reskilling of those who are currently active. We need to have the focus on collaboration in a world of narrow disciplines. For instance, biological transformation will require cross-discipline collaboration across sciences, whereas both, interdisciplinary thinking and deep specific knowledge are required.

With today's societal, cultural, economic and environmental challenges, not only the natural sciences and STEM subjects (science, technology, engineering, mathematics) should be included in the creation of new solutions, but also the social sciences, humanities and the arts and design are required. Currently, those are often integrated either too early or too late in the technological development process.

Collaboration between technologists and social scientists and even artists is not straightforward and does not necessarily lead to better application of new technologies, but it might lead to the production of more inclusive and user-friendly research solutions regarding questions of ethics, gender equality, environmental responsibility or social justice. There must be a mixed set of scientists at the core to make the collaboration more productive. There have been good examples in education and the cultural sector. Possibly, social sciences humanities or arts should not only accompany technological development but address global challenges together and on an equal footing. There is also a responsibility of industry here, especially on the discussion of ethical aspects and customer acceptance of new technologies that must be integrated earlier. Financial incentives can be designed and implemented in Horizon Europe in order to improve the participation of scientists from different backgrounds and industries, taking into account not only the objectives of industry but also the societal or environments impacts.

Furthermore, a systemic innovation approach can take a set of aspects and disciplines into account from a holistic perspective by cross-connecting and analysing consequences to develop solutions, technologies and services that are both climate friendly and sustainable from the societal perspective while strengthening the competitiveness of European industry.

4.3 Public (financing and) procurement

Although industry is generally seen as a catalyst for applying innovations, an important role is envisaged for the public sector, for example to overcome market imperfections that are observed in – especially – the health system. Europe has arguably the best health system in the world, but a competitive market in this sector is not well regarded by the public. However, the public trust in the health system empowers research institutions to develop further in this field and here, public procurement can serve to initiate pioneering research.

Public procurement can therefore serve as an important tool by helping to transform (slow) needs to direct demand. Participants agreed that this opportunity should be further exploited in order to speed up the implementation and acceptation of new technologies.

Creating a more receptive culture around public procurement will improve the financial ecosystem of venture capitalists and other funding sources.

4.4 Legislation

Technologies such as gene therapy will have a profound impact on many societal challenges, such as (i) green industry (bacteria that produce bio-cement or that kill infections or plastics), (ii) sustainable food production (reduce our footprint while feeding more people, increasing animal welfare), (iii) photosynthesis (transform light into chemical energy used for fuelling the organisms' activities), and (iv) healthcare (lifesaving therapies with a completely new cost dimension that will reshape social health insurance).

We should be prepared to communicate to citizens with greater transparency about these societal and political challenges. For this, a holistic and strategic approach is required; taking into account the precautionary principle limiting the use of technologies where we do not fully understand their impact and that might be potentially harmful to human health or the environment.

More flexibility in EU legislation is proposed that provides scope for innovation and assures social acceptance. China and the US have a completely different approach to regulation in this field, which also leads to a clear dominance in patenting in these areas. For example, the US offers more freedom when developing new technologies but puts liability fully on the side on the owner of these new technologies, where incidents can lead to high costs due to lawsuits.

An often-mentioned problem in health research is the difficulty in performing clinical trials under the EU regulation, which makes companies move to other parts of the world. This is a potential problem for keeping and attracting research.

4.5 Leadership through purpose and scale

The big societal challenges and Sustainable Development Goals as defined by the UN are becoming more and more important for the main research and technology organisations in directing their focus and research efforts. Therefore, it is good news that the Horizon Europe Framework Programme is moving in the same direction.

The proposed road maps help to build capacity and engagement. However, at the same time we should make sure that technologies, such as key enabling technologies (KETs), are not hijacked for specific goals, but are allowed to be tested in different ‘silos’. The technology does not matter to the industry – it is the solution that matters. Therefore, sharing ideas, technologies and applications across industries and making knowledge available on a broad basis rather than patenting it too individually is needed in Europe.

Adequate platforms and sharing mechanisms require a new form of communication of ideas and technologies.

The EU Member States and the European Commission can play an important role in creating future demand, for example for clean energy, where there is a lack of economic incentives and the market for these technologies does not exist yet. Governments can coordinate this innovation process in unexplored areas by defining road maps in order to create sustainable European value chains and ecosystems, while systemic innovation can implement the breakthrough technologies in a long-term sustainable way.

At the same time, Europe needs big and ambitious goals, bringing together all necessary resources to reach the critical mass as pre-requisite for efficiency, inclusiveness and broad adoption. Precise timing is of less importance. Currently, many European attempts are rather focusing on incremental innovation rather than breakthrough technologies, which also relates to different technological levels in the member states. Therefore, European wide technological expertise must be established in certain deep tech fields. Are we not ambitious enough? Should we strive for carbon neutral industry by 2030 in order to reach enough scale for a thriving market? We can already build houses with CO2 neutral cement at just 2% additional costs as compared to the traditional cement. To summarise the message of some participants: stop talking and start building!

But is there a different approach needed with these big ambitions? All large companies in some of the future technologies (solar, photovoltaics, batteries and hydrogen) are Asian owned. It is of vital importance that Europe develops such technologies and produces tomorrow's companies that can market these technologies. Europe accommodates a dynamic start-up ecosystem, a set of high standard technology infrastructures, well-established and competitive SMEs networks, large international branded companies and an ambitious large framework programme for research and innovation. Start-ups can be accompanied by scale-ups and entrepreneurial initiatives in order to drive technologies with large requirements of resources. (Venture) capital is currently quite amply available in the EU for start-ups and they seem to be able to deliver the most advanced technological solutions to the grand challenges.

A special aspect in this context is to keep Europe’s strengths in the manufacturing sector. Strong research and innovation activities at home are necessary. Only being excellent in innovation makes it more likely to keep manufacturing within Europe. This ranges from very early and basic research up to more applied research.

European research institutes can also contribute to reaching this scale and obtaining efficiency gains by combining scanning and foresight activities by sharing the so-called long lists. Especially for the smaller EU Member States, collaboration is imperative and finding common goals and road maps and further down the road - understanding data and intermediate results – are crucial. Efforts to create a collaborative network that can facilitate such cooperation need to grow even further. Connecting the “dots” is the only viable way to amplify synergies across innovation value chains players and drive more impetus toward public (European Commission and EU Member States) and private (companies, funds) investment in innovation.

There is an important role here for the EU to fight the dogmas and beliefs that decide the pace of European research. This will be a difficult task, to balance between the highly appreciated democratic values and pluralistic approach within the EU and the more focused science-based approach of other societies.

Annex 1: Participants

Leaders workshop Horizon scanning – future technology for prosperity

Oslo 2-3 July 2019

Cecilia Bartolucci

Cecilia Bartolucci, is Coordinator within the "Science & Technology Foresight Project" of the National Research Council of Italy. She leads a team which, with the support of international experts, carries out initiatives in order to define research strategies able to address crucial social problems related to food, health, energy, water as well as the cross-sectoral topic of breakthrough innovative materials. She holds a PhD in Chemistry, has over 20 years of experience in biochemistry and medicinal chemistry research, and 8 years of experience in horizon scanning and interdisciplinary networking. She often acts as CNR representative at national and international working groups and events.

Alexandra Bech Gjørv

Alexandra Bech Gjørv has been President and CEO of SINTEF, the largest independent research institution in Scandinavia, since 2016. SINTEF is one of Europe's largest independent, applied research institutes, providing technological and social science expertise to promote innovation across a broad span of sectors in society. Gjørv has a long leadership career in Norsk Hydro and Equinor behind her spanning New Energy Solutions and Automotive, as well as serving as Executive Vice President of HR, HSE and CSR. She chairs the board of the Norwegian energy company Hafslund-Eco and has previously held non-executive board member positions in Technip SA in France, as well as the Norwegian companies Schibsted, Eidsiva (chair) and Norske Skog. Alexandra is a qualified lawyer and spent five years as a partner at the Law Firm Hjort. She chaired the government appointed 22. July Commission following the terrorist attacks on the Government center in Oslo and the massacre on the island of Utøya in 2011.

Rebekka Borsch

Rebekka Borsch was appointed State Secretary to the Minister of Research and Higher Education Iselin Nybø on 17 January 2018. She has worked as Senior Adviser at the Norwegian Environment Agency and as Head of Information at The European Movement Norway, as an International Consultant on EU Affair at Actis. She has been a member of several boards and committees, and has served as a Chair in Venstre's International Committee. She is skilled in Communication and media, politics, organisational and strategic work and public administration. Borsch has in-depth knowledge in the areas of: environmental protection, climate, European politics, European integration, human rights, German/Norwegian politics.

Sigrid Bratlie

Sigrid Bratlie is a Senior advisor at the Norwegian Biotechnology Advisory Board, where she closely follows the cutting edge of biotech R&D, in particular gene technologies such as CRISPR. One of her main activities is science communication and public dialogue with a focus on both scientific, ethical and societal aspects. She is also a primary resource on aspects concerning national and international biotech legislation and policy, in particular to the Norwegian government, and participates in several international policy forums. Sigrid is a molecular biologist by training, with a degree in Molecular Biology from the University of Glasgow and Imperial College London, UK, and a Phd from the Institute for Cancer Research at the Norwegian Radium Hospital for which she was awarded the Kings gold medal.

Martin Buncek

Marin Bruncek is managing director at Technology Agency of the Czech Republic. He graduated from University of Pardubice, Faculty of Chemical Technology. Completed postgraduate studies at the Pharmaceutical Faculty of Charles University in Hradec Kralové and work stay at IMM in Oxford and TUe Eindhoven. He held the managerial position in R&D of a biotech company. Principal investigator or co-worker of national and international (FP6, FP7 EU) projects. He lectured molecular biology and gene therapy at the University of Pardubice and at Charles University. Gained experience in the protection of R&D results (patents, etc.), application of R&D results in practice, but also purchasing and use of know-how, including the due-diligence. He is the author or co-author of scientific publications and patents. At this time, he is active in research and innovation policy, is an independent expert in Eurostars! programme and occasionally provides lectures.

Adrian Curaj

Professor Adrian Curaj, PhD, EMBA is the Chief Executive of the Agency for Higher Education, Science and Innovation Funding in Romania (UEFISCDI), the head of the UNESCO Chair on Science and Innovation Policies at the National University of Political Studies and Public Administration, and Professor at the *Politehnica* University of Bucharest - Department of Automatic Control and Computer Science. Adrian Curaj had been working as a consultant for the World Bank, UNESCO, UNIDO, ETF and EC for studies in Tertiary Education, Science and Innovation, and Foresight. He is member of the Board of Directors of the US Fulbright Commission in Romania and fellow of the World Academy of Art & Science (WAAS). Professor Curaj is the artisan of the smart territorial development project, *Laser Valley-Land of Lights*.

Kristin Danielsen

Kristin Danielsen is Executive director for the Division for International Cooperation at the Research Council of Norway. She has a doctoral degree in Animal Husbandry from the University of Kentucky and has six years' experience from industry before joining RCN. She has, before becoming Executive director, been Department Director for several different thematic fields within RCN including e.g. bioeconomy, biotechnology, commercialization, regional innovation. Kristin has been Chairwoman for both EUREKA and the Association of Innovation Agencies in Europe (Taftie). She has been a member of the governing boards of several European partnership programs and was part of the European Commission expert group evaluating the Joint Programming process. She is board member of the Nordic Research Council, member of the Fulbright board in Norway and board Member of the Swedish Agricultural University.

Piotr Dardzinski

Piotr Dardzinski is President of the Łukasiewicz Research Network. As Secretary of the State at the Ministry for Science and Higher Education responsible for the science-business cooperation, he had supervised inter-ministerial works on the first and second innovation act, which resulted in rising R&D tax breaks from 30% up to 100% or 150%, significantly improving R&D expenditures in Poland. Piotr Dardziński is also the creator of a law about Applied PhDs, which offers an opportunity to pursue scientific and business career at the same time. He graduated with honours from the Faculty of Law and Administration at the Jagiellonian University and studied at the University of Hamburg. He defended his PhD in economic doctrines at the Jagiellonian University. He was a scholarship holder at the University of Friborg in Switzerland He is a graduate of the managerial program at IESE Business School in Barcelona and is a lecturer at the Jagiellonian University since 1998.

Erik Drop

Erik Drop is Director Knowledge Programming and Government Relations at TNO (www.tno.nl), the Netherlands Organisation for Applied Scientific Research, responsible for TNO's science strategy, quality, and utilisation. Erik's core responsibility is to analyze and connect external and internal developments and allocate and control the government funding in TNO accordingly. Erik studied Public Administration with a financial-economic focus at the University of Leiden, and started working for TNO in 1994 He has been intensively involved in the design and implementation of the Dutch National Science and Innovation Agenda. Since 2017 Erik is, on behalf of the Netherlands, member of the Board of Governors of the Joint Research Centre of the European Commission.

Peter Dröll

Dr Peter Dröll is Director for Prosperity, Directorate-General Research and Innovation. Peter works in the Directorate-General for Research and Innovation and innovation since 2008, first in charge of innovation, since 2016 for Industrial Technologies. Previous positions in the Commission include financial control, environment policy and enlargement policy. From 2004-2008 he was Head of Cabinet of the Science and Research Commissioner Janez Potočnik. Peter is a lawyer by training with a doctorate degree in German constitutional law and European law

Anne Kjersti Fahlvik

Anne K Fahlvik is Executive Director for industries and technologies at the Research Council of Norway (RCN). She holds a PhD in pharmacology from University of Oslo and has 20 years of industrial experience from R&D and managerial positions in Nycomed Imaging (now GE Healthcare) in Norway and US and as CEO of an internationally VC-funded biosensor start-up. Fahlvik was Executive Director for strategic priorities, incl. areas as emerging technologies, resources based industries, climate, welfare and education, in 2006-11 and has broad experience in areas as strategy development, R&I analytics, R&I policy, evaluations, int. cooperation, regional development, life science and commercialisation.

Geir Førre

Geir Førre, Managing Partner at Firda AS, is a serial entrepreneur who founded and led Chipcon and Energy Mico, two successful Norwegian semiconductor companies from inception to exit. He was also the founding investor and Chariman of Prox Dynamics, who pioneered a whole new industry within Nano UAV helicopters.

Harry Heinzelmann

Dr. Harry Heinzelmann is CTO of CSEM, a Swiss Research and Technology Organization that is developing and transferring technologies to industry. He had joined CSEM to build up its Nanotechnology and Life Science division, which he led until 2014. Harry is member of the Executive Board of EARTO, the European Association of RTOs. Further appointments include board and advisory positions for companies and funding agencies. Harry is a physicist by training and an MAES graduate from the Europe Institute in Basel as well as an IEP alumnus from INSEAD in Fontainebleau, Paris.

Anna Hultin Stigenberg

Dr Anna Hultin Stigenberg is VP Strategic Research at RISE Research Institutes of Sweden, an innovation partner with 2,700 employees active in international collaboration with industry, academia and the public sector. She holds a Ph.D. in Materials science from KTH, Stockholm, and has also 30 years of industrial experience. A main thread in her career has been the interface between R&D and business side, mainly from various management positions at the global engineering company Sandvik. She has for many years been active in the Research and Innovation community and have experience from various roles in boards and steering committees, both on company level and for public funded research collaborations on both national and EU-level. Some current examples are chair of the Materials committee at the Swedish Foundation for Strategic Research (SSF), chair of Vinnova Competence Center FunMat at Linköping University and member of the EIT Raw Materials Executive Board in Berlin. She recently also took part in the European Commission High-Level Strategy Group on Key Enabling Technologies.

Jadran Lenarčič

Director of the J. Stefan Institute, Ljubljana, Slovenia. Prof. J. Lenarčič received B. Sc., M. Sc., and Ph. D. degrees from the University of Ljubljana, Slovenia. In 1985, he was appointed Head of the Robotics Laboratory and in 1995 Head of the Department of Automatics, Biocybernetics and Robotics of the J. Stefan Institute. In 2005 he was elected Director of the J. Stefan Institute and is currently in his third term. He is also full professor at the University of Ljubljana and collaborates on regular basis with the University of Bologna. Basic research interests of J. Lenarčič are in robotics, robot kinematics, bio-robotics and humanoid robotics. A significant part of his work is dedicated to the development of new technologies in robotics and automation and their transfer to industry. He is co-author and co-editor of a number international books on robotics and on robot kinematics. He is Full Member of the Slovenian Academy of Engineering (served also as President). He is Corresponding Member of the Accademia delle Scienze di Bologna. Prof. Lenarčič serves in national and international committees and boards.

Lars Montelius

Lars Montelius is the Director–General of the International Iberian Nanotechnology Laboratory since 2014. Professor in Nanotechnology at Lund University, Sweden, Lars Montelius is the founder of several Swedish companies working with nanotechnology. Lars Montelius is also the President of the IUVSTA: The International Union for Vacuum Science, Technique and Applications with more than 150 000 members from 32 countries, member of the EC Executive High Level Group (HLG) at DG NMPB, and board member and Working Group Chair of the two European Technology Platforms NANOFutures: The European initiative for sustainable development by Nanotechnologies and EuMat: The European Technology Platform for Advanced Engineering Materials and Technologies. Between 2003 and 2009, Lars Montelius was Dean of the Physics Department, Science and Engineering Faculties at Lund University and between 2009 and 2011, he was director for Øresund University & Øresund Science Region, a cross-border cooperation between eleven universities and three regional authorities of two countries in the Øresund Region. Lars Montelius was also Chair of the Swedish Technical Standardization Committee on Nanotechnology from 2007 to 2014.

Anton Plimon

Anton Plimon is the managing Director of AIT Austrian Institute of Technology, Vienna. He graduated at the Studies of technical physics at the Graz University of Technology.His career also include Managing Director at the Austrian Research Centers – ARC and arsenal research, Head of transport technologies division, arsenal research. He has been a member of several boards and steering commitees such as the board of the University of Applied Sciences Technikum Wien, the board of FORSCHUNG AUSTRIA, the Steering Committee and Executive Board of Austria Mobile Power – AMP, the Steering Committee of Austrian Traffic Telematic Cluster – ATTC, the Supervisory Board of Profactor GmbH and Member of the Research Council of Salzburg

Gearoid Mooney

Gearoid Mooney, BEng Electronic Engineering 1984, is Division Manager, Research & Innovation with Enterprise Ireland. He has held CTO and project management positions in Irish owned high-tech start-ups, is a member of IET and is a Chartered Engineer. He joined Enterprise Ireland's Technology Transfer and Business Partnership Programme in 1991. Since then he has been involved in every aspect of Technology Transfer and Business Partnerships, from client consulting through to partner identification and from technology identification through to negotiations. In 2004 he became Director of Enterprise Ireland's ICT research commercialisation function. In 2013 he became Division manager Research and innovation which extended his responsibilities to all technology domains and international innovation collaborations. Gearoid is a former board member at NDRC an early stage investor in tech companies. He is a board member at TAFTIE, The Association for Technology in Europe. His interests include: Competitive Intelligence, RD&I, Disruptive Technologies, Technology Transfer, Research Collaboration, Technology Partnerships, Entrepreneurship and the international development of Irish Owned Industry.

László Monostori

Prof. László Monostori is Director of the Research Institute on Computer Science and Control (SZTAKI) of the Hungarian Academy of Sciences, and full professor at Budapest University of Technology and Economics. He is President of the Industry 4.0 National Technology Platform, Hungary. He has held leading positions in the International Academy for Production Engineering (CIRP), the International Federation of Automatic Control (IFAC) and the International Measurement Confederation. He is member of the European Academy for Industrial Management (AIM). He is founding Editor-in-Chief of the CIRP Journal of Manufacturing Science and Technology and member of the editorial boards of numerous international scientific periodicals. For his research achievements he has been awarded numerous prizes. Prof. Monostori is member of the Hungarian Academy of Sciences, member of the Hungarian Academy of Engineering, member of the National Academy of Science and Engineering (acatech), and foreign member of the Royal Flemish Academy of Belgium for Science and the Arts (KVAB). He is Senior Advisor of the Fraunhofer Society for Hungary, and Director of the Centre of Excellence in Production Informatics and Control (EPIC).

Julian Müller

Julian M. Müller is professor for logistics and operations Management at Salzburg University of Applied Sciences. He holds a PhD from Friedrich-Alexander University Erlangen-Nürnberg. His research areas include Industry 4.0 with special regard to supply chain management, the integration of small and medium-sized enterprises, as well as business model innovation and sustainability.

Lesley Potters

Lesley Potters is an Economic Analyst at the Joint Research Centre of the European Commission where he has been working in different roles since 2005, mainly studying the micro-economic impact of R&D and innovation on firm performance and more recently on Global Value Chains, innovation ecosystems, R&D internationalisation and R&D location decisions. He is currently obtaining his PhD in Economics at the Utrecht School of Economics and has an MSc in Business Administration of the Erasmus University of Rotterdam. He has also worked at the Dutch Ministry of Finance as a senior policy advisor.

Mathias Rauch

Mathias Rauch is Head of Department European Research Area & Director of the Fraunhofer EU Office in Brussels. Mathias has been with Fraunhofer for 14 years in senior management positions. An economist by training, he has authored several research reports on R&I policy evaluation, the EU's R&I Framework Programmes and national incentive schemes for innovation and entrepreneurship. Mathias is a member of the UNECE's Team of Specialists on Innovation and Competitiveness Policies and has done consulting work with OECD, World Bank and EBRD. He also served as a Seconded National Expert with the European Commission and held a Jean Monnet Visiting Professorship for European Integration in Vancouver, Canada.

Irina Reyes

Irina REYES is the policy assistant to the Director for Prosperity at the European Commission Director General for Research and Innovation. Prior to assuming this position in April 2017, she worked on data-driven science, foresight and strategy. She has also worked in the Directorate General for Home Affairs in the areas of prevention and protection and at the Swedish Red Cross as Programme Manager for Migration and Humanitarian law. Irina holds an International Master's in Political Science from the Linnaeus University, Sweden. Current interests are cradle-to-cradle design, algorithmic bias and well-being based fiscal policies.

John-Arne Røttingen

Professor John-Arne Røttingen MD PhD MSc MPA is the Chief Executive of the Research Council of Norway and Adjunct Professor at the Department of Global Health and Population, Harvard T.H. Chan School of Public Health. He was the founding interim Chief Executive Officer of CEPI – Coalition for Epidemic Preparedness Innovations; Executive Director of Infection Control and Environmental Health at the Norwegian Institute of Public Health; and Professor of Health Policy at the Department of Health Management and Health Economics, Institute of Health and Society, University of Oslo.

Iñaki San Sebastian

Iñaki San Sebastian is CEO of Tecnalia Research & Innovation (ES). He obtained his master degree in Industrial Engineer from the University of Navarra in 1989. In 2007 he received a Master Degree in Business Management (MBA-Executive) at the University of Deusto and in 2015 a Master Senior Management Program (PADE) by IESE Business School. After working for 16 years for Fatronik. In 2011, he was appointed Deputy Managing Director of TECNALIA, result of the merging of 8 Technological Centers. In March 2016, he was appointed CEO of TECNALIA. He has belonged to several relevant national and international committees related to the design and strategy of Science and Technology Systems, such as the High Level Strategy Group on Industrial Technologies. He is currently Vicechairman of EARTO (European Association of Research and Technology Organisations). He is also Chairman of EUROTECH Think-Tank (a high level think-tank composed by the CEOs of the 10 largest RTOs having a key role at national level) He is member of the Board of Directors of several spin-offs and participates in several clusters and business associations as member of the executive boards.

Erik Sauar

Erik Sauar, Cenate AS, is an experienced international executive and company founder with a proven track record in taking products and innovation from the initial concept phase through technology development, organizational development and to the market. Founder of one of the companies that later formed REC and thereafter CTO of REC from 2001-2012. Formal background from the field of physical chemistry, engineering and anthropology combined with broad international technology development and business experience including also finance, sales and M&A. Enjoy working in and with organizations that target rapid growth in a global market. Active seed investor in early stage companies. Focus on solar energy and battery technology based industry and development. Special attention through Differ on the 1-2 billion people with limited access to energy. Also motivated by other developments with large potential impact on the society we live in.

Doris Schröcker

Doris Schröcker is heading the Unit for Industrial R&I Agendas and Business Intelligence in Directorate General Research and Innovation in the European Commission. Her background is business administration with marketing and industrial management, and she has worked in different positions in EU R&I policy and programme management in the European Commission (mobility/transport and energy, industrial and key enabling technologies).

Stéphane Siebert

Stéphane Siebert graduated from Ecole Centrale de Paris. He obtained his PhD in Nuclear Chemistry. In 1989, he was a co-founder of CORYS, a spin-off company from CEA. He was deputy director-general for operations until 1995. Dr. Siebert initiated a large number of projects with the EC regarding nuclear power safety in Eastern Europe providing advanced training tools to Nuclear Power Plants in Russia, Ukraine, Czech Rep, Slovakia, Hungary, Bulgaria for VVER and RBMK reactors. Dr. Siebert subsequently was headhunted for the post of general manager of Grenoble city services. where he managed numerous ambitious projects in the field of smart cities. Grenoble was selected by the EC as one of three European finalists in the innovation capital competition. Dr. Siebert was also a member of the Board of the GEG Energy company. In 2013 he became Director for strategic projects and since 2016 CEO of the Technological Research Division at CEA (CEA Tech). CEA Tech is active in approximately 220 European projects per year and, has R&D technology partnerships with 11 of the world top 50 largest companies. In his capacity of CEO of CEATech, Dr. Siebert is in charge of conducting CEA Innovation strategy, responsible for tech transfer, start-ups creation and partnerships with companies.

Axel Steuwer

Dr Axel Steuwer is the Director for Science Support Services at the University of Malta. After graduating with a PhD in Materials Science from the University of Cambridge, he has been working in the centre of the quadruple helix bridging science, large scale research infrastructure, public authorities & industry for the last two decades.

Elisabeth Støle

Elisabeth Støle is CEO/Managing Director NORCE Norwegian Research Centre AS. She has 27 years of international executive management and non-executive board experience, developing and restructuring both public and private companies. leading non-profit research and innovation institutions, including commercial subsidiaries and merging and restructuring companies, In 2008 she was Senior Vice President Corporate Development/Communication SafeRoad Group. In 2013 she was CEO and Managing Director Møreforsking AS, responsible for Strategy, Communication, HR, HSE. Elisabeth has a wide public and industry network. and serves in several national committees and boards.

Dirk Torfs

Dr.ir. Dirk Torfs is CEO of Flanders Make vzw, the Flemish strategic research center for the manufacturing industry. Since 2014 he managed to start up the strategic research center by merging two knowledge centers with selected academic research groups of all 5 universities. He manages the non-profit organisation with 500 researchers of which 100 researchers on the payroll and coordinates about 400 researchers as virtual organisation. In about 5 years about 200M€ of innovation projects have been defined and started, of which about 10% are infrastructure related projects. Dirk participates in the board of directors of several innovation cluster organisations. Dirk Torfs has about 30 years of management expertise, before Flanders Make he was a general manager in several industrial companies, TRASYS, GLE, ABB and IMTECH. He is a mechanical engineer and received his PhD from KULeuven, Belgium. He is also an executive professor in the MBA program of Flanders Business School.

Frank Treppe

Prof. Dipl.-Ing. Frank Treppe, Managing Director Science Policy and International Affairs Fraunhofer-Gesellschaft, Munich. Prof. Frank Treppe graduated from the Technical University (RWTH) in Aachen, Germany, in mechanical engineering. His professional career started in 1982 at the Fraunhofer Institute for Production Technology in Aachen. He is an Associate Member of the Board and Managing Director Science Policy and International Affairs of Fraunhofer-Gesellschaft in Munich. He is in charge of Fraunhofer's international strategic business development. Moreover, he has a wide range of domestic and international responsibilities like Member of the Supervisory Board of Fraunhofer Austria and Fraunhofer Sweden. In addition, Prof. Treppe is Past President of EARTO, the European Association of Research and Technology Organizations, and he serves as evaluator in the technology programmes of the European Commission.

Antti Vasara

Dr. Antti Vasara is the President & CEO of VTT Ltd since 2015. VTT is a visionary research, development and innovation partner with over 2000 people and turnover exceeding 250 MEUR. He is president of EARTO (European Association of Research and Technology Organisations) and chairman of the board of Palta (Finnish Service Sector Employers). In addition, he is a non-executive director of Elisa Oyj (largest communications operator in Finland) and a board member at EK (Finnish confederation of Industries). He has served on several high-level groups on industrial and innovation policy of the European Commission in addition to several groups in Finland on artificial intelligence and research policy. Previously, he has worked in the private industry for close to 25 years at Nokia, Tieto, SmartTrust and McKinsey & Company. Earlier in his career, he was a researcher in optical communications with 20+ peer reviewed articles and one international patent. Dr. Vasara holds a Doctor of Science (Technology) degree from Aalto University in Finland.

Sophie Viscido

Sophie Viscido is Senior Policy Officer at EARTO, the European Association representing over 350 Research and Technology Organisations (RTOs) in Europe. She joined EARTO in 2015 and has since been in charge of EU Research and Innovation policies and funding programmes, including legal and financial framework conditions and impact. Prior to working at EARTO, she covered policy issues for CEDR, the Conference of European Directors of Roads, and FEHRL, the Forum of European National Highway Research Laboratories. Sophie Viscido has also conducted studies and analysis on EU funding programmes for the European Departments of IFSTTAR, a French RTO in the Transport sector, and of the Rhone-Alpes Region in France. She is a French national, graduated in EU Affairs and Public Policies and she has a Master Degree in Economics with a European focus.

Zoë Webster

Zoë is Director of AI and Data Economy at Innovate UK. She also has responsibility for Innovate UK's Horizon Scanning Unit. Zoë joined Technology Strategy Board in 2007 with a focus on innovation in Information and Communication Technology. Since then, she has held the roles of Head of Enabling Technologies, Head of High Value Manufacturing, Head of Resource Portfolio and Deputy Director – Strategy. Zoë has a computer science background and a PhD in artificial intelligence. Prior to joining Innovate UK, she worked QinetiQ and SEA researching, developing and demonstrating machine learning and information filtering algorithms for a range of applications including health and retail.

Aziz Zenasni

Dr. Aziz Zenasni is Director of Innovation Programs and member of the executive committee at the Luxembourg Institute of Science and Technology (LIST). He is also managing Corporate European and International affairs. He holds a Ph.D. in plasma physics and HDR in materials science (Habilitation à Diriger des Recherches). He was European affairs Manager and held several managerial positions across R&D at CEA Tech in France. He was principal coordinator or co-worker of national and international (ANR, FP7, MEDEA+, Horizon 2020 EU) projects and acted as Secretary General of the European Commission High Level Group on Key Enabling Technologies (KETs) from 2012 to 2015 dealing with innovation and industrial policies. He is a member of several scientific advisory boards and experts for national and European innovation agencies. Dr Zenasni is a board member of the European association of Research and Technology Organisation (EARTO), founder and board member of the Luxembourg Arab business association, member of the expert working group of the European Commission on Digital Innovation Hub, and member of the Institut de la Grande Region.

Annex 2: Programme

Leaders workshop 2-3 July 2019

Programme- 2 July

14.00 Welcome – John-Arne Røttingen and Peter Dröll

14.15 Opening session- Rebekka Borsch, Ministry of Education and Research

- Key notes from Geir Førre and Erik Sauar (Norwegian venture capitalist)
- Sigrid Bratlie, The Norwegian Biotechnology Advisory Board

15.15 First round of presentations and discussion

- Frank Treppe, Fraunhofer-Gesellschaft (DE)
- László Monostori, Hungarian Academy of Sciences, Research Institute for Computer Science and Automation
- Iñaki San Sebastian, Tecnalia (ES)
- Piotr Dardzinski, Centrum Lukasiewicz (PL)

16.30 Second round of presentations and discussion

- Anna Hultin Stigenberg, RISE (SE)
- Antti Vasara, VTT (FI)
- Alexandra Bech Gjørv, Sintef (NO)
- Axel Steuwer, University of Malta (MT)
- Stéphane Siebert, CEA Tech (FR)
- Lars Montelius, INL-International Iberian Nanotechnology (PT)

18.00 End of first day

The Research Council of Norway

Programme – 3 July

09.00 Wrap up first day: John-Arne Røttingen and Peter Dröll

09.20 Third round of presentations and discussion

- Harry Heinzelman, CSEM (CH)
- Gearoid Mooney, Enterprise Ireland (IR)
- Dirk Torfs, Flanders Make (BE)
- Anton Plimon, AIT, (AT)
- Jadran Lenarčič, Jozef Stefan Institute (SI)
- Zoë Webster, Innovate UK (UK)

10.50 Coffee

11.10 Forth round of presentations and discussion

- Elisabeth Støle, NORCE (NO)
- Aziz Zenansi, LIST, (LU)
- Adrian Curaj, UEFISCDI (RO)
- Martin Buncek, Technology Agency of the Czech Republic (CZ)
- Erik Drop, TNO (NL)

- 12.30 Conclusions
- 13.00 Lunch

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What are the next emerging technologies in which European industry should invest in? That was the key question of the workshop "Future technology for prosperity - Horizon Scanning, gathering leading figures of Europe's research and technology institutes in Oslo on 2-3 of July 2019.

This publication takes stock of the key recommendations from this workshop and presents five technological frameworks that have potential to create economic and societal prosperity: Biological Transformation, Smart Materials, Low Energy Data Transmission, Power to X and Marine Technologies.

The workshop also looked at methods to do technology horizon scanning, collaboration and technology transfer and put forward recommendations to national and European policymakers about technology investments from non-EU countries, ethics and social science, use of innovative procurement, legislation and leadership through purpose and scale.

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