FORGING

INDUSTRY-ACADEMIA FORUM
TO UNCOVER THE POTENTIAL OF
EMERGING ENABLING TECHNOLOGIES

# Emerging technologies for a changing world

## Narrating imaginaries for societal change


VTT



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| This report provides a collection of societal challenges, risks and opportunities related to the six technology frameworks analyzed in FORGING. The FORGING foresight process is introduced, with an overview of futures thinking, presentation of the methodology, and key results in the form of collected signals in the society-technology nexus (i.e. megatrends, trends and weak signals), insights from interviews with technology framework experts, and analytical mind maps derived from futures workshops. The report closes with a synthesis of societal concerns cutting across FORGING's six technology frameworks. |


| Keywords |
|---|
| Foresight, futures studies, images of the future, narrative foresight |

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# 1. Introduction

Attention to hopes, fears and concerns at the early stages of technology development helps find the key points where technology development needs to focus on to ensure responsibility. Early-stage technologies cannot be developed in isolation from society as there will inevitably be social impacts, even if the technologies are first introduced in industry. Therefore, it is important to think about the social impacts at the stages where they can still be influenced.

This report provides a collection of societal challenges, risks and opportunities related to the six technology frameworks, as defined in the "Industry 5.0 Policy Brief" released by the EC in January 2021[1]:

1) Human-centric solutions and human-machine-interaction
2) Bio-inspired technologies and smart materials
3) Real time-based digital twins and simulation
4) Cyber safe data transmission, storage, and analysis technologies
5) Artificial Intelligence
6) Technologies for energy efficiency and trustworthy autonomy.

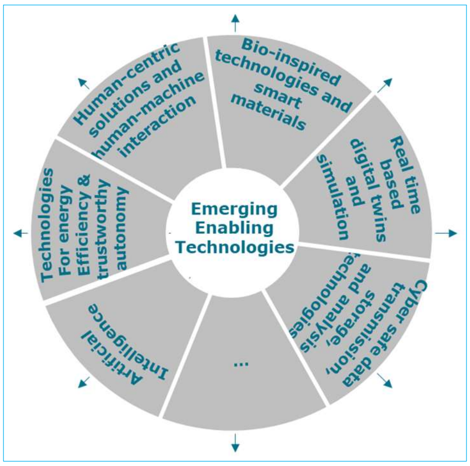


*Figure 1: Technological frameworks supporting the industry 5.0 paradigm.*

The insights presented in this report are derived from a close collaboration with technology experts, from interviews and workshop activities.

The complexity surrounding transition to the deployment of the technological frames under analysis in FORGING, required a scenario methodology specifically designed to explore the sociotechnical and long-term nature of the transition pathways. The development of sociotechnical scenarios enabled an identification of the critical factors impacting the transition in terms of development uses and options, and how they might affect and be affected by the behaviour and practices of various stakeholders. The approach transcends an understanding of the technological frames exclusively as technical systems that revolve around artefacts, and brings centre-stage an understanding of how the technological frames are embedded within social, political and economic dimensions (Savaget et al., 2019; De Haan et al., 2014).

In that sense, the development of sociotechnical scenarios operated as a sensemaking exercise of the driving forces and promising combinations, emerges from the intersection of the technology frames with societal, economic, political and institutional trends. As a consequence, the sociotechnical scenarios developed should not be read as predictions, and rather as stakeholder-based narratives embodying broader perspectives (Fortes et al., 2015), and operationalising a creative way of thinking about the future that takes stock of key issues and tacit assumptions that would otherwise not be identified (Weimer-Jehle et al., 2020).

[1] Industry 5.0 - Towards a sustainable, human-centric and resilient European industry

In this report we will introduce the FORGING foresight process, with an introduction to futures thinking, presentation of the methodology, and key results obtained to date. Some of the main results, such as the narratives and futures images, will be reported separately in a refined and visualized form so that they will be accessible to both the FORGING FORUM members and the wider public.

## 1.1 Understanding societal change

Knowledge of potential futures is visionary knowledge that combines knowledge of the present, interpretive knowledge of the past, with a creative ability, daring and imagination (Malaska & Holstius, 2009). While we can know the past through our memories, and through tacit knowledge in the form of written accounts and artefacts, and the present is accessible to us through our sensory perception, futures as such do not yet exist. However, it has been argued that futures thinking may be the most important evolutionary driver for our memory systems, language and to a degree even our senses: they exist to enable our futures thinking (Suddendorf & Corballis, 1997). In this sense, we can have futures related knowledge in the form of our expectations, fears, hopes, and presumed probabilities for future events that all have an impact on our actions in the present.

Futures studies as a social science dedicated to understanding change in the present for the purpose of preparing for alternative futures is a relatively novel field. From its conception, the aims of the field have included fostering peace, conserving nature, stabilizing population growth, promoting democratization, and eliminating hunger, poverty and exploitation through engaging in forward-looking thinking (Bell, 1996, Poli, 2017, Malaska & Virtanen, 2009).

There are many varieties to how futures studies can be approached in practice. Yet, there are some fundamental assumptions that unite most approaches. Roy Amara (1981), an American futurist, has formulated these into three principles for studies of the future. They are: 1) The future cannot be predicted: we can only formulate images and conceptions of possible futures. 2) The future is not pre-determined: we can assess probabilities of potential futures, and 3) Actions and choices have an effect on the future outcomes: therefore, it is important to assess the possibility and probability of different kinds of futures, but also to discuss the preferability of different options. (Amara, 1981).

When thinking about future, it is typical to approach it through a projection of a linear view from the present to one particular future. However, for the purpose of analysing future in a more analytical way, it is essential to understand the possibility of different outcomes that may result from the present-day events, trends and decisions. Thus, there is a convention to refer to futures in a plural to remind of the importance of maintaining alternative future possibilities in mind when considering futures. At the heart of scenario thinking is this plurality, a fan of possible futures that make up the mental space for futures thinking (Jouvenel, 1967). A *futures cone* (Voros 2017) is an illustration of aspects of futures that draws attention to our tendency to only consider future possibilities that from today's perspective seem probable or at least plausible. Yet, often the significant changes in the world requiring our attention are those that do not fall into either category. Therefore, in foresight the aim is typically to tease out ideas that seem implausible, sometimes even impossible, because they hit our core beliefs regarding possibility and probability. An eminent futures scholar James Dator (2019) has formulated this thought into his "Second Law of the Future". It states that any useful idea about the future should appear ridiculous. This approach of encouraging free thinking in an atmosphere that is accepting of novel and unconventional ideas is at the core of all foresight work.

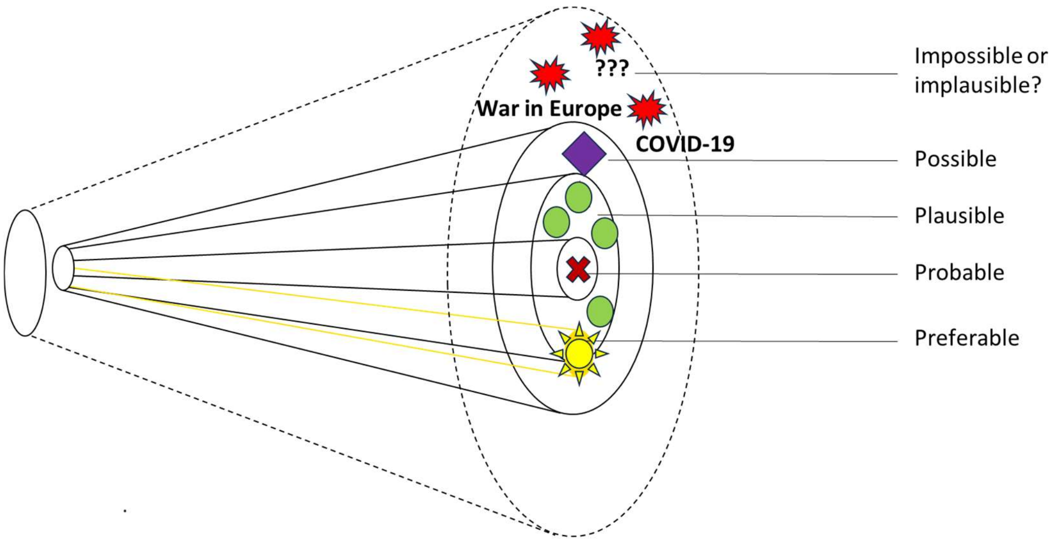



*Figure 2. The futures cone*

## 1.2 Horizon scanning as an approach for identifying change

When analyzing the history and trajectories of new ideas, it has been found that novelties emerge from the fringes of society, and surface typically first in art and basic research (e.g. Hiltunen, 2008. See also figure 3). Horizon scanning refers to a method and practice of uncovering novelties from various sources for the purpose of deriving insights on potential change.  A widely used definition of horizon scanning defines horizon scanning as follows:

*Horizon Scanning means the systematic outlook to detect early signs of potentially important developments. These can be weak (or early) signals, trends, wild cards or other developments, persistent problems, risks and threats, including matters at the margins of current thinking that challenge past assumptions. Horizon Scanning can be completely explorative and open or be a limited search for information in a specific field based on the objectives of the respective projects or tasks. It seeks to determine what is constant, what may change, and what is* *constantly changing in the time horizon under analysis. A set of criteria is used in the searching and / or filtering process. The time horizon can be short-, medium- or long-term.* (Fraunhofer 2015)

In the FORGING-process we engaged experts with deep knowledge of the cutting edge of research in each technology framework for identifying elements for potential futures. We combined to this deep technological expertise broader generalist views in order to co-identify those present-day signals and inform the creation of futures images.

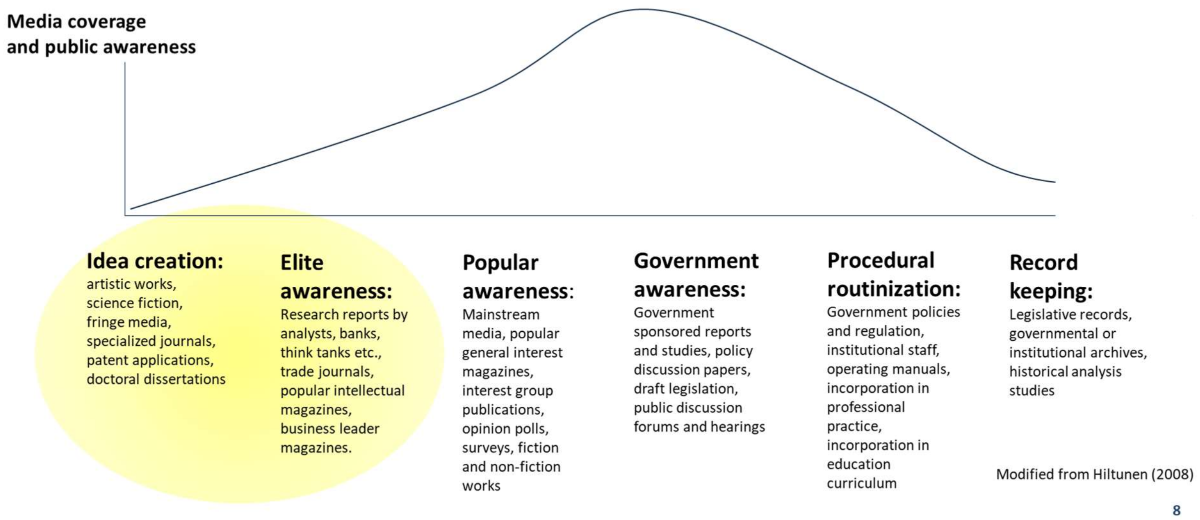



*Figure 3. Development of awareness of novel ideas*

## 1.3 Concepts for analyzing change

In gathering understanding about drivers for alternative futures, it helps to distinguish between key categories of change factors. A typical way to cluster change signals is to divide them by their observed magnitude.

A **Megatrend** is a recognizable and coherent *global* set of interlinking phenomena, that has a history and direction of development. Understanding this direction requires focusing on the whole megatrend, as it cannot be understood by only examining its individual parts. A megatrend includes several different and even contradictory sub-phenomena and chains of events ("Trends"). Typical examples of megatrends include climate change and globalization.

A **trend** means a continuation of a past development, for example it can refer to a linear development that can be identified in existing data. Trends have a foreseeable direction. Trends are typically more local than megatrends, and their temporal length is also more restricted.

**Weak signal** is a phenomenon or incident which does not necessarily seem important as it happens. They are subjective, so depending on the observer and context, different things may be identified as weak signals. Weak signals are of interest in foresight as they may be the first manifestation of a change, or it can be a trigger that re-directs the course of events. Weak signals are difficult to verify objectively as weak signals, but for instance observing a cluster of atypical phenomena around a common theme may make weak signal analysis more robust.

## 1.4 Role of foresight in FORGING and structure of the report

A key aim in the FORGING project is to explore the desirability, societal impact and implications of novel technologies. The collected aspects of societal development are considered in the project's later phases when co-creating technological solutions and their short and long-term impact. The plurality of potential future directions help in drawing attention to the social shaping of technology development and avoiding narrow visions for the future.

In this report we present the methodology applied in foresight work and introduce key findings from the different phases of the foresight process. In conclusion we reflect on the insights from the process that connect the six frameworks.

# 2. Methodology

## 2.1 Horizon scanning

Horizon scanning in foresight refers to the examination and understanding of changes in phenomena from a holistic perspective of the various future consequences of events, decisions and choices from a holistic perspective. It includes forming an understanding of macrolevel global developments, but also a systematic outlook to detect early signs of potentially important developments. These can be weak (or early) signals, trends, wild cards or other developments, persistent problems, risks and threats, including matters at the margins of current thinking that challenge past assumptions.

In the FORGING foresight process we have collected change signals in expert interviews (N=8) and through the FORGING scenario workshops (a total of 61 technology experts participated in the workshop) and a desk study on emerging issues. The signals collected were both technology specific, and more general level societal trends.

The **signals were discussed and co-created at the futures workshop, where they functioned as basis for the co-creation of images of the future.**

## 2.2 PESTEC

PESTEL framework is a corporate foresight method that examines the political, economic, social, technological, ecological and cultural state and future of a phenomenon or organisation (Aguilar 1967). In this project PESTEC was used as an organizing structure for the co-creation of futures images in the expert workshops.

## 2.3 Futures workshops

Future workshop is a classical method for visionary foresight. The original Future Workshop was developed by Robert Jungk in the 1950s as a tool for democratic grassroots advocacy (Jungk & Müllert, 1987). Its aim is to elicit enriching and new perspectives on the future by breaking away from conventional thinking and preconceptions. The Future Workshop typically aims to engage a diverse range of participants for orienting towards the future, exploring future options and exploring the alternatives for futures.

Several variations of the Futures workshopping method have been developed. In the FORGING project that aims to understand how emerging technologies impact societies on a long time perspective, we have engaged especially experts who have a deep understanding of the technologies that make up the emerging technological framework. In addition, we have invited people who combine to the technological expertise a more general ability to connect the technological developments to the societal context.

The multidisciplinary futures workshops were structured to focus on building understanding of the opportunities and threats of each emerging enabling technology framework. The workshop participants had two days to engage in a futures thinking exercise, where they first were exposed to an orientation session on basics of futures thinking. The futures workshop kicked off with a horizon scanning session, where the experts identified megatrends, trends, and weak signals in the present with a connection to developing technology frameworks. They then used these signals of change to compile an image of the future as an extension of the signals they had gathered towards 2050. The last exercise took them to write a narrative from the perspective of an individual, proceeding through exposition, conflict and climax to falling action and resolution.

The work was done in small groups of 5-7 experts, where each group was given a theme for their image of the future. These themes were borrowed from Jim Dator's four scenario archetypes (Dator, 2009) and were termed continued *growth, collapse, discipline*, and *technological transformation*.

Each of the images is a typical narrative for a certain kind of future, where **Continued growth** projects a (typically positive image) of a future where the ideal of economic growth is the most important value in ensuring a well-functioning society. **Collapse**, as its name implies, depicts a situation where an internal or external change leads the society to return to a significantly less developed form, or to face a complete destruction. Collapse should not be viewed necessarily as a negative future, as it may also be viewed as an enabler of renewal. **Discipline** is a narrative that emphasizes the required systemic changes for preserving well-being. There, the economy and the society refocus on survival, fair distribution, and the preservation of important places, processes and values that are felt to be threatened. Finally, the **technological transformation** is a narrative for fantastic, utopian or dystopian futures where technology transforms all life, including humanity, from its present form into a new "posthuman" phase. Used as a methodological approach, the four archetypes aim to frame the futures thinking towards different narratives with distinct viewpoints from which to investigate for instance the impacts of technology on a society as in this workshop.

## 2.4 Semi-structured interviews

Semi-structured interviews are a way to systematically collect informants' views on the research topic, following a pre-meditated interview guide outlining the questions and topics that need to be covered. There is an order in which the questions ideally are posed, but the interviewer can make detours if the conversation leads to other topics the interviewer judges relevant for the research. (e.g. Koskinen, Alasuutari & Peltonen, 2005). Interviews in this research were used as a method for gathering in-depth information from technology experts to provide background information for the futures workshops. Theme interviews focused on key emerging issues in each technology framework. All interviews were recorded either by researcher notes or by technical recording, and analysed with qualitative content analysis methods (Krippendorff, 2004; Alvesson, 2011). The interviews produced key insights on the technology frameworks.

# 2.5 Images of the future and narratives

it can be argued that it is characteristic for humans to want to know about the future by developing imaginaries about the future. Such thinking may be conscious, or it can be an unconscious process. An image of the future is a concept originally proposed by a pioneering futures scholar Fred Polak in his book “The Image of the Future” (1973). His main argument was that images of the future, either socially shared, or personal, are a key driver in social change. According to Bell (1996) and image of the future is a bundle of concepts, values, and aspirations that address the future in the mind of an individual. Therefore, if one is to understand the directions for the future, one needs to study the images of the future affecting the actions and goals of individuals (Bell, 1996, see also Aligica, 2011). The concept of image of the future has been turned futures research method by Anita Rubin (2000), and we used it as part of the FORGING futures workshops.

In the futures workshops, the experts were asked to imagine the future states of the selected signals in their given scenario archetype in 2050. The group wrote their descriptions on post-its, and based on discussing the descriptions they formed a short description for each PESTEC category. The final descriptions were written on post-its in the futures table.

Based on these PESTEC descriptions of future states, the experts were asked to co-write a description of the world in 2050. The experts were also asked to name their future image. This futures image acted as the context for a narrative describing a day in 2050, where the events would unfold in context of the world described by the future image. Milojevic and Inayatullah (2015) define narrative foresight as an exploration of the worldviews and myths that underlie our understanding of futures. Narrating for the futures requires typically a transformation of current narratives, thus exposing valuations and critique for the existing narratives. In the FORGING project we used co-created narratives as the main vehicle for communicating the workshop results.

The experts were asked to describe their main character (the experts were informed of a possibility to include also non-human protagonists) and narrate the day. For the narration, experts were prompted to utilize Freytag’s narrative writing model (figure 4). The experts were asked to present their narrative by using any form of expression (examples provided included role play, musical, poem, and audio drama).

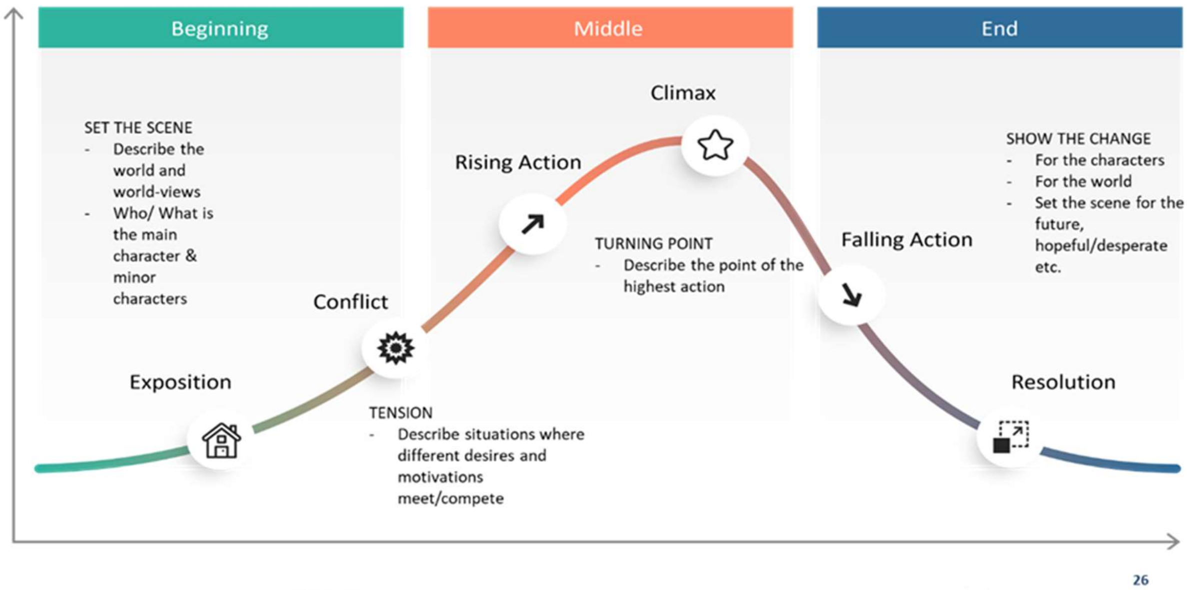



*Figure 4. Freytag's narrative writing model*

The resulting narratives were disseminated to the participants for reflection, and will be used in the later phases of the project in a visualized form to prompt consideration of possible futures as a basis for value-sensitive technology development.

# 3. Results

## 3.1 Horizon scanning results

In Figure 5. we present the collected signals in the society-technology nexus. The signals are divided into megatrends, presented at the core of the image, and trends and weak signals, at the periphery. The signals are color coded according to the technology framework, as we group them here by the framework under which they were presented. The signals may be technology specific, or more general level societal phenomena.

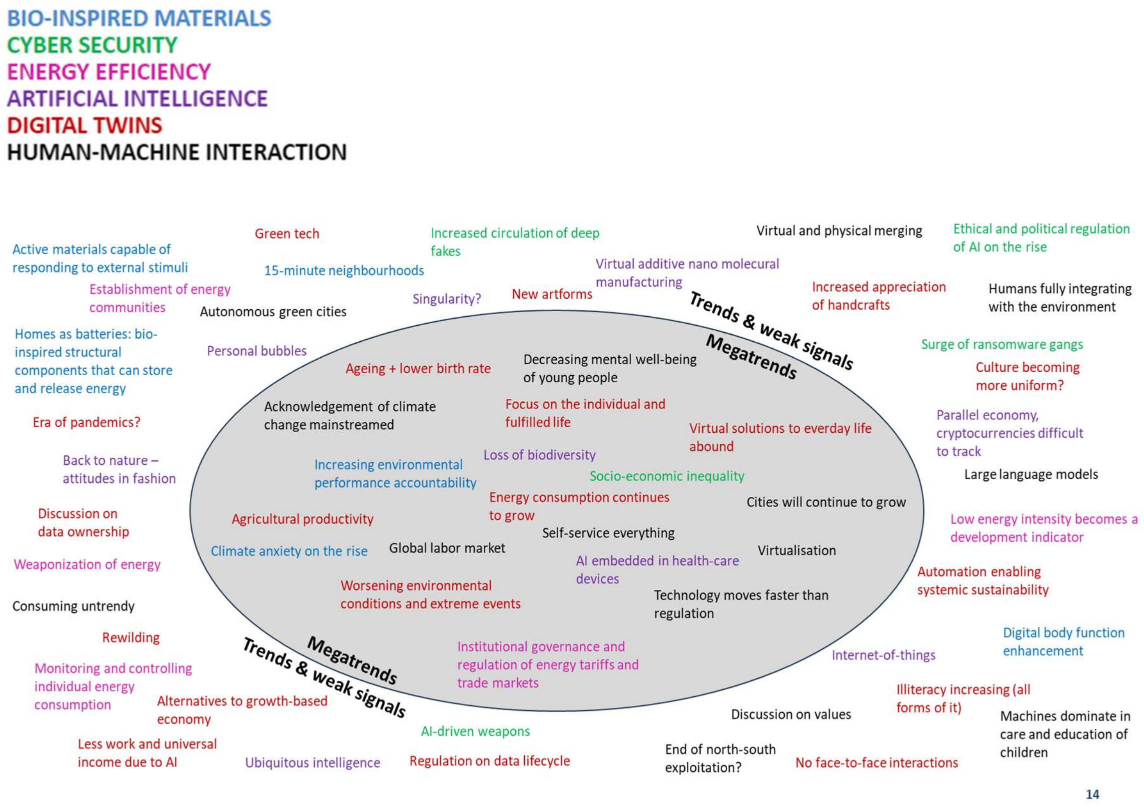



*Figure 5. Signals of change*

## 3.2 Insights from expert interviews

In this chapter we present a summary of insights from the technology framework expert interviews, conducted in order to gather background information for the design of the futures workshops.

**Artificial Intelligence**

Artificial Intelligence is a vast framework consisting of different technologies in the software sector, and defining AI in an all-compassing way might not even be possible.
This problem of definition expands into difficulties to impose meaningful regulation: as the same functions can be achieved by AI, by human intelligence, or by other methods, the question becomes if we should we regulate the use of AI or the various functions it enables? Currently AI is recognised as a special technology framework that requires regulation in the EU level, and an AI act is currently under preparations (in spring 2023. At the time of writing the report, process of finalizing the principles and standards governing companies' approach to AI development in the EU under the AI Act is ongoing).

Artificial intelligence and automatization have taken huge leaps in the past years, and often these have not received as much attention as they might have deserved. For instance the transformation of social media as AI powered algorythms have become common.
AI might be becoming business as usual in many fields: in technological sector, AI might not even be a revolutionary technology anymore, changes in professions or loss of jobs caused by it are not discussed as much now as they were a few years back.

**Human-centric solutions and human-machine-interaction**

A growing concern for the future, but already an existing issue regarding human-machine interaction is the black box effect: users of technology, including workers in industry, do not necessarily have any understanding of the working principles of the technology they are using. This is amplified by additional layers of technology, e.g. artificial intelligence, in the implementation of technological functions. As these, for an average user, are difficult to understand, a so called double black box effect is likely to be created.

Networked models are becoming more common, enabling locate-independent remote controlling and monitoring of systems. This might reduce the number of people with technological knowledge working on-site in factories.

Overall, the role of workers in industry is undergoing a change: due to technological advancements, the needs will shift from skills to tools for carrying out the implementation in factories.

**Cyber safe data transmission, storage, and analysis technologies**

Due to increasing digitalization, and a move to online platforms, the possibilities of cyber-attacks are on the rise. Therefore, the future of cybersecurity lies in preparing for the threats that a more comprehensive digitalization may bring about.

Cybersecurity is currently developed mostly in the private sector, where there currently are two focus areas: quantum safe encryption methods and data storage, and artificial intelligence, which can be used both for and against cybersecurity.

**Real time-based digital twins and simulation**

Originally a digital twin has referred to a precise representation of a real process or factory line, where the output is identical to the original.

At present, the word digital twin can also be used for any representation that shares properties with the original, and collects information from many sources (e.g. a digital twin of a city). The next step in development will be to simulate the development of complex systems over long time period (e.g. digital twin of a ecosystem): what happens in the market, in regulation, or in human behaviour.

Often it is beneficial to have humans involved in designing digital twins, as the use of artificial intelligence might be very energy intensive. (Humans know that water flows. The AI has to find the laws of physics itself.) As digital twins become more common, they may pose threats to cybersecurity. When a large amount of information is collected to one digital location, it can be an appealing target for cyber-attacks.

**Technologies for energy efficiency and trustworthy autonomy**

Energy efficiency is both about the development of more efficient technologies, and about using the existing technologies more efficiently.

Currently, producing renewable energy is less energy efficient compared to fossil fuels in the sense that more primary energy is needed to produce the same amount of electricity. This is something that improving the technologies could have a potential to change.

There are three important focus areas in the development, at the moment:

- Industrial sector, which is very energy intensive, even if using renewable energy sources.
- Transport sector, which is already quite energy efficient, and where technologies are improving all the time.
- Building sector, where insulation, materials used and heating methods, among other things, play a crucial role on improving energy efficiency.

In addition, the energy intensity of growing data use is widely discussed at the moment.

**Bio-inspired technologies and smart materials**

Currently, developing a sustainable production process is a hot research topic. Aim is to be able to produce a closed process (that however uses e.g. water) that aims to work naturally, so that nothing is wasted. Bio-inspiration means mimicking natural processes, assembling mechanisms from nature, and modifying micro-organisms.

For instance, VTT has a process to turn food industry waste stream that previously was incinerated, into fiber for insulation with the use of certain yeast strains.

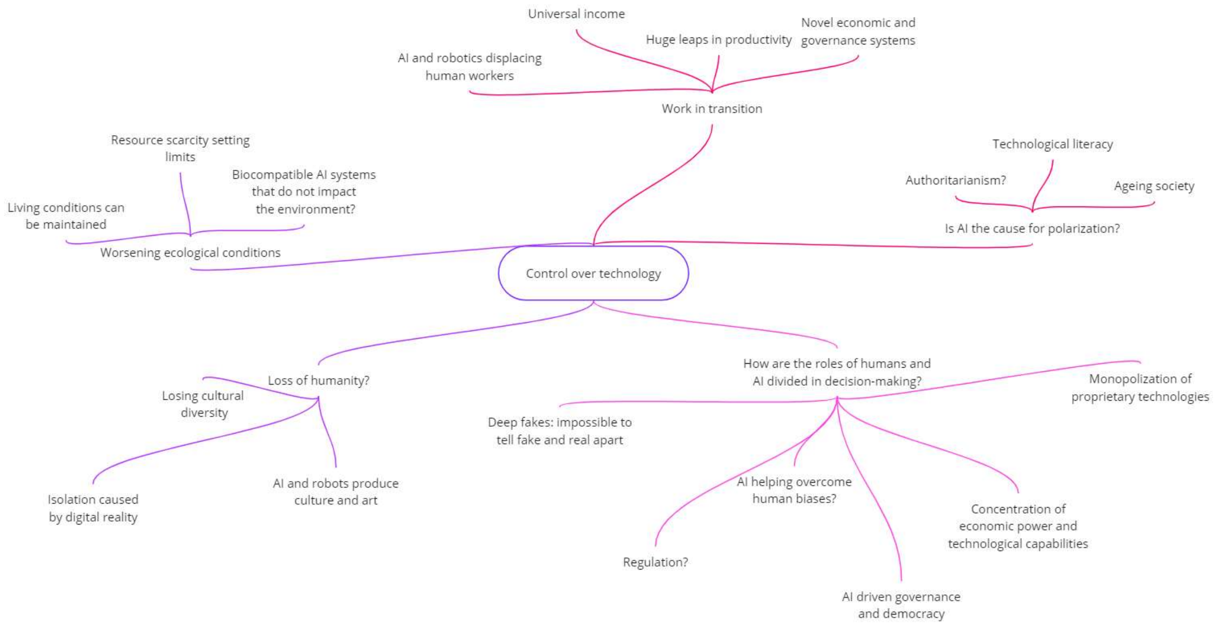
USA is currently the leading country in biotechnological solutions. Lately a big influence has been a $2 M investment for research and infrastructure and training in this field, and this has had a stimulating effect on the whole sector globally.

Possible pitfalls in replacing oil-based solutions with sustainable ones, for instance can be found in how to reach the same level of cost-effectiveness: there are already some promising proof of concepts, but they are not yet economically viable in large scale. Also political decisions are needed to remove subsidies from chemical and oil industry. EU legislation on biological, genetically modified organisms is strict and authorisation processes are heavy. As a result, some of the industry and related know-how have relocated to China.

## 3.3 Results from the workshops

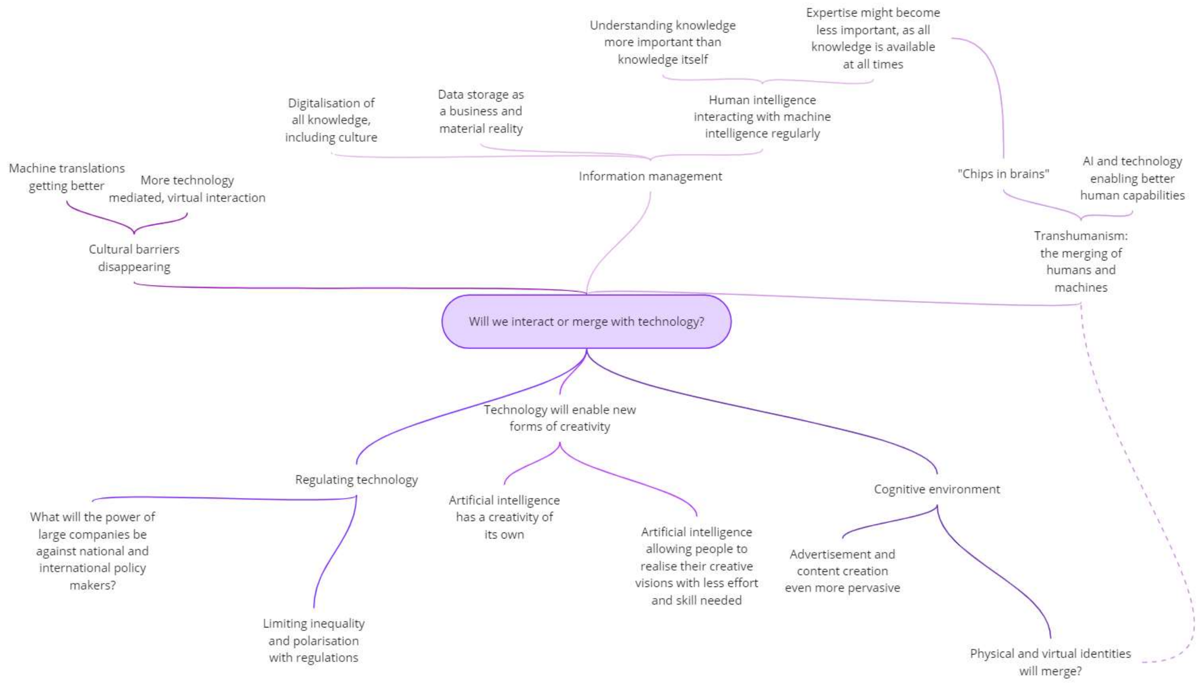
A thorough analysis of the images of the future and narratives produced during the workshops will be reported in the upcoming Deliverable 3.2. They are presented in the subsequent subchapters in the form of analytical mind maps derived from experts' futures workshops, depicting the key societal issues identified by participants for each technology framework.

# 3.3.1 Artificial intelligence



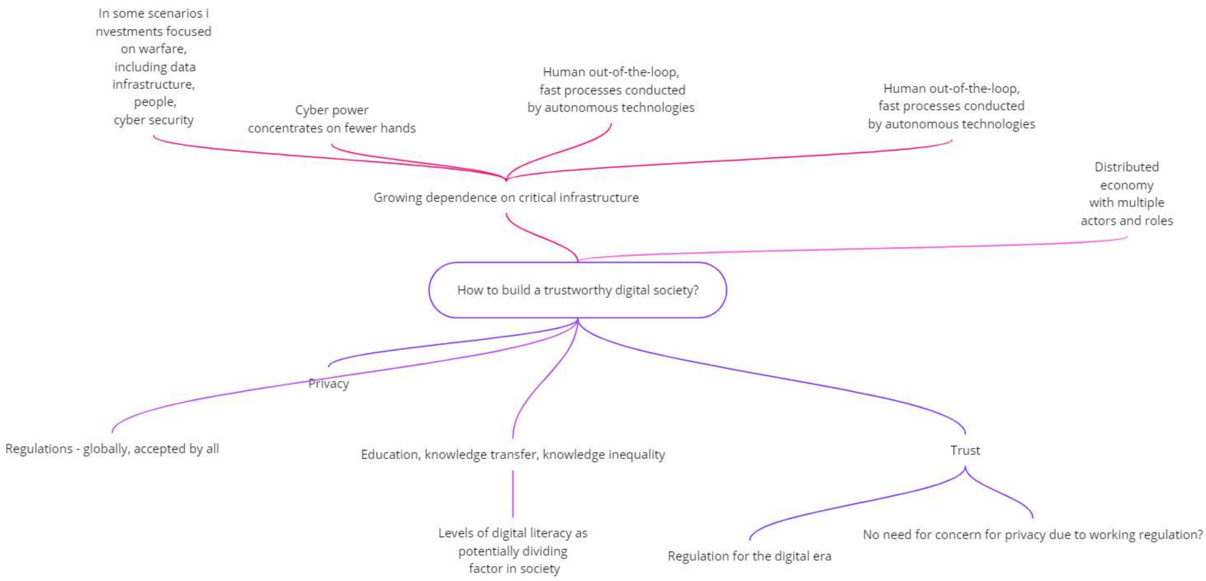

Societal challenges, risks and opportunities related to AI were narratively framed from the perspective of control of the technology and forms of control enabled by the technology, which were understood to engender social detachment and isolation. An economic-centred development of the technology was perceived to accentuate patterns of centralization and the emergence of monopolies, which exacerbate inequality and disrupt work as a source of meaning to individuals. The possibility of developing biocompatible AI systems was identified as potential pathway to mitigate worsening ecological conditions at a global scale. In the absence of such an approach, environmental degradation furthered by resource-intensive AI development was perceived to potentially lead to social unrest and to the deepening of societal divisions. Similarly, the complexity of regulating AI was acknowledged as an instrument to balance tensions between AI as a decision-maker with potentially better decision-making capabilities than humans, and the safeguarding against the risks of potential authoritarian drifts or the use of AI to weaponize disinformation.

# 3.3.2 Human-centric solutions and human-machine interaction



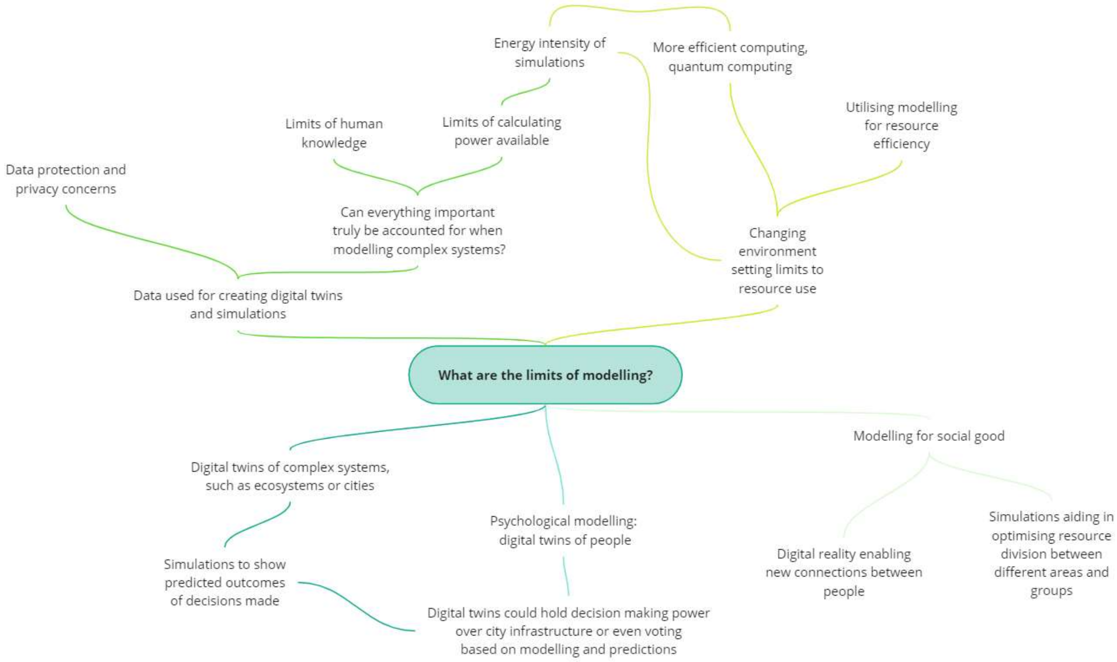

Societal challenges, risks and opportunities related to human-machine interaction were narratively framed by the prospect of further integration and merging of humans and technology. On the one hand, the materialization of transhuman hybrids has led to interrogations surrounding the syncretism between physical and virtual identities and the promise of human capabilities enhancement. The same logic of hybridization was understood to impact culture and forms of creative expression. Whilst met with enthusiasm for the possibility to exercise less effort and mobilize knowledge and skills that are not necessarily held by individuals, this vision raises questions concerning the significance understanding of knowledge. On the other hand, the recognition of the creative agency of technologies such as AI was understood to pose difficulties in regulating the expected growth in power by large companies and an expected rise in societal inequality and polarization.

## 3.3.3 Cyber safe data transmission, storage, and data analysis technologies



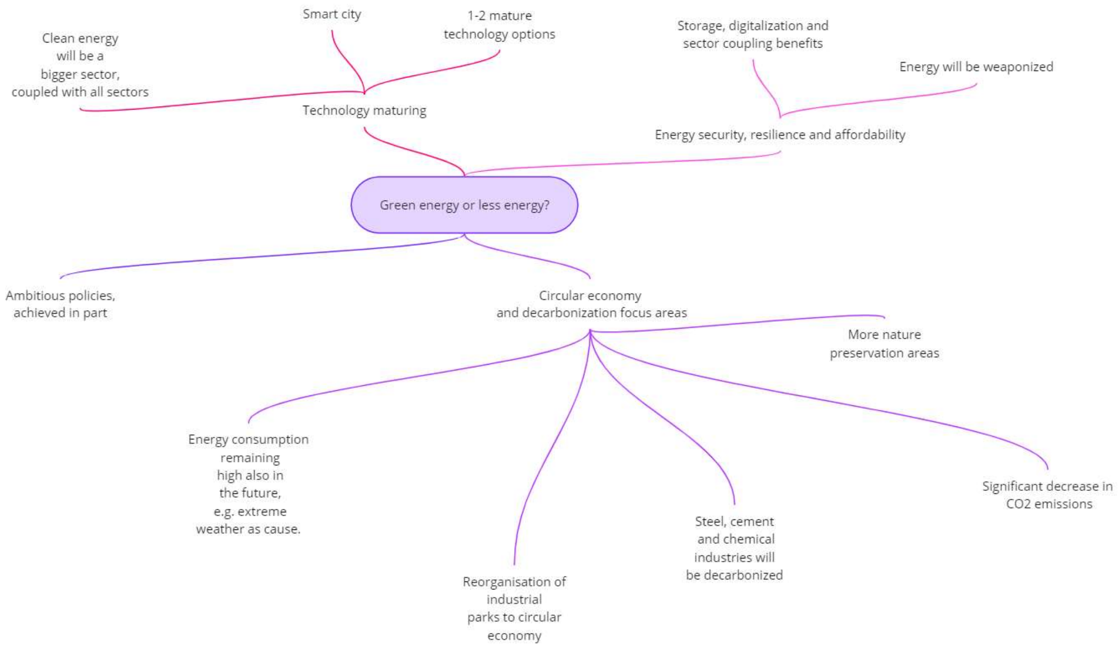

Societal challenges, risks and opportunities related to cyber safe data transmission, storage, and analysis technologies were narratively framed by the concern to shield the digital society from increasing threats to privacy and trust. The recognized growing dependence on critical data infrastructure will exacerbate vulnerabilities related to accentuated exposure to warfare and to processes conducted by autonomous technologies. Bringing the human back into the loop was framed as a core societal challenge, requiring education, skills and knowledge transfer to enable a robust response to security and privacy threats, and by extension to counter the polarising trends that will emerge if security and privacy erosion patterns accelerate.

## 3.3.4 Real time-based digital twins and digital simulation



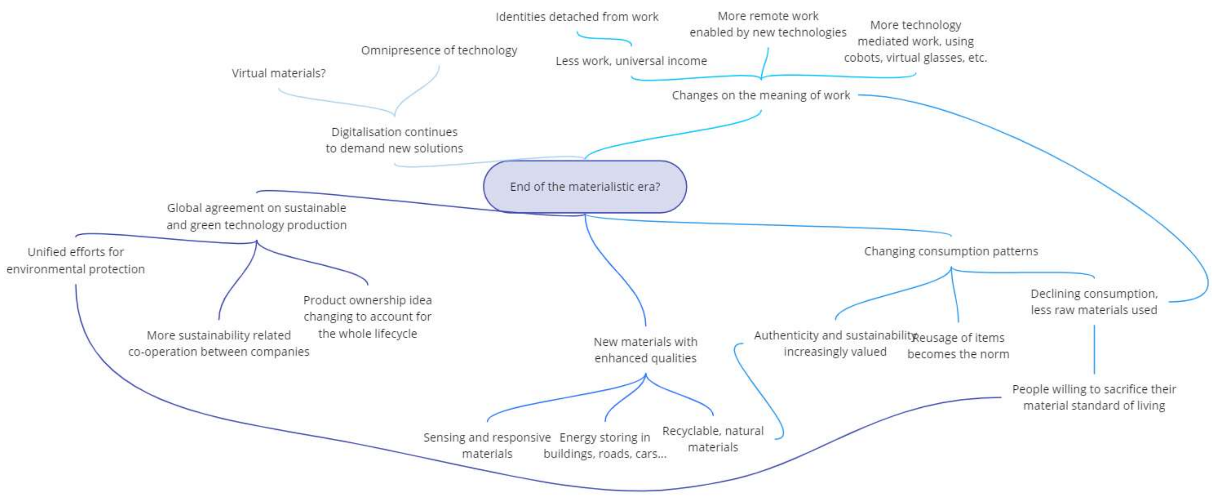

Societal challenges, risks and opportunities related to digital twins and digital simulation technologies were narratively framed as an interrogation to the limits of digital modelling. This includes risks related to digital twins at the levels of data protection, privacy and cyber threats. Nevertheless, at a societal level, digital twins were understood to enable a better understanding of complex systems, and even of individual and collective psychology, which could be used for supporting decision making through behaviour modelling. Discerning differences in the uses of modelling will be key, as will be the determining what should be modelled or what might be lost when modelling. Quantum computing was understood to enable modelling capabilities, but ecological concerns were expressed in connection to the energy intensiveness of digital twins.

# 3.3.5 Energy efficiency and trustworthy autonomy




Societal challenges, risks and opportunities related to technologies for energy efficiency and trustworthy autonomy were narratively framed through an exposed tension between the aim to reduce energy consumption, and the aim to decarbonize the energy system. Energy security, resilience and affordability of energy were acknowledged to have a central role when developing future energy systems. While participants anticipated that the co2 emissions of energy use will decrease significantly, there are various change factors that point towards increased energy usage in the future. Steel, cement and chemical industries were identified as sectors that are difficult to decarbonize. In addition, the financial sector was understood to be more growingly involved in energy, and sector coupling benefits are expected to provide novel approaches to organising energy production.

# 3.3.6 Bio-inspired technologies and smart materials




Societal challenges, risks and opportunities related to bio-inspired technologies and smart materials were narratively framed by the promise of bioinspired materials to provide more sustainable opportunities to produce novel materials with enhanced sensing and responsive capabilities, but also capable of performing energy storage functions. Nevertheless, an acknowledged priority concerns reducing the consumption patterns towards less use of materials, which entails the acceptance of lifestyle changes. A less materialistic lifestyle is linked to a number of other signals related to changing patterns in work, economy, and consumption. For biobased sustainability to proceed, global regulation, more co-operation with key players, and focus on the whole lifecycle of the products are required. In summary, biobased materials alone cannot guarantee sustainability, but they can be an important element in the societal shift towards a lighter footprint and keeping within planetary boundaries.

# 4. Conclusions

Societal concerns related to emerging technologies share common features. The experts recognized that regulation plays a big role in shaping the societal impacts of the developing technologies. Some of the regulation needs are technology specific, and there the experts also acknowledged the challenges related to fast moving technological development but also a need to forge common rules, preferably with a global reach. On the other hand, existing regulation may also hinder needed developments and guide towards societally undesirable directions at least in some technology frameworks. A common concern regarding overall societal development, with implications to potentially harmful impacts of technology, were the trends indicating the concentration of political power, wealth and technological capabilities in fewer hands. Overall, polarization of societies was identified as a threat for the realization of the more desirable societal future visions, and regulations would be needed for instance for the prevention of inequal distribution of skills. A common concern for all framework is the bleak outlook on environmental futures. However, improving the state of the natural environment was also a motivational factor for the development of some of the technologies, as they were seen to offer various opportunities for technology-based solutions. Finally, tensions between agency, distributed control and complete take-over are observed across the six technology frames, with experts identifying changing patterns in work, economy, consumption, the governance of societies, and processes of decision-making. To sum up, the experts in all technology frameworks found that technological approaches may respond to key societal issues provided that political decision-making guides and supports the development by providing rules for the development, in a way that responds to shared ideals and values about desirable societal development.

# References

Aguilar, F. 1967. Scanning the Business Environment. Macmillan, New York.

Aligica, P.D. 2011. A critical realist image of the future – Wendell Bell's contribution to the foundations of futures studies. Futures. Vol. 43, Issue 6.

Alvesson, M. 2011. Interpreting interviews. Thousand Oaks: Sage.

Amara, R. 1981. The futures field: Searching for the Definitions and Boundaries. The Futurist 15 (1): 25–29.

Bell, W. 1996. Foundations of futures studies: human science for a new era. Vol. 1, History, purposes and knowledge.

Dator, J. 2009. Alternative futures at the Manoa School. Journal of Futures Studies.

Dator, J. (2019). What Futures Studies Is, and Is Not. In: Jim Dator: A Noticer in Time. Anticipation Science, vol 5. Springer, Cham. https://doi.org/10.1007/978-3-030-17387-6_1

de Haan, F.J., Ferguson, B.C., Adamowicz, R.C., Johnstone, P., Brown, R.R. and Wong, T.H., 2014. The needs of society: A new understanding of transitions, sustainability and liveability. *Technological Forecasting and Social Change*, 85, pp.121-132.

Fortes, P., Alvarenga, A., Seixas, J. and Rodrigues, S., 2015. Long-term energy scenarios: Bridging the gap between socio-economic storylines and energy modeling. *Technological Forecasting and Social Change*, 91, pp.161-178.

Fraunhofer 2015. Models of Horizon Scanning. How to integrate Horizon Scanning into European Research and Innovation Policies. https://www.isi.fraunhofer.de/content/dam/isi/dokumente/ccv/2015/Models-of-Horizon-Scanning.pdf. Retrieved 29.11.2023.

de Jouvenel, B. 1967. The Art of Conjecture. London: Weidenfield and Nicolson.
Hiltunen, E. 2008. Good Sources for Weak Signals: A Global Study of Where Futurists Look For Weak Signals, Journal of Future Studies, May, Vol. 12:4, pp. 21-44.

Koskinen, I., Alasuutari, P. & Peltonen, T. 2005. Laadulliset menetelmät kauppatieteissä (Qualitative methods in business research). Tampere: Vastapaino.

Krippendorff, K. 2004. Content Analysis: An Introduction to Its Methodology (2nd ed.). Thousand Oaks, CA: Sage.

Jungk, R. & Müllert, N. R. 1987. Future Workshops: How to Create Desirable Futures. Institute for Social Inventions.

Malaska, P. & Holstius, K. 2009. Modern Futures Approach. Futura 1/2009.

Malaska, P. & Virtanen, I. 2009. Theory of Futuribles and Historibles. Futura 1/09.

Milojevic, I. & Inayatullah, S. 2015. Narrative foresight. Futures 73, 151-162.

Polak, F. 1973. The image of the future. Amsterdam: Elsevier Scientific Publishing.
Poli, R. 2017. Introduction to Anticipation Studies. Cham: Springer.

Rubin, A. 2000. Growing up in social transition: In search of a late-modern identity. Annales Universitatis Turkuensis. Ser. B, Humaniora; tom. 234.

Savaget, P., Geissdoerfer, M., Kharrazi, A. and Evans, S., 2019. The theoretical foundations of sociotechnical systems change for sustainability: A systematic literature review. *Journal of Cleaner Production*, 206, pp.878-892.

Suddendorf, T. & Corballis, M. C. 1997. Mental Time Travel and the Evolution of the Human Mind. Genetic, Social, and General Psychology Monographs, 123(2), 133–167.

Voros, J. 2017. Big History and anticipation: Using Big History as a framework for global foresight. In R Poli (ed.) Handbook of anticipation: Theoretical and applied aspects of the use of future in decision making, Springer International, Cham. doi:10.1007/978-3-319-31737-3_95-1,

Weimer-Jehle, W., Vögele, S., Hauser, W., Kosow, H., Poganietz, W.R. and Prehofer, S., 2020. Socio-technical energy scenarios: state-of-the-art and CIB-based approaches. *Climatic Change*, 162, pp.1723-1741.

# Attachment 1. Contributing experts

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