FORGING

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

FORGING Toolbox
for responsible development
and implementation of
emerging technologies

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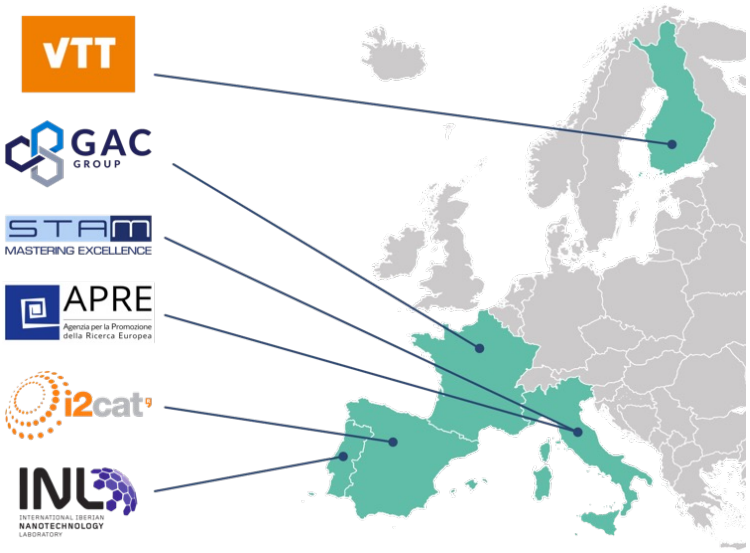
Introducing the FORGING project

FORGING sets up a Forum and works with leading European experts to uncover the potential of Emerging Enabling Technologies. FORGING has established a co-creative process with diverse stakeholders to stimulate new technological visions and pathways – attentive to the environment and society, and human-centred in alignment with Industry 5.0. technological frameworks.

FORGING is funded by the European Commission and running 2022-2025. The FORGING consortium consists of 6 European partners.

To learn more about the project visit the project website: https://forging-hub.eu/



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Welcome to using the FORGING Toolbox!

FORGING Toolbox – what is it?

FORGING Toolbox is a resource for developers and adopters of emerging technologies, offering tools and methods for responsible technology development processes. Especially the Toolbox is designed for academics and industrial entities, but anyone working with emerging technologies might find the methods and tools useful. Cross-sectoral co-creation and co-operation is at the heart of the FORGING values reflected in this Toolbox. The Toolbox introduces the co-creative approach of FORGING project, showcasing the methods and tools of the project.

FORGING Toolbox creation has been an iterative and practice oriented process during the FORGING project timeline. Project partners have described and documented their processes in order to share their best practices, to find fit for the purpose methods and tools, and to share new methods and tools for future usage.

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Emerging technologies:
six technology frameworks

FORGING project and this Toolbox focus especially on six technology frameworks. Each of these frameworks describes emerging technology sectors with huge potentials for future applications.

In the FORGING methodology, most of the same workshop methods are adapted for each of the six technology frameworks. Therefore, all of the methods and tools provided in this prototype Toolbox are suitable for all emerging technology frameworks.

Real time based digital twins and simulation

Bio-inspired technologies and smart materials

Human centric solutions and human machine interaction

Artificial intelligence

Cyber safe data transmission, storage, and analysis technologies

Technology for energy efficiency & trustworthy autonomy

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Storytelling videos

FORGING project put effort on storytelling and creating videos in a short impactful way to illustrate especially key dilemmas and ethical tensions in the development and use of emerging technologies.

FORGING videos aim to:
-Stimulate reflection and ethical discussion
-Foster critical thinking
-Engage diverse stakeholders (researchers, industry, policy, citizens)

You can access the videos on Youtube and consider the questions below:
https://youtu.be/LtOwBm9pQ1Y?si=k9SXQcnpAzi8nmdd

After watching a video, consider asking:
What ethical concerns or tensions did you notice in the story?(e.g., privacy, bias, accountability, inclusion)
Who are the stakeholders, and how might they perceive the situation differently?
What values are in conflict in this story?(e.g., innovation vs. precaution, efficiency vs. fairness)
How could the outcomes have changed if other choices were made?
What responsibilities do researchers, companies, and governments have in this scenario?

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Who is this Toolbox for?

Companies

- Technology, innovation and offering development: Gain in-depth knowledge of emerging technologies and their potential impacts on business to accelerate the development of innovative solutions that meet future needs and requirements.
- Strategists, leadership and management: Make informed decisions that support the company's long-term goals and anticipate risks improving the company's resilience and readiness to gain competitive advantage.

Research Organizations

- Researchers and research teams: Produce scientifically significant results that are valid in real market contexts and viable in short- and long-term.
- Research and Project Managers: Obtain tools and methods for project planning and management, and especially for co-creation improving the project success.

Industry associations

- Ensure the member companies develop and implement new technologies responsibly and in accordance with value sensitive principles.
- Promote collaboration among the members in researching and applying emerging technologies to take leaps in learning and transformation.

Public Sector

- Policy experts and authorities: Gain in-depth knowledge of emerging technologies and their impacts on society, aiding in policy planning.
- Innovation and education: Understand the systemic enablers and needed capabilities for the emerging technology applications and growth.

Consumers and NGO's

- Early adopters and technology enthusiasts: Deepen the emerging technology understanding and assess the use cases in the everyday contexts.
- Non-governmental organizations and activists: Raise awareness about emerging technologies in the communities and assess their potential impacts.

Design and consultation agencies

- Utilize the Toolbox methods in customer projects as an intermediary, helping to co-develop innovative solutions that address environment and people as equal actors in economically responsible solutions.
- Support strategic business decisions and roadmaps by concretising the future narratives and solutions for emerging technologies

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ABOUT THE TOOLBOX

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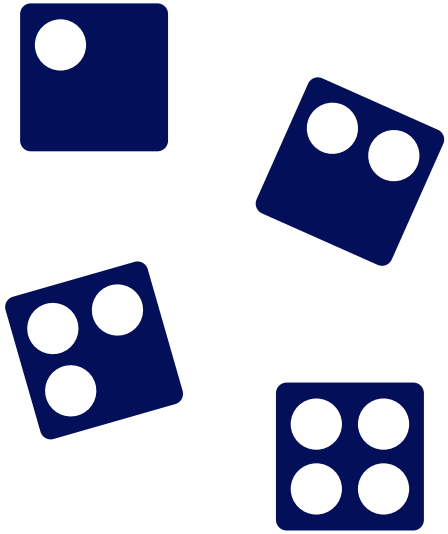
How to use the FORGING Toolbox?

FORGING Toolbox is here to guide other projects and organisations dealing with emerging technologies into a responsible and co-creative journey of their own. This Toolbox offers an array of methodologies and tools used in FORGING project.

In this section you'll find the principles for successful usage of the Toolbox and its methods, that are summarized on the methods and results overview page. Further, the value innovation journey is illustrated: While FORGING project predominantly deals with earlier stages of the journey as it explores the emerging enabling technologies, many of the methods and tools can be used also in later stages of the innovation journey.



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FOUR PRINCIPLES IN FORGING TOOLBOX UTILISATION

Principle 1

1. Co-creation and intervention among experts, businesses, end-users, and other stakeholders invites diverse perspectives in identifying various needs, challenges, and opportunities related to emerging technologies. The method fosters innovative solutions that are more applicable by the key actors meeting their real needs and motives. Early stakeholder engagement and intervention also prevent unintended consequences and increases the chances of achieving societally acceptable outcomes, leading to a positive holistic impact.

In practice:

- Identify diverse and wide group of human and non-human actors (such as nature) by mapping and analysing the stakeholders: Who are integral to successful solutions creation and implementation, and who are impacted by these targeted solutions.
- Engage the selected stakeholders in dedicated co-creation sessions and provide several means to give input in the iterative process. Tailor the methods to support stakeholder-specific motives and practices, and empower them to act as change agents for technology scaling.
- Boost co-learning and shared understanding between actors from different sectors and disciplines with an experienced facilitator. Pay attention also to co-creation spaces (physical, digital, and hybrid) to promote open discussion, ideation, documentation, and interaction.

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FOUR PRINCIPLES IN FORGING TOOLBOX UTILISATION

Principle 2

2. Stories and visualization effectively communicate and boost a shared understanding of future concepts and visions, making them accessible and understandable to stakeholders, decision-makers, and a broader audience. Stories evoke emotions and boost ideation, which is essential in identifying emerging technologies' related needs, opportunities, and impact. Visualization is a powerful method in illustrating yet abstract thoughts and ideas that emerging technologies can offer in complex and alternative futures.

In practice:

- Employ a visualization expert and use interactive tools to present data, ideas, alternatives, and concepts clearly and engagingly. Concretise and create visual prototypes that act as tools to test stakeholder reactions such as emotions, thoughts, concerns, and new ideas.
- Use storytelling to create narratives that explain what changes: how it is today and how it might be in the future. Concretise emerging technology's role in the change: its purpose, benefits, potential impact, and alternatives.
- Encourage stakeholders to share their own stories and visualizations to build a collective vision and understanding of the futures and emerging technologies. This helps stakeholders to connect emotionally and intellectually in the collaboration and shared targets.

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FOUR PRINCIPLES IN FORGING TOOLBOX UTILISATION

Principle 3

3. Empathy and ethics are fundamental in emerging technology research and development. Empathy allows researchers, developers and businesses to understand and address the needs and concerns of users and nature, ensuring that technology serves environment and humanity effectively. Ethical considerations guide in making responsible decisions, preventing harm, and promoting fairness and inclusivity. Together, empathy and ethics foster trust and integrity in technological advancements, paving the way for sustainable and socially beneficial innovations.

In practice:

- Strive for inclusive participation including a representation of nature. Ensure that participants understand their role in the co-creation process and provide related informed consent for e.g., photographing, recording, using the results, publishing participant names, and sharing contact details.
- Maintain a safe space for open and creative discussions, and transparency throughout the process about goals, methodologies, and findings. The ownership of the ideas should benefit all stakeholders and the results should be shared as collective outputs.
- Clearly communicate any plans for future use of collected data, respecting privacy and intellectual property rights. Ensure that all stakeholder data is handled in compliance with privacy laws (i.e. GDPR) and ethical standards.

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FOUR PRINCIPLES IN FORGING TOOLBOX UTILISATION

Principle 4

4. Foresight and systems thinking help to navigate in the rapidly changing and complex operational environment by analysing future changes, continuities, possibilities, and challenges to do with specific stakeholders or emerging technologies. Foresight capability increases resilience through preparing for anticipated disruptions and developing strategies that boost positive long-term developments. Foresight not only enables the identification of alternative solutions but also tests and validates those in alternative future contexts and maps the impact-making factors in the system.

In practice:

- Employ a visualization expert and use interactive tools to present data, ideas, alternatives, and concepts clearly and engagingly. Concretise and create visual prototypes that act as tools to test stakeholder reactions such as emotions, thoughts, concerns, and new ideas.
- Use storytelling to create narratives that explain what changes: how it is today and how it might be in the future. Concretise emerging technology's role in the change: its purpose, benefits, potential impact, and alternatives.
- Encourage stakeholders to share their own stories and visualizations to build a collective vision and understanding of the futures and emerging technologies. This helps stakeholders to connect emotionally and intellectually in the collaboration and shared targets.

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Value sensitive innovation journey

The Value Sensitive Innovation Journey is a depiction of the FORGING approach towards responsible innovation processes. It combines multiple existing approaches to innovation processes, adding the layer of value sensitive considerations into the widely recognised phases of innovation process.

Depending on the phase of the innovation journey currently relevant in the project or development at hand, this Toolbox offers fit for the purpose methods for that specific situation. However, it is encouraged to treat this Toolbox as an inspiration and take an iterative approach: In addition to following the innovation journey and the order of the methods, it is also useful to start where needed and try out various tools when exploring and anticipating emerging technologies.

“We encourage you to treat this Toolbox as an inspiration and take an iterative approach”

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VALUE SENSITIVE INNOVATION JOURNEY

Overview

Research

What is done?
Scientific research on new technological capacities and technologies

Key responsibility considerations:
Inclusive, ethical and open research practices

Potential future impacts of new technologies

Development of concepts & products

What is done?
Scientific discoveries are turned into concepts and products to be adopted by consumers/ users

Key responsibility considerations:
Designing for social good and fairness, anticipatory mindset

Sustainable & responsible design

Introduction & early implementation

What is done?
New technological products are introduced & adopted to use in a limited environment or by a limited group of people.

Key responsibility considerations:
Ensuring user rights

Monitoring environmental impacts & performance

Scaling-up & fine-tuning established technologies

What is done?
New technologies become part of the everyday life as "normal" or even necessary.

Key responsibility considerations:
Ensuring inclusion in shifts of hegemonic practices, understandability for users.

Resource use, systemic impacts to patterns of consumption

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METHODS & RESULTS

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Methods and results overview:

METHOD:

Workshop for Exploring the Future Impacts of Emerging Technologies

RESULT:

Immersive story of a future for challenging assumptions of technology in society (Theseus)

RESULT:

Perspective cards for creating conversations between different perspectives towards technologies

RESULT:

Technology Journey maps for reflecting on responsible technology practices

METHOD:

Scoping workshop for technology application areas

METHOD:

Workshop for evaluating value-sensitivity of technologies

METHOD:

Workshop for emerging technology use case co-creation

METHOD:

Technology pathways for absorption and deployment of value-sensitive technologies

METHOD:

Measuring the impact of emerging technologies in their early stage

This icon takes you back to this page METHODS & TOOLS

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METHOD

Workshop for Exploring the Future Impacts of Emerging Technologies

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METHOD

Workshops for Exploring the Future Societal Impacts of Emerging Technologies

Futures workshop methodology is a creative, participatory co-creation method for building alternative futures images. It is best used for understanding and exploring potential impacts of emerging technologies. The method calls for stakeholders to use their expertise and imagination as tools for understanding implications of potential technological trajectories.

The workshop methodology is based on structured group discussions. The groups can be divided based on the four scenario archetypes (Dator 2009), each group building their future image on the selected archetype. To facilitate active participation of all participants, group sizes should be small, about five participants per group, each facilitated by an expert facilitator

How to use?

To use futures workshops method you need:

Experienced facilitators with basic understanding of futures thinking. Participants with (at least) a basic understanding of the technological possibilities, representing diverse perspectives to avoid narrow visions of the future

A face-to-face workshop setting is optimal for vibrant discussions, but also online implementations are possible.

Sufficient time for unhurried discussions. It is also recommended to set aside time for informal discussions in between the group working sessions.

TIP!

You may consider dividing the workshop into two days, having the introductory lecture and social dinner in the first day. This allows participants to get to know each other before the creative group working sessions.

Dator, J. (2009). Alternative Futures at the Manoa School. Journal of Futures Studies 14 (2), 1–18.

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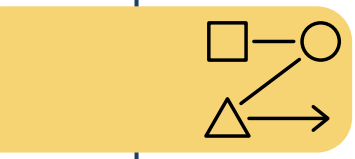
WORK FLOW

Futures workshops



1. Introduction lecture to futures thinking and dividing into groups e.g. using Four scenario archetypes. **Time: 1 hour**
2. Presentation on the workshop methodology **Time: 10 minutes**
3. Warm-up exercise **Time: 5 minutes**
4. Group work 1: Core assumptions **15 minute**
5. Group work 2: Selecting signals of change **30 minutes**
6. Group work 3: Describing the future state of the signals **30 minutes**
7. Presentation on narrative building **10 minutes**
8. Group work 4: Creating futures images and narratives **90 minutes**
9. Presenting futures narratives **35 minutes**
10. Closing session and collecting feedback **15 minutes**

TIP!

Make sure that the participants are ensured enough breaks and refreshments

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TOOL

Four scenario archetypes

CONTINUED GROWTH

Scenarios are built around the ideal of economic growth as the most important value in ensuring well-functioning society.

COLLAPSE

Scenarios anticipate how system's internal or external change factors lead to a return to a significantly less developed society, or to a complete destruction. May be viewed positively as enabling renewal.

DISCIPLINE

Scenarios emphasize the required systemic changes needed to preserve wellbeing. The economy and the society refocus on survival, fair distribution, and preserving important places, processes and values that are felt to be threatened.

TECHNOLOGICAL TRANSFORMATION

In these scenarios technology transforms all life, including humanity, from its present forms into a new "posthuman" form.

TIP!

For the workshop, groups can be divided based on the four scenario archetypes (Dator 2009), each group building their future image on one of the archetypes.

Edited based on Dator 2009.
Dator, J. (2009). Alternative Futures at the Manoa School. Journal of Futures Studies 14 (2), 1–18.

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Warm up: One-two-three

What is this and why should I use it?

This is an easy warm-up exercise and ice-breaker before starting group work. Despite being easy, the warm-up is also a safe way to fail and laugh together, breaking the ice. In addition to the laughter and connection with other participants, the method is physical, which enables creative thinking in the workshop.

There are other warm-up exercises that can be used, such as the “divergent thinking” exercise introduced in the Method: Workshop for evaluating value sensitivity of technologies

How to use?

Everyone stands up and picks a pair, preferably someone they don’t know previously. Facilitators demonstrate before each round.

First round: first of the pair says “one”, the second continues “two”, the first again “three”, after which the second starts from the beginning by saying “one”. After the facilitators have demonstrated a few times, the participant pairs go through the first round.

In the second round, “one” is replaced by snapping fingers, followed by “two” and “three”.

In the third round, “one” is snapping fingers, and “two” is also replaced by clapping hands.

In the fourth round, “three” is also replaced by foot stomping, and no numbers are said aloud anymore. Most pairs will find the exercise surprisingly difficult, which provokes laughter and liberates the atmosphere.

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TOOL

Core assumptions

What is this and why should I use it?

A core belief means an initial fundamental truth, a certainty, the base upon which other beliefs are constructed. Core beliefs are cornerstones of decision-making, they are often unspoken, partly unconscious and may even contain mythical elements. Therefore, they often are not questioned. This exercise aims at identifying core beliefs. While not always easy, making core beliefs explicit and discussing them is an important phase, enabling the expansion of the limits of what is deemed possible and thus facilitating the construction of alternative future narratives. Examples of possible core beliefs could be: “Economic growth is an important societal objective”, “Human beings need physical interaction”.

How to use?

1. Which things you believe will not change by 2050? Identify 3-5 core beliefs and write them down on post-its, first individually.
2. Discuss the core beliefs in your group.
3. You can return to this list of core beliefs at the end of the workshop. Were any of these beliefs impacted by the work?

15 min.

CANVAS

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TEMPLATE

Identifying core assumptions

TEAM:

1. Which things you believe will not change by 2050? Identify 3-5 core beliefs and write them down on post-its.
2. Discuss the core beliefs in your group and place them on the template.
3. You can return to this list of core beliefs at the end of the workshop. Were any of these beliefs impacted by the work?

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TOOL

Signal Matrix

What is this and why should I use it?

This tool helps to collect and analyse trends, megatrends, weak signals and drivers of change (signals of change) as basis for images of the future for each scenario.

Participants identify signals of change they have observed, and place them in a 2x2 matrix where the quadrants are defined by impact and certainty. Special focus is on finding signals in the hight impact low certainty quadrant.

Signals may represents any of the PESTEC-categories* (political, economic, societal, technological, ecological or cultural). The use of the tool requires background expertise in the topic, along with a trained facilitator.

How to use?

1. Write on post-its individual choices for significant or interesting signals of change for each PESTEC category.
2. Discuss the selected signals together and agree on a place for them on the signal matrix.
3. Select ONE signal of change for each PESTEC category for the next phase of group work. Preferably choose signals from the high impact – low certainty quadrant of the signal matrix.

- You will base your scenario work on the selected signals.

30 min.

CANVAS

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* The PESTEC framework (variations include PESTLE) derives from the work of Aguilar, Francis J. Scanning the Business Environment. New York: Macmillan, 1967. xiii + 239 pp.

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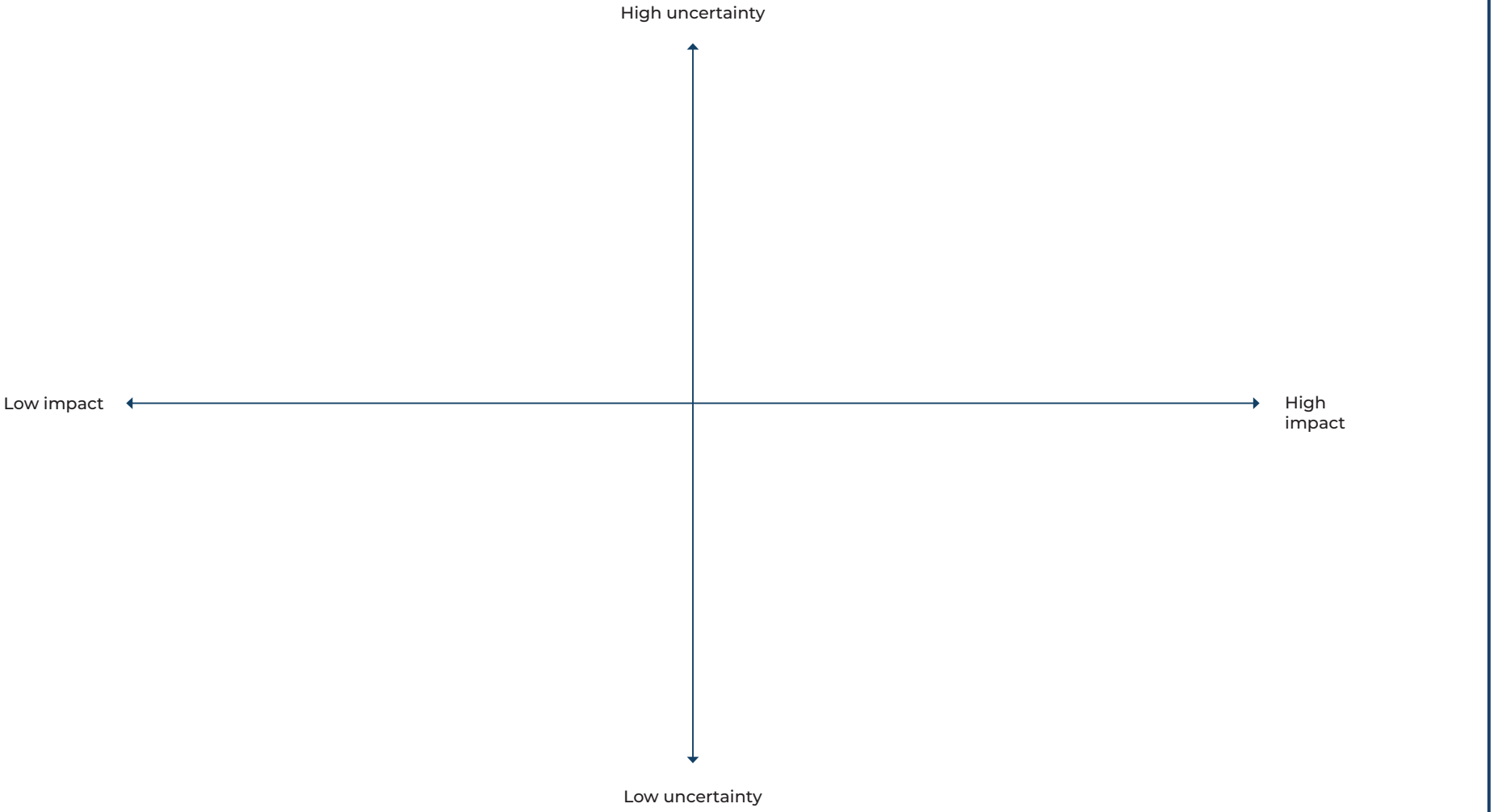
TEMPLATE

Signal matrix

TEAM:

PESTEC* categories	POLITICAL	ECONOMIC	SOCIAL	TECHNOLOGICAL	ENVIRONMENTAL	CULTURAL
	Social order, regulation, directives, legislation etc.	GDP, inflation, markets, regional development	Demography, consumer behaviour, education	Information, bio-, energy, nanotechnologies and their combinations	Both the natural and built environment	Lifestyles, beliefs, moral values, traditions, customs



* The PESTEC framework (variations include PESTLE) derives from the work of Aguilar, Francis J. Scanning the Business Environment. New York: Macmillan, 1967. xiii + 239 pp.

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TOOL

Futures Table

What is this and why should I use it?

This version of a Futures Table is a tool for describing the future states of the signals. It is used as a tool for prioritising the most interesting signals of change and for facilitating the description of the scenario.

The tool makes a leap from the identified present day signal to imagining its impact in the future (future state). Descriptions of the future states of identified signals for each PESTEC- category (political, economic, societal, technological, ecological or cultural) form the basis of the future image.

Ask the participants to imagine how the signals selected in the previous phase could manifest themselves in their scenario in 2050, keeping in mind the scenario archetype designated for each group.

How to use?

1. Write your descriptions of possible future states on each of the selected signals on post-its
2. Discuss the descriptions and form a coherent (short) description for each PESTEC category
3. Write the final group descriptions on post-its in your futures table

- The filled futures table is the starting point for the next phase

30 min.

CANVAS

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The PESTEC framework (variations include PESTLE) derives from the work of Aguilar, Francis J. Scanning the Business Environment. New York: Macmillan, 1967. xiii + 239 pp.

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TEMPLATE

Futures table

TEAM:

1. Write your descriptions on post-its
2. Discuss the descriptions and form a coherent (short) description for each PESTEC category
3. Write the final descriptions on post-its in your futures table

FUTURES TABLE	Political	Economic	Social	Technological	Environmental	Cultural
Signals						
Future state 2050						

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TOOL

Futures Images

What is this and why should I use it?

People imagine futures through more or less coherent images of the future, both consciously and unconsciously. Some of the images are socially shared, while some are personal. Images of the future manifest as hopes, fears, and expectations, and therefore they have an influence on individual and collective behaviour. This tool helps to articulate the images of the future co-created in the workshop for each scenario. The future images are used as the basis for future narratives.

How to use?

Co-write a description of the world in 2050 according to your futures table

1. Base your future image on your futures table bearing in mind the selected signals and their states in 2050, as well as the scenario archetypes designated for each group.
2. Name your future image with a punchy name

45 min.

CANVAS

Future Images: method inspired by Polak, Fred L. (1961). The Image of the Future: Enlightening the Past, Orienting the Present, Forecasting the Future. Translated and abridged by Elise Boulding. New York: Oceana Publications and Zwicky, F. (1969). Discovery, Invention, Research through the Morphological Approach. Toronto: Macmillan

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Enhanced humanity: Example from the human-machine interaction scenario workshop , June 1-2, 2023, Brussels;

IMAGE OF THE FUTURE

1. Children live surrounded by technology and it dominates their time use.
2. School trips to the wild part of the world take place.
3. Technology enabling discovering different places and living in them.
4. Human enhancements available, but not for small children, also as “add-ons” such as backpacks. Not all human enhancements are good – regulations, social norms.

ENHANCED HUMANITY

Photo by Ecliptic Graphic on Unsplash

5. Time-space coordinates have a different meaning.
6. Learning something will take significantly less time.
7. What is learning in the future? No more need to know things by heart. External brains in addition to biological ones. Learning critical thinking and interpretation, learning how to learn as a child when the brain is adaptive.

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Futures News

What is this and why should I use it?

Future News is a method that facilitates narrating the future image in a compelling way. Creating a news piece about the future image brings the element of storytelling to the future image and adds a human-centric element to concretising the societal impacts of technology.

How to use?

You will spend a moment working in the editorial team of Future News.

1. Create the front page appearing in a newspaper in 2050. Create a headline that describes the image of the future you have created earlier and a small article describing an event. You can also create visuals to support the news.
2. If you have time, you can add other, smaller news as well.

45 min.

CANVAS

Future News: There is no single, traceable inventor of the “future news / news-from-the-future” exercise. It has evolved from (a) the participatory future workshop tradition (1970s), (b) scenario-planning headline/press-release techniques used in foresight practice from at least the 1980s, and (c) the design-fiction / “speculative press release” tool-kit that became explicit in the 2000s–2010s.

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Boy who tried wolf: Example from the human-machine interaction scenario workshop , June 1-2, 2023, Brussels

FUTURE NEWS

No. xxx38
FRIDAY
1st of June 20XX

THE BOY WHO TRIED WOLF

A 12-year-old boy went to a school trip to the wilderness part, his first time ever leaving his hometown physically. The children used soft exoskeletons that allowed them to view wolves close up. An educational AR told them that the wolf was able to detect a rabbit that was there half an hour ago. The boy became interested in experiencing having that ability. He asked his parents to apply for the permission for temporary smell censor enhancements. He is now asking for support for his application on a digital crowd funding platform. He promises to visit 10 first funders children's party in his wolf form.

Image: FORGING Futures Workshop June 1-2, 2023, Brussels

SCHOOL TRIPS TO WILDERNESS

School trips to wilderness became popular after people had lived in the city for decades and a decision was made to make these trips part of the school curriculum to support children's well-being.

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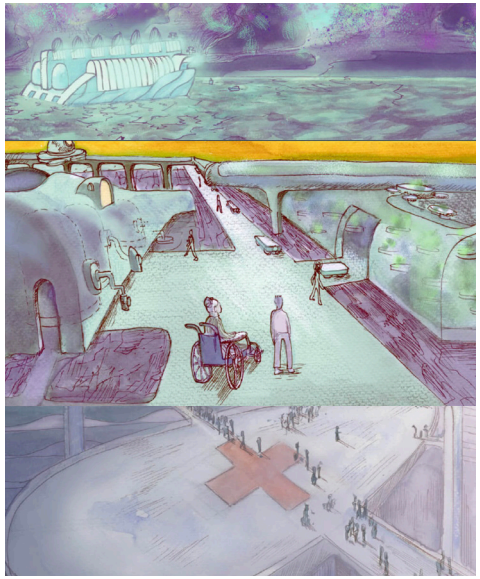
RESULT

Future narratives

Storytelling and visualization is an effective tool for presenting project outputs (e.g. workshop results, scenarios, trends) in a persuasive, scientifically relevant and narratively coherent format, bringing technologies closer to people. The stories and images can capture the whole spectrum of technology uses, potentials and even the complexity fostering a sense of empathy, and envisioning possibilities and opportunities.

In FORGING project a visual artist and art educator was commissioned for a process of co-creation of the storyline and translation of the story into imagery through the lens of hope.

See the project team video for the background information:
https://youtu.be/L--We2jAGf0
See Theseus logbook for the future stories:
https://forging-hub.eu/ready-to-travel-to-2050/



Images: Samuel Putkonen (2024)

While exploring Theseus (or other future stories), reflect the questions below

- How the stories make you feel? What makes you sad or afraid? What makes you hopeful or relieved? Why?
- What surprised you? What kind of assumptions or biases you might have about the future of technology or society? Why?
- What kind of new technology uses and possibilities you see in the stories? What could go totally wrong with your ideas?
- Use “Actor cards -method” to take different perspectives towards the future stories: What are the new ideas that they bring?

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RESULT

Perspective Cards

Find the cards at the end of document!

What is this and why should I use it?
Industry 5.0 takes humans to the centre of industry. Using perspective cards generate empathy and understanding of the future world views for the perspective holder when designing applications of an emerging technology. With the card deck you take different perspectives to approach emerging technologies: Developer (the entity that creates, designs and releases an application); Citizen (including perspectives of agency, education and activism); User (individual, company); Regulator (different levels of governance, including non-traditional regulation actors); Malicious agent (interest group, organized crime, state, individual)

How simple is this tool to use? What is needed?
Perspective cards are best used in a role-playing game, where each player takes the perspective of the key stakeholder and examines the set of questions with a particular technology in focus. The five perspectives provide detailed prompts around the interests of the actors, providing ground for the exploration of considerations about the societal impacts of technology. The technology card provides a set of emerging technologies and their priority application areas that are to be discussed individually on each round of the game.

How to use?

This is a game with no individual winner or losers, but a game that evoke discussion and generate new ideas, contribute to identifying potential problems, and the solutions for those problems.

Players should not pick a perspective card that represents their actual role i.e., a technology developer should not pick the “developer” perspective card.

You can take multiple rounds and change the perspectives, and you can start the game over with a new technology. A full round can be played in 1 hour, but the game can take as long as new perspectives are generated.

There is an additional technology card presenting an emerging technology within a use context which should be tailored according to the goal of the game e.g., refining the use-case, interrogating applications of a specific technology, identifying future pathways or social and environmental development of a new product or service.

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RESULT

Technology Journey Maps for reflecting on responsible technology practices

Find the maps at the end of document!

What is this and why should I use it?

Technology Journey Maps offer worthwhile questions and considerations for emerging technology research, development, implementation and scaling. They support in identifying both the desired impact and especially the unintentional negative consequences that emerging technologies might initiate. Each Technology Journey Map therefore considers the potential and risks of each emerging technology in the scope of FORGING project and discusses the ecological and social aspects in the value sensitive innovation journey. By discussing the aspects presented in the Technology Journey Maps the organizations and project groups gain a more concrete and shared understanding of the emerging technologies, their opportunities, risks and related research questions.

With the six emerging technologies and related Technology Journey Maps presented here, it is also easier to approach other technologies with more systematic impact and consequences consideration.

Technology Journey Maps do not cover 100% of the considerations in our interconnected systemic world but it gives a great start to have the needed discussions with the stakeholders and future value network actors including both actors integral to success and impacted by the technology development. The Technology Journey Maps are therefore an evolving tool to collect and share learnings for the ultimate purpose of value sensitive innovation

TIP!

The six emerging technologies are:

- Artificial intelligence
- Real-time based digital twins and simulation
- Cyber safe data transmission storage and analysis technologies
- Bio based inspired technologies and smart materials
- Human centric solutions and human machine interaction
- Technologies for energy efficiency and trustworthy autonomy

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METHOD

Scoping workshop for technology application areas

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METHOD

Scoping workshop for technology application areas

What is this and why should I use it?

This anticipatory co-creation methodology brings together technology experts from different expertise areas to build on previous research findings. The aim is to gain new insights, understand potential barriers and challenges faced by emerging technologies, and identify potential solutions. Additionally, the workshop aims to detect signals of new technologies through engagement with experts who have cutting-edge insights.

The workshop method begins with introducing desk research results from Strategic Matrix analysis and outcomes from the Workshop for Exploring the Future Impacts of Emerging Technologies outcomes (referred here as Futures Workshops method). The goal is to shift the focus from a purely technological perspective to considering socio-environmental aspects relevant to the development of emerging technologies.

One of the cornerstones of this method is interdisciplinarity. This workshop method brings together experts from different technological frameworks to gain diverse perspectives. When combining different technology frameworks, it is preferable to bring together those that share some characteristics or are complementary. For example, in the FORGING project, the AI experts were brought into same workshops with cybersecurity experts.

TIP!

To use this methodology you need:

- Previous research to form a basis of the group work done during the workshops. In the case of FORGING, this meant desk research about emerging technologies and their use sectors in each of the six technology frameworks, as well as the futures workshops results.
- Facilitators of the workshops should have at least basic understanding of the technologies under discussion.
- Selection of experts is crucial, as the workshop results are based on their expertise. These workshops should have a wide range of expertise from the selected technology areas.

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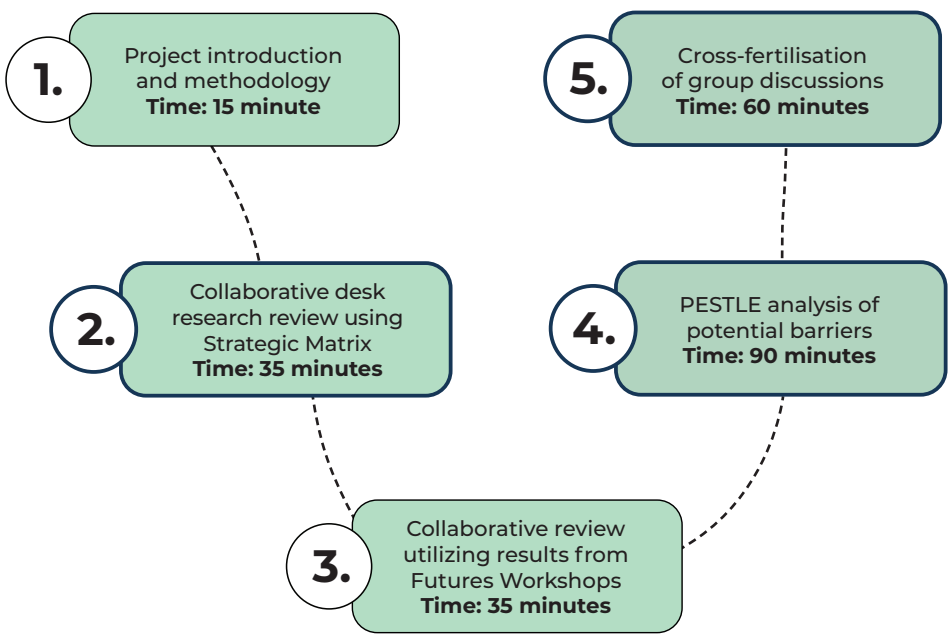
WORK FLOW

Scoping workshops



TIP!

Bringing experts with different technological backgrounds together into the same workshop might result to more fruitful cross-fertilization. In FORGING, for example, a group of AI experts was brought together with cybersecurity experts for the cross-fertilization session.

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TOOL

Collaborative desk research review

What is this and why should I use it?

This workshop phase aims to facilitate discussion about previous research results to gain expert insights on them. This discussion should lead to new insights about the desk research topics, specifically spotting anything that might have been missed in the desk research phase and finding practical ways to use the recognised technologies to solve societal needs.

In FORGING, the previous research results consisted of the Strategic Matrix (see Fact Sheet in FORGING project website http://forging-hub.eu/wp-content/uploads/2024/09/FORGING-Factsheet_Strategic-Matrix__.pdf) and results from the Futures Workshops method.

Strategic Matrix

The Strategic Matrix methodology resulted from the desk research aimed to recognize currently emerging technologies while combining them with their primary application areas. The research process was repeated for each of the six technology frameworks used in FORGING.

The Strategic Matrix methodology included the following steps:

1. Review on recent literature, including trend reports, to recognise currently emerging technologies inside each tech framework.
2. Reviewing data on patent and research databases to find technologies that are currently emerging but have not yet reached a mature phase.
3. Matching emerging technologies with application sectors based on the data reviewed.

The results included a list of technologies per each tech framework paired with relevant application sectors. This analysis formed the starting point for the scoping workshops.

35 min.

CANVAS

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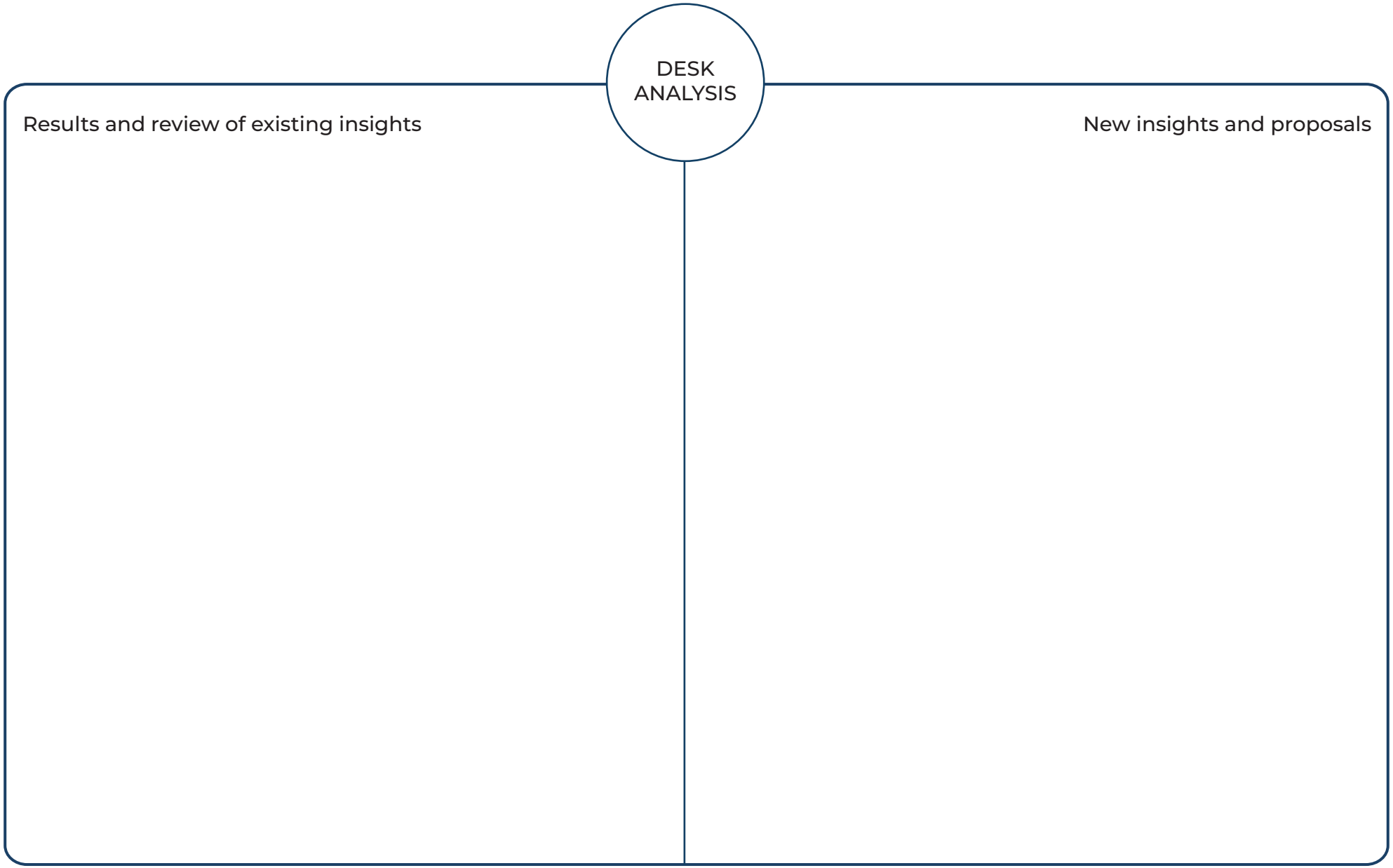
TEMPLATE **Collaborative desk research review**

TEAM:



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TOOL

PESTLE analysis on potential barriers

What is this and why should I use it?

This is a workshopping tool aimed at understanding challenges and barriers of emerging technologies. PESTLE stands for Political, Economic, Societal, Technological, Legal and Environmental, reflecting the different perspectives for the analysis. The tool should lead to a shared understanding of possible ways to foresee and overcome possible challenges related to the PESTLE aspects.

Ideally, one technology is analysed during the exercise, but different framings of the analysed unit are possible. To gain the full advantage of the tool, select experts with diverse expertise about the topics addressed. Too similar expertise areas might lead to limited perspectives during the discussions.

How to use?

1. In the beginning, allow time for individual thinking and note-taking on post-its. Ask the participants to consider each of the PESTLE categories in this stage, listing potential barriers or challenges for the chosen technology.
2. Discuss each of the six aspects of the PESTLE starting from the sticky notes produced individually.
3. Aim at finding potential solutions to the recognised barriers or challenges.

90 min.

CANVAS

METHODS & TOOLS

The PESTLE framework (also used in form of PESTEC): Aguilar, Francis J. Scanning the Business Environment. New York: Macmillan, 1967. xiii + 239 pp.

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TEMPLATE

PESTLE analysis – topics to be explored

TEAM:

POLITICAL

Political context which may effect a sector. E.g. Fiscal policy, rates and fares, import taxes

TECHNOLOGICAL

Progress and tech innovation. E.g. automation, tech change rates, tech incentives

ECONOMIC

Factors that may influence business and industry tendencies. E.g. Economic growth, interest rates, inflation

LEGAL

Aspects related to people's rights. E.g. Antitrust, right to work; right to health; right to safety

SOCIAL

Social changes that may influence the society and having effects on consumers. E.g. demographic growth, age, health, security

ENVIRONMENTAL

Aspects related to global situation. E.g. global warming, greenhouse effect, natural disaster

The PESTLE framework (also used in form of PESTEC): Aguilar, Francis J. Scanning the Business Environment. New York: Macmillan, 1967. xiii + 239 pp.

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TOOL

Cross-fertilisation

What is this and why should I use it?

This is a workshopping tool aimed at fostering interdisciplinarity and increasing knowledge exchange across technological application areas. This tool is based on multidisciplinary exchange of ideas with experts who know different, but possibly complementary technology frameworks (e.g. AI and cybersecurity).

This tool builds on the PESTLE analysis done in the previous phase of the workshop, bringing the results to be discussed with a wider group of experts.

To meaningfully choose the thematic(s) covered during the cross-fertilization, the expertise of the participants should be considered. The themes should rise from the previous group exercise.

How to use?

1. Two groups of experts from different technology frameworks (e.g. AI and cybersecurity) gather in one room.
2. Facilitators summarise the PESTLE discussions of each of the groups.
3. Each group in turn describes a potential barrier or challenge they have recognised during the PESTLE exercise and want to discuss further.
4. The topics are discussed, specifically aimed at creating shared understanding and finding potential solutions.

60 min.

METHODS & TOOLS

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METHOD

Workshop for evaluating value-sensitivity of technologies

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METHOD

Workshop for evaluating value-sensitivity of technologies

This is a collaborative workshop methodology designed to engage stakeholders in the evaluation and prioritization of responsible Emerging Technologies. It focuses on co-defining evaluation criteria and establishing a priority clustering of technologies with an emphasis on responsible innovation and sustainability.

The methodology leverage co-creation and participatory decision-making to ensure a broad range of perspectives are considered in assessing the potential impact and desirability of technologies. It facilitates a deeper understanding among stakeholders of the societal, environmental, and ethical implications of emerging technologies. The expected outcome is the development of a priority clustering of technologies that reflects a consensus on their potential impact and desirability, considering responsible and sustainable innovation aspects.

The structure of the workshop is designed to take place online, but it can be easily adapted for a face-to-face format.

TIP!

To use this methodology you need:

- Prior analysis should be conducted to form a starting point to the workshop. These should include initial suggestions for the criteria for clustering responsible technologies and a technology catalogue.
- Aim for multidisciplinary, diverse group of participants to achieve multiple perspectives on the evaluation criteria.

METHODS & TOOLS

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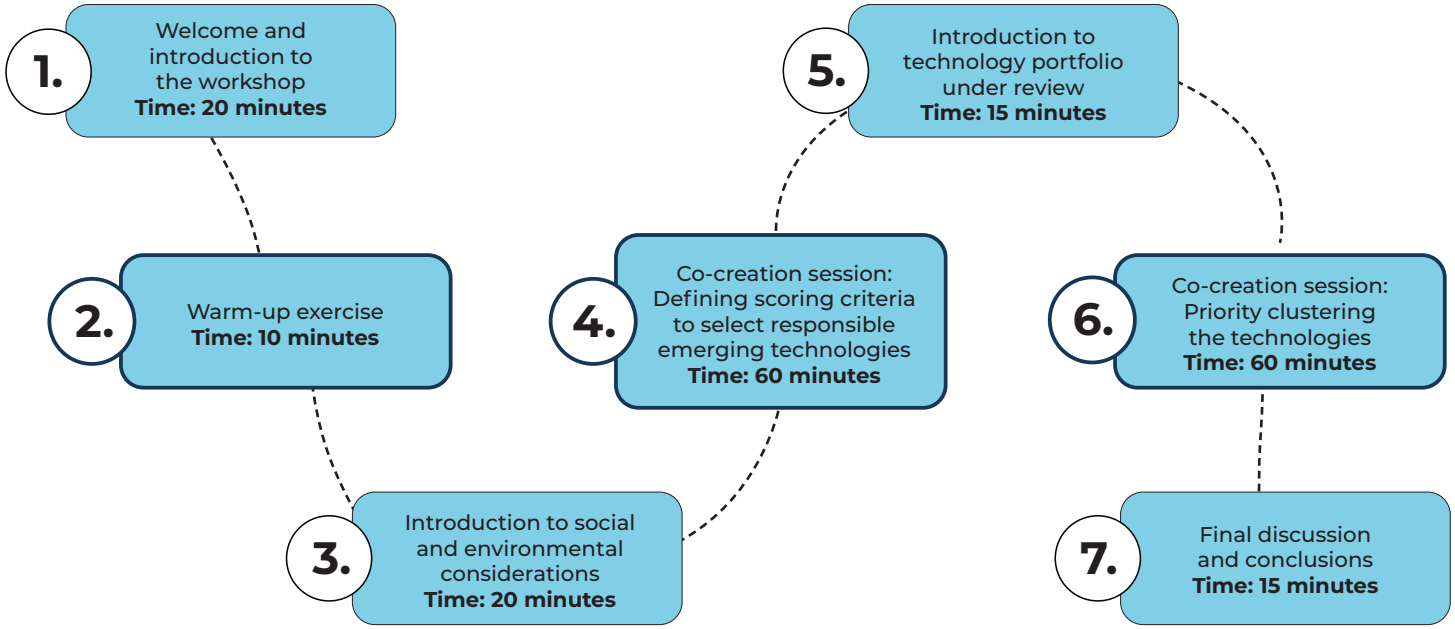
WORK FLOW

Workshop for selecting responsible technologies



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TOOL

Warm-up: Divergent thinking (ME-US)

What is this and why should I use it?

This tool is an icebreaker to be used at the beginning of a workshop to engage the participants. It is a tool that can be adapted to multiple situations (both online and face-to-face). This warm-up allows participants to acclimatize to creativity, preparing the mind for collaborative work and overcoming the initial barrier of expressing their opinions to the group.

There are other warm-up exercises that can be used, such as the “one-two-three exercise” exercise introduced in the Method: Workshops for Exploring the Future Societal Impacts of Emerging Technologies.

How to use?

1. Everyone picks an object on hand or in sight. It has a primary purpose (i.e. how the object is ordinarily used). Think about how it could be used differently.
2. ME: List as many other purposes for the object as possible (2 min).
3. US: Declare the alternative uses we have thought of and see which of us have been more innovative (5 min).

10 min.

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TOOL

Co-defining scoring criteria to select responsible technologies

What is this and why should I use it?

The aim of this workshopping tool is to co-define criteria that can be used to prioritize emerging technology applications that are likely to lead to sustainable and responsible outcomes. The criteria are co-created for three aspects: technical, environmental, and social.

The tool is intended for working on a prior analysis that is introduced to the participants before the co-creation session. Providing participants with a suggested set of criteria and technologies steers the work towards relevant application areas.

It should be ensured that the criteria is drafted for the relevant level of abstraction considering the technological applications that are being evaluated. Too narrow framing makes the exercise difficult, while too broad focus limits the usability of results.

How to use?

1. Introduce background research before beginning to work on the canvas.
2. Allow time for individual thinking and writing in the beginning.
3. Discuss the inputs together. At this point, it is important to give space for the participants' ideas and thoughts, and allow the criteria to be drafted co-creatively during the discussion.
4. As the suggested criteria is in place, let the participants vote for the criteria which they find the most relevant. Let the voting define which criteria are taken up in the latter phases of evaluating emerging technology applications.

60 min.

CANVAS

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TEMPLATE

Canvas for co-defining scoring criteria

TEAM:

In this section you can find an indicative set of criteria. Please provide us with your input in defining criteria to prioritise potentially sustainable and responsible emerging technologies.

INSTRUCTIONS:
1. Add and comment criteria
2. Vote the criteria you believe are most relevant to the technology's responsible development and deployment

SESSION 1: CO-DEFINING SCORING CRITERIA

TECHNICAL

ENVIRONMENTAL

SOCIAL

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TOOL

Clustering technologies of responsible technologies

What is this and why should I use it?

In this workshopping tool, the criteria created in the previous phase of the workshop is utilized to evaluate technologies. This phase assumes a prior analysis to conduct a list of promising technologies to be evaluated. In FORGING, the Strategic Matrix methodology was used to produce a technology portfolio.

The aim of this phase of the workshop is to collaboratively define a priority order of technologies with the highest responsibility potential based on the co-created criteria. The catalogue of technologies presented is evaluated at this stage according to the criteria co-created in the previous session.

Note:
This tool does not produce a quantitative assessment of the technologies but rather facilitates discussion and reflection among participants. For a measurable evaluation, a voting system can be used as an alternative In this version, participants can vote for the technologies they believe best meet the co-created criteria. This provides a quantifiable count of votes received by each technology.

How to use?

1. Participants are invited to position the proposed technologies along a horizontal scale from 1 to 10 for each of the selected criteria. The score reflects how well each technology meets the specific criterion, where 1 indicates a poor fit and 10 indicates an excellent fit.
2. Technologies that are placed in the second half of the scale (the red circles in the canvas) are considered the most promising, as they score highly across the criteria in the technical, environmental, and social categories.

This visual clustering helps prioritize technologies that show balanced strength across multiple sustainability dimensions.

60 min.

CANVAS

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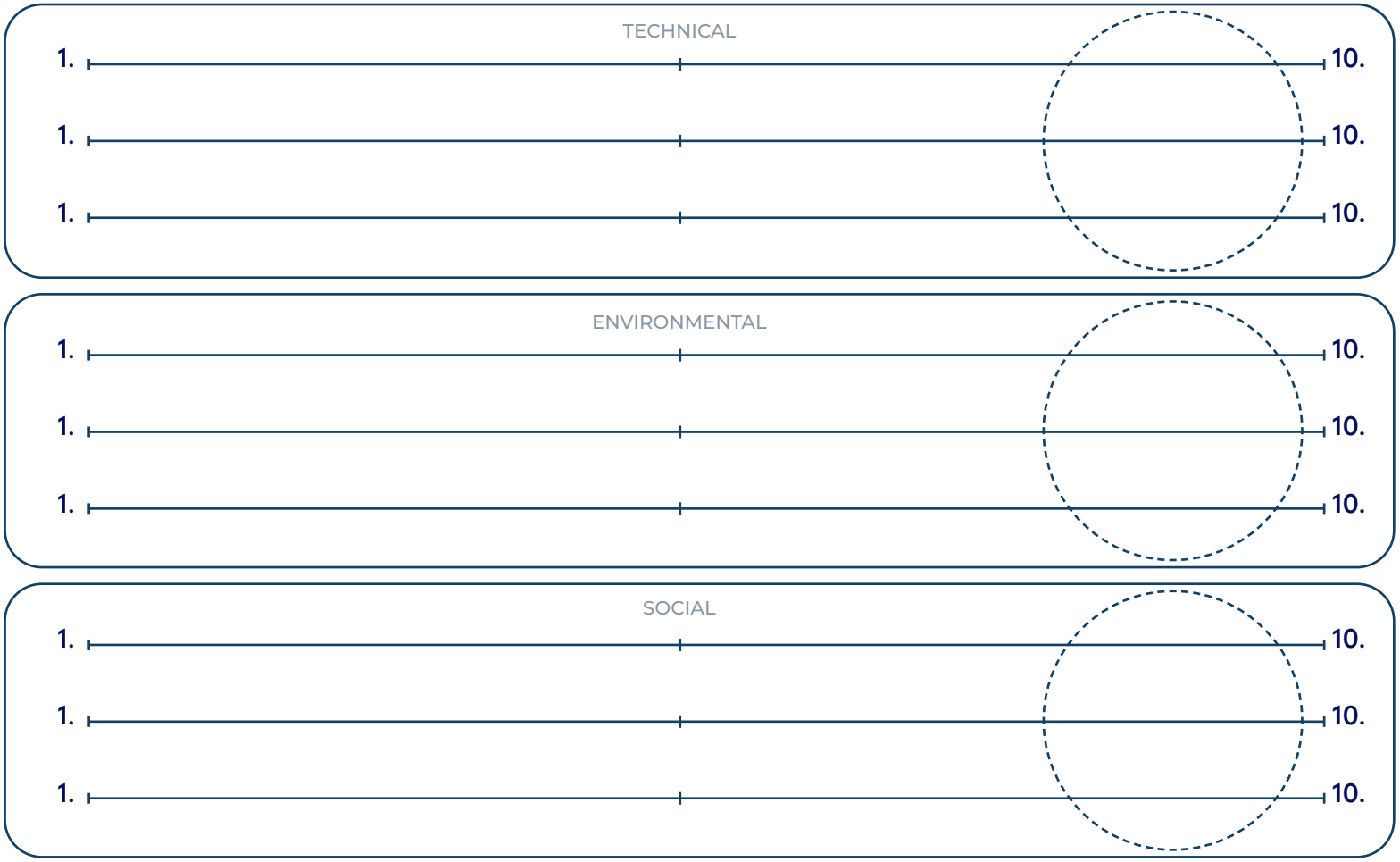
TEMPLATE

Canvas for technology clustering

TEAM:

INSTRUCTIONS:
Place selected technologies along the line of the each criterion according to how well they meet the criterion on a scale of 1 to 10 where 10 is the highest score.

SESSION 2: CO-CREATION OF PRIORITY CLUSTERING



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METHOD

Workshop for emerging technology use case co-creation

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METHOD

Workshop for emerging technology use case co-creation

What is it and why should I use this methodology?

This is a human-centered, need-driven co-creation method aligned with Industry 5.0 values to develop sector-specific use-cases for emerging technologies. The aim is to make technological innovation address real human needs and societal issues rather than only technical features.

This workshop method leads the participants to focus on a specific sector and its needs, aiming at recognizing a technology use case that can answer a critical need in a responsible manner. Value-sensitivity and human-centered approach are at the core of this workshop method. Human and industry needs are taken as a starting point, and emerging technologies are brought in to answer these needs.

This collaborative approach guarantees a gradual convergence from general sectoral issues to tangible, socially relevant use-cases ready for further development

How to use?

To use this methodology you need:

Expertise: Experienced facilitators with skills in managing multidisciplinary groups and guiding co-creation processes. Familiarity with emerging technologies is an advantage.

Participants: A diverse group of stakeholders with varied sectoral and disciplinary backgrounds relevant to the focus topic.

Preparation: initial research and input material is needed, such as technology portfolio to start with.

TIP!

Prior to the workshop, facilitators should align on how to guide each canvas step, ensuring consistency across groups.

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FORGING

Setting the scene with networking

An introductory session (day 1) before the workshop (day 2) is crucial to set up trust, mutual understanding, and motivate the participants. Hosting an evening session on the night before the workshop allows participants to get to know each others in advance, which creates a more open environment for discussions during the workshop.

In this initial session, the project and themes to be tackled in the workshop can be introduced. This is an opportunity to go beyond practical guidance and offer a lecture that arises the participants' curiosity.

You can use a pitching session for inspiration. Allow participants to pitch their own ideas/use-cases that they are working with to make workshop content engaging for them and encourage discussion.

Use the networking cocktail session to encourage casual discussion.

Image: Shutterstock - Viktoria Kurpas

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WORK FLOW

Workshop for emerging technology use case co-creation

DAY 1.

Setting the scene
(approx. 2,5 hours)

1. Opening keynote
   Time: 30 minutes
2. Presentation of the initiative and technologies
   Time: 30 minutes
3. **(Optional) pitching session:** participant use-case presentations
   Time: 30 minutes
4. Networking cocktail and informal exchange
   Time: 60 minutes

DAY 2.

Workshop
(approx. 4 hours)

1. Introduction to methodology
   Time: 20 minutes
2. **Co-creation session 1:** identifying sector specific problems
   Time: 60 minutes
3. **Co-creation session 2:** Detailing a solution's core features
   Time: 50 minutes
4. **Co-creation session 3:** Refining the use-case impacts
   Time: 40 minutes
5. Group presentations and discussion
   Time: 40 minutes

TIP!

Setting the scene and an introductory session is crucial to set up trust, mutual understanding, and motivate the participants. Use the networking cocktail session to encourage casual discussion.

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TOOL

Problem and solution tree

What is this and how should I use it?

This workshopping tool utilizes a specific canvas to choose a crucial problem in a specific industry, and collaboratively work towards finding an effective solution.

In the first part of the exercise, the underlying causes and effects of the chosen problem are mapped. Then, they are converted into needs and desired results. “Negative effects” of the problem are turned into the expected impacts of the proposed solution.

How to use?

1. Select in the group an industry sector you want to discuss.
2. Start with the problem tree. First, identify a specific problem in the selected sector. Then, identify its root causes and effects. Use post-its to fill in the canvas.
3. Move on to the solution tree. Propose a (technological) solution to the discussed problem. Discuss the industry sector’s needs and impacts related to the proposed solution. Use post-its to fill in the canvas.

60 min.

CANVAS

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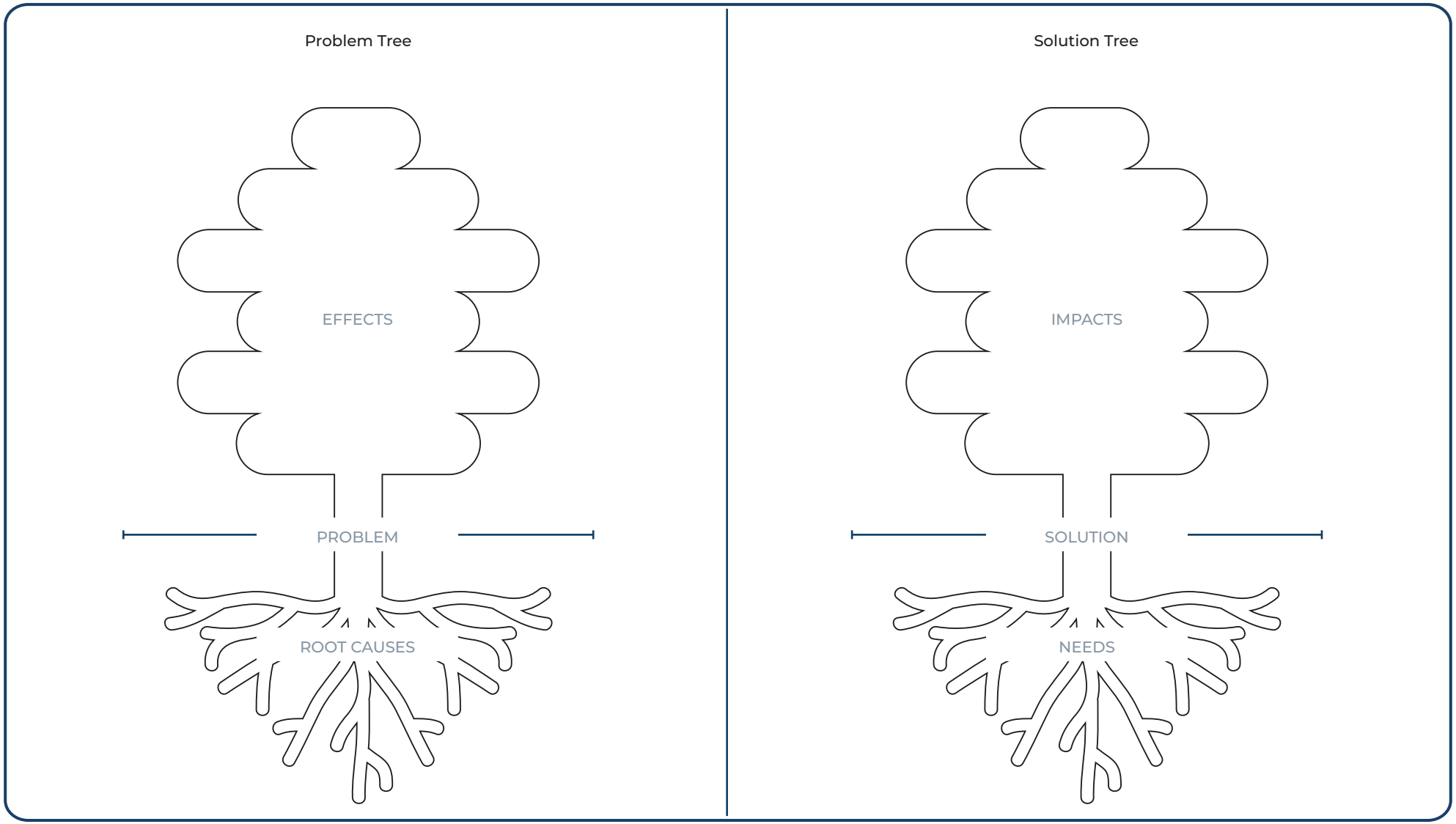
TEMPLATE **Problem and solution tree**

TEAM:



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TOOL

Feature canvas

What is this and how should I use it?

Once a potential solution has been identified with the problem and solution tree exercise, this feature canvas is used for deeper exploration of the features of the potential solution.

With this canvas, you can examine the context, enabling technologies, actors, value propositions, resources, and possible barriers for suggested solution. The key question to answer is whether one of the presented technologies has the potential to facilitate the fulfilment of the identified needs. The exploration enables a deeper understanding of the potentials and limitations of the solution.

How to use?

1. Start with the solution identified in the problem and solution tree canvas.
2. Go through the boxes of the feature canvas one by one, detailing the key features of the solution. You can start from the questions that are easy to answer for your group and fill in the boxes in any order.

50 min.

CANVAS

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TEMPLATE **Feature canvas**

TEAM:

FRAME YOUR IDEA

KEY SECTOR
Which is the sector?

MAIN PROBLEM
What is the main problem we would like to address?

PROPOSED SOLUTION
What is the solution we envisage?

VALUE PROPOSITIONS
What value do we deliver to the end-users?

MATCH NEED AND TECHNOLOGY
Does one of the technologies have the potential to meet the need? Why? How?

KEY ACTORS
Who are our actors affected by the problem?

KEY RESOURCES
What key resources do our value propositions require?

FEASIBILITY VS RESTRICTIONS AND LIMITATIONS
What can prevent us from solving these problems and supporting people in these situations?

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TOOL

Use-case canvas

What is this and how should I use it?

This canvas focuses on expanding the thinking process towards wider societal and environmental impacts. This canvas can be used to work on the solution detailed in the feature canvas. Different probes and tools can be utilized to expand the participants perspectives on the social and environmental impacts of their proposed solution. For example, the **“Perspective Cards”**, can serve as probes to add perspectives to the discussions.

How to use?

1. Start with the use-case detailed in the feature canvas. Write the basic info about the use-case in the use-case canvas based on earlier discussion.
2. (Optional): Use probes, such as Perspective Cards, to kick-start the discussion about the impacts of your solution.
3. Fill in the most important benefits and impacts of your solution, considering both social and environmental aspects.

40 min.

CANVAS

TIP!

Encourage groups to look at both positive outcomes and potential negative societal or environmental impacts.

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TEMPLATE **Use-case canvas**

TEAM:

USE - CASE

ADD HERE THE TITLE OF YOUR USE-CASE:			ADD HERE YOUR TARGET GROUP:
NEED	**SOLUTION**	**BENEFITS**	**IMPACTS**
NEED? Which major user needs are being addressed?	**WHAT?** What is your solution?	**SOCIAL** What are the social benefits?	**SOCIAL** What are the social impacts?
	HOW? How the technology will serve the solution?	**ENVIRONMENTAL** What are the environmental benefits?	**ENVIRONMENTAL** What are the environmental impacts?

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METHOD

Technology pathways for absorption and deployment of value-sensitive technologies

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METHOD

Technology pathways for absorption and deployment of value-sensitive technologies

Technology pathways development methodology aims to facilitate absorption and deployment of emerging technologies through co-creation. The method enables acceleration of the technology development through collaborative R&D projects. It brings together all relevant stakeholders needed to develop the technologies, actors with complementary technologies, industrial partners able to commercialise the technology, those able to adopt the technologies and regulators, policy makers and the civil society that may be impacted by the technologies.

The workshop methodology is based on a series of structured discussions led by a highly experienced technical expert with a vision of a particular technology deployment to address a specific existing need. Active participation of all stakeholders leads to success.

In FORGING project this method was deployed after the technology use case co-creation activities. The use cases were a starting point for the technology pathway development.

How to use?

To use this methodology you need:

- An experienced collaborative R&D bid writer, a brief concept note of the project, a funding opportunity identified, a willing and able technical lead, a critical mass of stakeholders with complementary roles in the project.
- Several online meetings to present the project and refine the outline, define partner roles and their match against the funding requirements.
- An in-person all-day workshop to flesh out the workplan, the expected impact of the project and the science behind it.
- A mix of online and offline sessions to prepare a written collaborative R&D project proposal

TIP!

Timing is of crucial importance as there needs to be enough time for stakeholders to prepare a high-quality project proposal but also not too long to risk distractions coming in the way.

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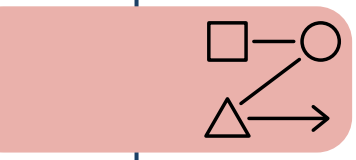
WORK FLOW

Technology pathways for absorption and deployment of value-sensitive technologies



STEP 1. Online meeting

1. Presenting the project outline, and identifying needed partner roles and a funding opportunity

STEP 2. Follow-up meetings

2. Revising state-of-the-art, closing the project outline and the consortium

STEP 3. In-person workshop at the technology adopter/end user site

3. Facilities visit (if possible) - preferably end user

4. Presentation of the technology adopter´s challenge/need **Time: 15 minutes**

5. Facilitated co-creation session using Impact Canvas **Time: 2 hours**

6. Facilitated discussion on requirements or barriers that may arise **Time: 1 hour**

7. Workplan co-creation facilitated by the technical lead **Time: 3 hours**

8. Identification of the science (state-of-the-art) behind the project facilitated by the technical lead **Time: 1 hour**

STEP 4. Online iteration

9. R&D bid writer leads the proposal development via online engagements until ready for submission.

TIP!

Note: Step 1 to Step 4 can take from 3 to 12 months depending on project size, maturity of the proposed outline and availability of the stakeholders to work on the proposal.

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TEMPLATE **Project outline**

TEAM:

The project outline should answer the following questions:

WHO? Which concrete sectors? Who are the existing industrial players in the area?	WHY? Which matter does the new technology address? What can be their impact on business? What relative advantages of new technologies? Which cross-sectorial effects can it generate?
WHAT? Which specific new technology will be adopted? Which are the relevant value and supply chains and which value they accumulate	HOW? How can it be financed? What are the options to test the innovation before making an adoption? Which are the skills required? Are there any other technologies/ services needed to be brought together to make viable products work?

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TEMPLATE **Impact Canvas 1/3**

TEAM:

IMPACT canvas is crucial in elaborating a collaborative R&D project proposal because it shows how the project will deliver real-world benefits aligned with country or region-specific priorities, ensuring the use of funds create societal, economic, or environmental value. It also demonstrates a clear plan for how results will be used, shared, and sustained beyond the project's lifetime.

SPECIFIC NEEDS/CHALLENGES

Add learnings from the end user presentation on their specific needs/ challenges that can be addressed with the technologies to be developed.

EXPECTED RESULTS

Describe the key results your project will deliver, e.g. new device, platform, method, dataset, process, proof-of-principle, etc.

OUTCOMES

State the most important scientific and/or technological outcomes expected by the end of the project. These are the critical stepping stones toward achieving long-term impact.

Main expected outcomes of the project:
State how these outcomes go beyond current capabilities and represent
a radical innovation

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TEMPLATE **Impact Canvas 2/3**

TEAM:

IMPACT canvas is crucial in elaborating a collaborative R&D project proposal because it shows how the project will deliver real-world benefits aligned with country or region-specific priorities, ensuring the use of funds create societal, economic, or environmental value. It also demonstrates a clear plan for how results will be used, shared, and sustained beyond the project's lifetime.

TARGET GROUPS

- Which key actors will play a central role in turning project results into
- Future innovations (e.g. industry, innovation hubs public agencies, early stage researchers, investors, policy makers, academics)?
- What specific expertise, resources, or networks do these actors bring?
- How and when will you engage them throughout the project?
- What support, capacity-building or incentives will be provided to enable their engagement in the post-project phase?
- What mechanisms (e.g. co-design workshops, pilot deployments, advisory boards) will ensure their active involvement?

IMPACTS

Economic Impact
- How the outcomes lead to new markets, industrial applications, start-ups, spin-offs, or competitiveness gains?
- Identify the sectors or industries most likely to be affected and how.
- Include expected time horizon and scale of economic effect.

Technological Impact
- How will this technology enable or accelerate other innovations?
- How can this technology influence future research trends?
- Any measurable technical KPIs you can list here?

Environmental Impact
- How the outcomes contribute to sustainability, resource efficiency, emissions reduction, pollution prevention, or circular economy?
- Clarify the type of environmental benefit and provide estimates where possible.

Societal Impact
- How the project improves quality of life, equity, inclusion, education, or citizen engagement?
- Identify the societal groups or communities that benefit most from this project.

INNOVATION POTENTIAL

- What novel capability will your project deliver?
- What future innovations or applications could emerge from it?
- Which market(s) or sectors could be significantly transformed or newly created?
- How might these results be exploited after the project?
- What actors or pathways could enable commercialization?
- Could this breakthrough lead to additional enabling concepts, either
- technological or societal?

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TEMPLATE **Impact Canvas 3/3**

TEAM:

IMPACT canvas is crucial in elaborating a collaborative R&D project proposal because it shows how the project will deliver real-world benefits aligned with country or region-specific priorities, ensuring the use of funds create societal, economic, or environmental value. It also demonstrates a clear plan for how results will be used, shared, and sustained beyond the project's lifetime.

COMMUNICATION & DISSEMINATION & EXPLOITATION MEASURES

Communication (communicate about project and the results), Dissemination (Share project results with targeted audiences who can benefit from them), Exploitation (Use project results for commercial, societal or policy-purposes).

Describe the dissemination and communication measures that are planned, and the target group(s) addressed (e.g. scientific community, technology scale up facilitators, end users, funders, citizens) for raising awareness about the project's outcomes (can include KPIs such as number of publications, citations, workshops, attendees...).

Communication measures should promote the project throughout the full lifespan of the project. The aim is to inform and reach out to society and show the activities performed, and the use and the benefits the project will have for citizens.

Activities must be strategically planned, with clear objectives, start at the outset and continue through the lifetime of the project. The description of the communication activities needs to state the main messages as well as the tools and channels that will be used to reach out to each of the chosen target groups.

All measures should be proportionate to the scale of the project, and should contain concrete actions to be implemented both during and after the end of the project, e.g. standardisation activities. Your plan should give due consideration to the possible follow-up of your project, once it is finished. In the justification, explain why each measure chosen is best suited to reach the target group addressed.

Describe possible feedback to policy measures generated by the project that will contribute to designing, monitoring, reviewing and rectifying (if necessary) existing policy and programmatic measures or shaping and supporting the implementation of new policy initiatives and decisions.

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TOOL

Requirements and Barriers Canvas

What is this and why should I use it?

Requirements canvas outlines requirements and potential barriers that may jeopardize the execution of the project. Bringing them to awareness helps ensure realistic planning and risk management. It creates shared understanding of what's needed for success, and that the impact of the requirements and barriers was taken into account, making the project proposal more credible and robust.

In FORGING project this method was deployed as a last stage of the project, after the technology use case co-creation activities. The use cases elaborated were a starting point of the technology pathway development.

TIP!

The requirements and barriers are not the same as critical risks of a project. The risks are uncertain events that, if they occur have a significant negative impact on the project execution, whilst requirements are essential conditions needed for project to succeed and barriers are obstacles that may hinder project progress.

CANVAS

METHODS & TOOLS

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TEMPLATE **Requirements and Barriers Canvas**

TEAM:

REQUIREMENT OR BARRIER	IMPACT IF UNRESOLVED	MITIGATION STRATEGY / ENABLING MEASURE
Legal / Policy Regulatory approval for technology deployment	Could delay or block market entry	Early dialogue with regulators; compliance by design
Technical Availability of high-purity materials for fabrication	May affect feasibility or scalability	Develop alternative supply chains or in-house synthesis
Societal / User User acceptance of novel interface or device	Limited adoption or use-case integration	User centred design; stakeholder engagement from early stages
Societal / User User acceptance of novel interface or device	Delays in demonstration and performance validation	Secure access via partners or external test-beds
Market / Technical Lack of standardization or interoperability protocols	Limits integration into existing ecosystems	Contribute to standards development and ensure modularity

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METHOD

Measuring the impact of emerging technologies in their early stage

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METHOD

Measuring the impact of emerging technologies in their early stage

This method, inspired by a work from Wikström et al. (2024), centers on Key Values (KV) and Key Value Indicators (KVI). The approach emerged from a realization that traditional metrics and indicators were inadequate for capturing the true value of emerging technologies: the stakeholders were more focused on the values and real-world problems that technology could directly address.

In FORGING project, a bottom-up methodology was created based on the Quadruple Helix (4H), which involves businesses, academia, administrations, and citizens. This ensured that the values identified were not abstract but were a genuine reflection of the needs and aspirations of all stakeholders. This approach effectively reveals the social and transformative value of technology even in its nascent stages. KV and KVI provide a common language to align technological goals with societal needs, offering a more human-centered approach to impact assessment.

As a result, Value-driven Impact Assessment based on KV and KVI methodology allows for the creation of a new paradigm for quantifying technological impact and more human-centric way to measure innovation.

How to use?

To use this methodology you need:

- An understanding that the method prioritizes value over metrics at the early stages of technological development.
- Stakeholders representing diverse perspectives, including businesses, academia, administrations, and citizens, to ensure the values identified are a genuine reflection of real needs.
- A workshop setting that encourages participants to share stories and aspirations related to real problems in their daily lives.

TIP!

By using KV and KVI, you can reveal the hidden social and transformative value of technology in its early stages and ensure that its potential impacts align with the values of the people involved.

Wikström, G., Bledow, N., Matinmikko-Blue, M., Breuer, H., Costa, C., Darzanos, G., Gavras, A., Hossfeld, T., Mesogiti, I., Petersen, K., Porambage, P., Stoica, R.-A., & Wunderer, S. (2024). Key value indicators: A framework for values-driven next-generation ICT solutions. Telecommunications Policy, 48(6), Article 102778. https://doi.org/10.1016/j.telpol.2024.102778

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WORK FLOW

Measuring the impact of emerging technologies in their early stage

STEP 1. Workshops

1. **Organize initial workshops:** Focus on discovering the values and real-world problems of the participants, rather than traditional metrics.

STEP 2. Methods

2. **Investigate and adapt:** Look into existing methodologies but be prepared to find they don't meet the need. The goal is to build a process tailored to your project.

STEP 3. Indicators

3. **Translate values into indicators:** Use the KV and KVI concepts to turn the values identified in the workshops into a measurable form.

STEP 4. Validation

4. **Implement a bottom-up approach:** Involve stakeholders from the Quadruple Helix (4H)—businesses, academia, administrations, and citizens—to ensure the values are a genuine reflection of their needs.

STEP 5. Usage

5. **Use for use cases:** Apply the methodology to project use cases to reveal the social and transformative value of the technology.

TIP!

Pitfalls to avoid?

- Do not rely on existing methodologies like SRL and other impact analysis approaches, as they often do not capture the importance of the values identified in early development workshops.
- Avoid a top-down, theoretical approach. The method should be built from the ground up, adapted to the specific reality of the project and the needs of the stakeholders.
- Ensure the process actively involves all stakeholders to avoid the values becoming an abstract list.

METHODS & TOOLS

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FORGING

NEXT GEN PUBLIC ADMINISTRATION

Objective: Enhance trust, security and integrity in public administration through distributed data storage, secure-by-design architecture, and standardised data classification.

Challenges and Socials Needs: Low trust in public administration, cyber risks, poor digital literacy, insecure data handling. Unequal digital literacy, exclusion risks, limited data rights awareness.

KV:
Environmental: Paperless processes, digital resource efficiency.
Social: Trust, transparency, digital rights, inclusivity.
Economic: Cost reduction, cybersecurity resilience.

KVI:
KVI (Environmental): % of administrative transactions performed without paper
KVI (Social): % of citizens reporting increased trust in data systems
KVI (Economic): % reduction in public administration data breach costs

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ATTACHMENT

Perspective Cards

TECHNOLOGIES FOR ENERGY EFFICIENCY AND TRUSTWORTHY AUTONOMY

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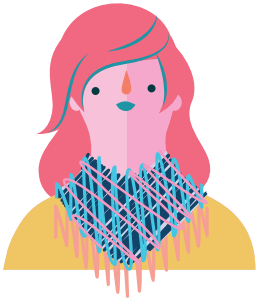
FORGING

DEVELOPER

QUESTIONS TO CONSIDER:

- Can I develop solutions that make use of energy waste, for instance excess heat?
- How can I balance between the aim for developing energy efficient systems and the need for clean energy solutions that may be less efficient?
- How do I balance between the need for novel efficient clean energy solutions and the environmental costs of their production?
- How can I contribute to introducing more sustainable energy solutions to very energy intensive industries?
- Can I develop solutions that do not require any energy use?
- How can I involve users and citizens in the development to better understand the impacts of my energy solutions?
- New questions?

CITIZEN



QUESTIONS TO CONSIDER:

- Do I have access to electricity and energy regardless of my socio-economic status?
- Is my voice heard when energy systems are being planned in my living environment?
- Can I have influence on ensuring equal access to electricity in my community?
- Am I being treated fairly in the development of novel energy systems?
- Can I take a more active role in my energy usage, e.g. by setting up or joining a community focused on the production and distribution of energy?
- Where can I find information and help when looking to minimize my energy consumption?
- New questions?

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FORGING

USER

QUESTIONS TO CONSIDER:

- Can I trust that I am being offered the most sustainable energy solutions?
- Am I supported to find ways to minimize my energy consumption?
- Do I have incentives to make investments to more sustainable energy solutions affecting my daily use of energy?
- Do I have enough information on the sustainability of different solutions to compare and choose between alternative options?
- Is the burden of minimizing the rebound effect (meaning that energy efficiency in one place often leads to more energy usage somewhere else) on my shoulders alone?
- Can I trust that the energy systems I depend upon are robust and resistant to external threats?
- New questions?

REGULATOR

QUESTIONS TO CONSIDER:

- How can I incentivise the research and development of novel energy solutions that are sustainable throughout their life-cycle, from material sourcing through to production processes, and potential environmental impacts?
- How can I develop regulations that promote user control and decision-making within energy systems, ensuring equitable access and affordability?
- How can I enforce comprehensive life-cycle assessments and transparent risk management protocols for novel large-scale energy solutions?
- How can I contribute to the development of regulations for an ethical development and deployment of autonomous systems, whilst addressing concerns about data privacy, transparency and human oversight?
- How can I ensure that the design of regulations for the energy sector fully incorporates mechanisms for periodic participatory review and updates based on emerging technologies and societal needs?
- Considering the interconnectedness of energy systems, how might the development of common standards contribute to international collaboration to address global energy challenges?
- New questions?

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FORGING

INVESTOR

QUESTIONS TO CONSIDER:

- How can I best identify high-impact, early-stage energy solutions considering both technological breakthroughs and behavioural changes?

- How can I assess the level of risk associated with investing in autonomous decision-making systems applied to critical infrastructure?

- How can I make sure that my investment decisions contribute to equitable access to clean energy and to the empowerment of marginalised communities?

- How can I best determine the potential for unintended consequences of novel energy technologies such as rebound effects, resource scarcity or environmental degradation?

- Have I considered the option to prioritise investing in adaptable solutions with modular designs and open-source elements, even if this means incurring in higher initial development costs?

- Do I participate sufficiently in collaborative initiatives that address specific societal challenges, even if the financial returns are less immediate or indirect?

- New questions?

MALICIOUS AGENT

QUESTIONS TO CONSIDER:

- How can I exploit vulnerabilities in autonomous energy management systems to disrupt critical infrastructure, for instance through manipulating energy consumption or creating blackouts?

- Can I leverage the use of decentralised energy solutions such as microgrids for the manipulation of energy prices?

- Can I manipulate the algorithms used in energy distribution systems to impact specific communities or sensitive ecosystems?

- Can I exploit security vulnerabilities or potential environmental accidents to create distrust in novel energy solutions?

- How can I influence investors to prioritise short-term benefit over long-term sustainability goals?

- How can I exploit open-source technologies and collaborative research and development initiatives to obtain undue control over critical energy infrastructure?

- New questions?

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FORGING

CYBER SAFE DATA TRANSMISSION, STORAGE, AND ANALYSIS TECHNOLOGIES

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FORGING

DEVELOPER

QUESTIONS TO CONSIDER

- How can I minimize the environmental footprint of the solutions both in the usage of equipment and in the conservation of energy?

- How can I design and implement secure systems that protect critical infrastructure, such as power grids, transportation networks, and communication systems, from cyberattacks?

- How can I place the user at the center of my design process in ways that adequately consider the ethical capture, storage and processing of data?

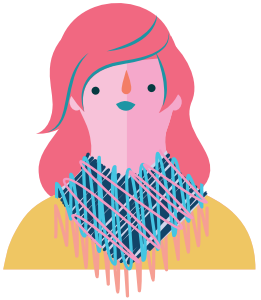
- How do I make sure that my design process addresses the unmet needs of traditionally unrepresented groups?

- Am I confident that the products or services I develop fully take account of social and environmental impacts?

- Can there be an alternative to a patching approach when confronting security gaps?

- New questions?

CITIZEN



QUESTIONS TO CONSIDER:

- What kinds of safeguards can be implemented to protect my individual privacy rights?

- How much do I know about the roles and obligations of those that collect or process the data?

- What is my personal responsibility over the protection of my privacy?

- Do I understand enough about the potential implications of the data usage to my life?

- Do I know enough to make others accountable for the breaches to the integrity of my data?

- To what extent can I take an active role in the design of the technologies that enable safe data collection, transmission and processing?

- New questions?

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FORGING

REGULATOR

QUESTIONS TO CONSIDER:

- Can I establish sufficient incentives / deterrents to ensure the best possible data security approaches are being applied in the market?
- How can I make sure markets have enough players to avoid concentration of power for too few actors?
- How can I best create an environment of collaboration with cybersecurity experts, law enforcement agencies, citizens, and government regulators to combat cybercrime?
- How can I ensure there is a balance between the need for cybersecurity and other important factors, such as economic growth, privacy, and civil liberties?
- How can I further international cooperation to establish and enforce cybersecurity standards for critical infrastructure, financial institutions, and other sectors?
- How can I collaborate more proactively with technology developers to implement effective cybersecurity standards and practices?
- New questions?

USER

QUESTIONS TO CONSIDER:

- Do I understand the risks and implications involved in using data collection, storage and processing systems that might not be secure enough?
- Do I have the financial resources to implement cyber security measures?
- Do I understand where, how, by whom and for what purposes my data is being used?
- Am I confident in the degree of knowledge that I have about novel threats and vulnerabilities in the systems that I use?
- Do I have the capabilities to implement cyber security measures?
- Do I have a choice between more secure options?
- New questions?

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INVESTOR

QUESTIONS TO CONSIDER:

- Do my investment decisions consider the development of usercentric security solutions that offer users greater control over their data?
- How can I move beyond static defense principles and embrace proactive threat detection and response mechanisms?
- Do my investment decisions prioritise companies developing security solutions that are adaptable, compatible and interoperable with existing infrastructure?
- How can I prioritise sustainable security investments and identify companies developing cyber security solutions that offer robust encryption while minimising energy consumption and computational resources required?
- How can I support the development of open-source security frameworks that are based on community collaboration for faster innovation while maintaining robust access controls and the right mechanisms to prevent malicious exploitation?
- How can I ensure that companies developing AI-powered security solutions demonstrate a commitment to fairness, accountability, and transparency?
- New questions?

MALICIOUS AGENT

QUESTIONS TO CONSIDER:

- How can I identify vulnerabilities in data collection, storage and transmission systems?
- How can I best exploit vulnerabilities in data collection systems, such as online forms, mobile apps, and social media platforms?
- How might I use emerging techniques to automate attacks, evade detection, and manipulate data?
- How might I use cyberattacks as weapons of war to disrupt critical infrastructure and compromise national security?
- How might I exploit the unique security challenges posed by the increasing integration of digital devices into critical infrastructure systems and the everyday life of citizens?
- How might I use targeted cyberattacks to manipulate financial markets, steal funds from financial institutions, or disrupt financial transactions?
- New questions?

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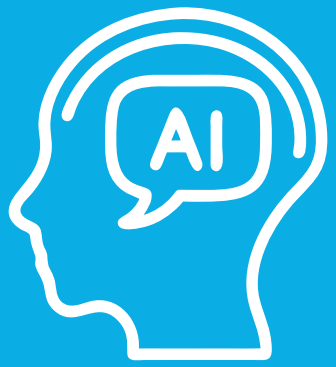

ARTIFICIAL INTELLIGENCE

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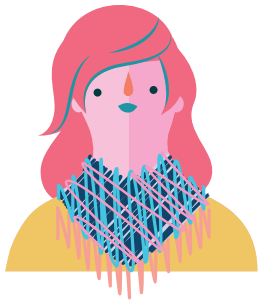
DEVELOPER

QUESTIONS TO CONSIDER:

- How can I design unbiased AI?
- What kinds of applications should I design to serve humanity's interests? What should I not?
- Can I design AI applications to help us become more ecological?
- Do I have the right data for building accurate models?
- How can I influence the most ecological hardware solutions?
- How can I develop solutions that require relatively less computing power?
- New questions?

CITIZEN



QUESTIONS TO CONSIDER:

- How does AI contribute to a desirable future for all?
- Can I have influence on what kinds of AI applications are available?
- Do I understand enough about the training or build the models for AI?
- Will I be able to maintain enough connections to other humans, in physical settings?
- Can I resist the lure of technologies even if I felt they were not to my benefit?
- Am I more afraid of the negative outcomes that I can see the potential benefits?
- New questions?

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REGULATOR

QUESTIONS TO CONSIDER:

- How can I proactively collaborate with all stakeholders to implement effective regulation to target emerging societal issues?
- How can I protect vulnerable groups, such as children, from harmful use of AI?
- Should individuals have a chance of refusing the use of AI? How can I ensure it?
- How can I regulate for emerging technologies that could be harmful to society?
- How can I make sure there are enough intensives and deterrents for minimizing the energy usage of AI?
- How can I make sure markets have enough players to avoid concentration of power for too few actors?
- New questions?

USER

QUESTIONS TO CONSIDER:

- Do I understand the risks and implications involved in using AI?
- Does the AI application exclude me as a user?
- Do I know when I am interacting with a human, and when with an AI?
- What are the needs where AI best serves me?
- Do I feel I am a part of the process and practice of developing AI?
- Do I think of AI as a technology or as a being I have a relation to?
- New questions?

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INVESTOR

QUESTIONS TO CONSIDER:

- How do I identify and prioritize investment proposals that have a significant impact on the betterment of human lives, such as making better decisions or making mundane tasks easier?

- How do I purposefully balance between open science and protecting intellectual property rights, considering both potential misuse of data or technologies and the use purposes that might require licensing?

- How do I ensure that my investments contribute to societally acceptable, environmentally sustainable, and ethical development of AI?

- When do I need to decide to not develop AI applications for certain functions?

- How my investments support making a clear distinction between AI powered applications and human interaction?

- How can my investment decisions support the creation of a world where the users can opt out from the use of AI applications that could potentially be harmful for them?

- New questions?

MALICIOUS AGENT

QUESTIONS TO CONSIDER:

- How can I exploit emerging vulnerabilities for my own benefit?

- How can I manipulate individuals, publics and decision-makers through fake news, propaganda, and deepfakes?

- How can I use AI to develop autonomous weapons to promote my objectives?

- How can I use AI to gather data on individuals and use it to reach my goals?

- How can I use AI to launch sophisticated cyber-attacks?

- How can AI be used to manipulate markets, for instance though manipulating stock prices or engaging in high-frequency trading?

- New questions?

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BIO-INSPIRED TECHNOLOGIES AND SMART MATERIALS

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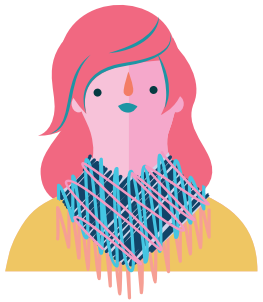
DEVELOPER

QUESTIONS TO CONSIDER:

- How can I make sure the materials I develop do not promote the use of virgin natural resources?
- Can I turn waste or pollution into materials?
- How do I make sure that the materials I develop can be recycled and / or composted?
- How do I change the perspective of my development work from the aim to satisfy human needs to the aim to balance the natural ecosystems?
- Am I trying to understand the consequences of the innovations I develop from the perspective that they will be scaled up, and part of every-day practices?
- How can I take into account the whole production and life cycle of the innovations I am developing so that their sustainability can be ensured?
- New questions?

CITIZEN



QUESTIONS TO CONSIDER:

- Can I trust that the sustainability of the novel materials has been assessed from multiple perspectives, and with consideration of different environmental values, such as climate change, biodiversity and toxicity?
- Am I able to experiment with new materials or is their use restricted by licences?
- Can I trust that there are processes in place that evaluate the costs of new materials primarily from their whole costs to ecosystems and the society?
- Is there an equal access to new materials with active (sensing, responding) and passive (antibacterial) functionalities that can enhance the quality of life?
- Are systems for recycling novel materials available and accessible to me?
- Can my community afford novel, more sustainable solutions and materials?
- New questions?

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REGULATOR

QUESTIONS TO CONSIDER:

- How can I balance the need for innovative R&D with the mitigation of potential risks related to untested functionalities and unknown long-term impacts?

- How can I make sure, from a standards perspective, that bioinspired technologies and smart materials effectively promote sustainability throughout their lifecycle at the levels of material sourcing, production processes, and end-of-life options?

- How can I ensure, from the perspective of regulations, the safety and privacy of users interacting with smart materials that have sensing and responding functionalities?

- How can I ensure that the benefits of bio-inspired technologies and smart materials are distributed fairly and equitably across user groups from the point of view of accessibility, affordability and bias limitation?

- How can I manage the burden on resource exploitation associated with the large-scale adoption of bio-inspired technologies and smart materials?

- How can I develop regulations and evaluation mechanisms that anticipate and evaluate the unforeseen long-term social and environmental impacts of bio-inspired technologies and smart materials?

- New questions?

USER

QUESTIONS TO CONSIDER:

- Do I have available products or services that have minimized the use of materials in their production?

- Can I select products that have been produced locally?

- When using smart materials that have functionalities affecting me or my direct environment, do I understand my rights and the implications to my privacy?

- Can the products that I have be repaired and are they reusable?

- Are health-care solutions based on new materials and biosensing based solutions available to me?

- Are the novel products/ services enhancing or extending my abilities in ways that I understand to be useful and beneficial?

- New questions?

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FORGING

INVESTOR

QUESTIONS TO CONSIDER:

- How can I identify high impact of bio-inspired technologies and smart materials whilst mitigating potential risks related to untested functionalities and environmental impacts?

- How can I assess the long-term commercial viability of new materials from the perspective of user trust and adoption, production costs, regulatory compliance and competition from established industries?

- How can I ensure that my investment decisions in bio-inspired technologies and smart materials contribute to social inclusion and equity and address access disparities and potential job displacement challenges?

- How can I comprehensively evaluate the sustainability of new materials throughout their lifecycle from the perspectives of circularity, waste reduction and resource conservation?

- How can I anticipate the evolving ethical concerns and unforeseen potential disruptions to existing industries?

- How can I collaborate more pro-actively with other entrepreneurs, researchers and regulators to create an ecosystem for the responsible development and deployment of bio-inspired technologies and smart materials?

- New questions?

MALICIOUS AGENT

QUESTIONS TO CONSIDER:

- How can I disrupt the early-stage research of bio-inspired technologies and smart materials through introducing undetected vulnerabilities and harmful functionalities?

- How I exploit the properties of new materials with active or passive functionalities to create new weapons or tools for espionage or social manipulation?

- How can I exploit security gaps in smart materials that may be used to attack critical infrastructure?

- How can I exploit bias in AI-enabled material design to target specific groups and exacerbate social inequalities?

- How can I exploit the complexity of long-term material interactions and leverage the potential of delayed toxicity and ecological imbalances?

- How can I disrupt the public perception of new materials to create distrust and harm confident adoption?

- New questions?

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FORGING

HUMAN-CENTRIC SOLUTIONS AND HUMAN-MACHINE-INTERACTION

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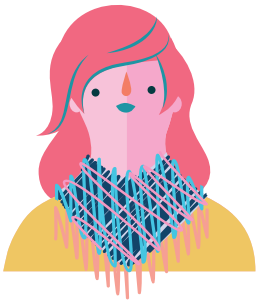
FORGING

DEVELOPER

QUESTIONS TO CONSIDER:

- How can I develop human-centric solutions that are intuitive, user-friendly, and ethical?
- How can I leverage the latest advancements in NLP, human augmentation, AR/VR, explainable AI, collaborative robotics, and ethical AI to create innovative solutions?
- How can I support individuals in the utilization of technologies, including AI, to enhance their capabilities and fully reach their creative potential?
- How can I develop human-centric solutions that improve healthcare outcomes, facilitate personalised medicine, and tailor treatments to individual patients' needs?
- How can I involve users in the design process to ensure that my solutions meet their needs and preferences?
- How can I make sure that critical solutions (e.g. when inserting technology to human bodies) cannot be attacked to harm the user?
- New questions?

CITIZEN



QUESTIONS TO CONSIDER:

- How can human-centric solutions improve my quality of life and make my interactions with technology more seamless, intuitive and personalised?
- How can I ensure that human-machine interaction is safe, fair, and respectful of my privacy and autonomy?
- How can I be an active participant in shaping the development and use of human-centric solutions?
- How do I develop my own worldview when decision-making is strongly guided by technology?
- How can I identify and support companies that are developing and implementing sustainable human-centric technologies?
- How can I contribute towards a balance between open collaboration enabled by human-centric technologies and the safeguarding of individual creativity?
- New questions?

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FORGING

REGULATOR

QUESTIONS TO CONSIDER:

- How can I establish clear guidelines and regulations to ensure the responsible development and use of human-centric solutions?
- How can I promote ethical practices and prevent the misuse of human-machine interaction for malicious purposes?
- How can I, in practical terms, balance the benefits of human-centric solutions with the need to protect individuals' rights and privacy?
- How do I ensure that citizens have an equal access to technology so that deepening inequalities and divides in access to knowledge can be avoided?
- How can I balance the economic benefits of technological advancements in human-centric solutions and human-machine interaction with the potential risks of job displacement and social disruption caused by the pursuit of an optimization rationality?
- How can I ensure that bodily enhancements that might become necessary for certain jobs or positions do not create cognitive or physical harm to users?
- New questions?

USER

QUESTIONS TO CONSIDER:

- How can I benefit from the enhanced capabilities and personalised experiences that human-centric solutions offer?
- How can I understand and navigate the ethical implications of human-machine interaction in a digital immersive world?
- How can I protect my privacy and make informed decisions about the data I share with AI systems and other digital tools?
- Will I be able to opt out from technologies that I do not consider desirable?
- How can I be aware of the influences of the nudging techniques that are being used by the developers to shape my behaviour?
- How can I make informed decisions to avoid the use of products or services that may have a negative impact on the environment?
- New questions?

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FORGING

INVESTOR

QUESTIONS TO CONSIDER:

- Taking forward my commitment to long-term value creation, how can I identify and support companies that are developing human-centric solutions that address pressing social and environmental challenges?
- How can I ensure that my investments in human-centric solutions are aligned with ethical considerations and promote responsible development and use of these technologies?
- How can I contribute to the democratization of access to human-centric solutions and ensure that these technologies benefit all people?
- How can I influence the companies I fund to shape their solutions to be more human-centric and ethically robust?
- How can I ensure that my investment decisions are focused on human-centric technologies that enhance and complement rather than replace human intelligence?
- How can I support start-ups that cater to the needs of diverse user groups, including minorities?
- New questions?

MALICIOUS AGENT

QUESTIONS TO CONSIDER:

- Could I use human-centred design principles to create deceptive interfaces that trick users into giving up personal data or engaging in harmful behaviour?
- How can I exploit ethical concerns and biases in AI development to promote my own agenda or gain an advantage?
- Could I hack into human augmentation devices, such as braincomputer interfaces and wearables, to control or manipulate users?
- How do I identify the vulnerabilities in human-machine interfaces to deceive and manipulate the user?
- How can I use existing systems for spreading misinformation and manipulating public perception?
- How can I exploit social and psychological factors to promote intolerance, discrimination and undermine trust in institutions?
- New questions?

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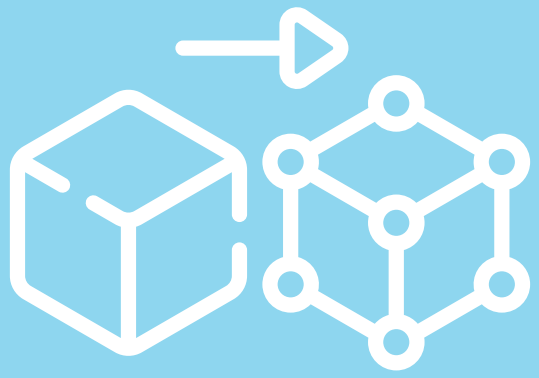

REAL TIME-BASED DIGITAL TWINS AND SIMULATION

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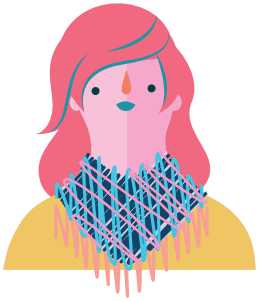
DEVELOPER

QUESTIONS TO CONSIDER:

- How can my solutions support better quality decision-making based on high-quality data?
- Can I create solutions that reduce the need for physical travel?
- How are my solutions supporting environmental sustainability and social fairness?
- Am I making sure that I am developing solutions that are inclusive and create opportunities for everyone, e.g. for those who have restrictions in moving in the physical world?
- Are my solutions discouraging people from being active in the physical world?
- How do I ensure that my use of data preserves individuals' privacy?
- New questions?

CITIZEN



QUESTIONS TO CONSIDER:

- Will I be able to maintain human contacts if I am hospitalized or placed in elderly care?
- Will some of the services I depend on be offered only in virtual spaces or will I have the possibility to select an option in the physical world?
- Will the use of digital twins and simulations offer me more opportunities to get involved in the development of my neighbourhood or city?
- Will the use of digital twins and simulations enhance my capabilities to participate in the working life?
- Can I trust that my privacy is always ensured even with the increased use of data?
- Are the services I am being offered optimized for economic rationality or human needs?
- New questions?

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REGULATOR

QUESTIONS TO CONSIDER:

- How can I promote energy-efficient algorithms and infrastructure to mitigate the environmental impact of digital twins and simulation, while ensuring sufficient computational power for complex models?

- How can I ensure responsible data collection, storage, and utilisation in digital twin and simulation applications, especially through clear frameworks for data ownership, privacy, and transparency?

- How can I address potential negative societal impacts of digital twins and simulation, including social isolation, job displacement, and the influence of biased algorithms in decision-making processes?

- How can I champion the development of inclusive digital twin and simulation technology, ensuring affordability and usability for all social groups, regardless of income, disability, or technological literacy?

- How can I make use of foresight within regulatory bodies to anticipate the potential long-term social, economic, and environmental consequences of large-scale digital twin and simulation implementations?

- How can I develop regulations that establish ethical guidelines for the evolving relationship between the physical and virtual worlds facilitated by digital twins and simulations?
- New questions?

USER

QUESTIONS TO CONSIDER:

- Is my job being threatened by my activities being modelled for simulations?

- Will someone notice and help if I get too involved in virtual spaces and start to suffer mentally because of it?

- What are the risks that I should be concerned about regarding the possible monopolization of digital twin and simulation technologies?

- Is the usability, functionality and affordability of the solutions I use ensured to all groups as well as possible?

- Is moving between the virtual and the real world seamless from all perspectives (economic, social, political, psychological etc.)?

- Do I understand enough about the solutions that I am using to make informed decisions about their use, for instance regarding their energy use or privacy related issues?

- New questions?

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INVESTOR

QUESTIONS TO CONSIDER:

- How can I identify early-stage digital twin and simulation applications with disruptive potential, considering not only technological breakthroughs but also integration with existing infrastructure and workforce capabilities?
- How can I prepare for the potential disruption of quantum computing in the digital twin and simulation space?
- How can I balance the benefits of open-source data and simulation platforms with the need for intellectual property protection for proprietary algorithms and functionalities?
- How can I ensure that I prioritise companies with strong data privacy practices, accessibility considerations, and focus on solutions that address societal challenges beyond economic gains?
- How can I make sure that my investment decisions prioritise companies with robust methodologies for bias detection and mitigation, ensuring fair and equitable outcomes?
- How can I ensure my portfolio is adaptable and focused on modular and interoperable solutions that can be easily adapted to changing user needs and advancements in related fields such as AI and augmented reality?
- New questions?

MALICIOUS AGENT

QUESTIONS TO CONSIDER:

- How can I exploit the complexity of real-time simulations to mask my activities and make it difficult to detect or attribute malicious actions?
- How can I manipulate real-time data streams within digital twin simulations to disrupt decision-making in critical infrastructure or financial markets?
- Am I able to weaponise personalised avatars and deepfakes within simulations to create discord, manipulate behaviour, or spread misinformation?
- Can I manipulate user perception or introduce delays to lead to critical errors in human-machine interface of real-time simulations?
- Can I use real-time social simulations to exacerbate societal tensions, polarise public opinion, or incite violence?
- Can I exploit potential blind spots in regulations or bypass ethical and security measures designed to prevent malicious manipulation of real-time simulations?
- New questions?

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ATTACHMENT

Technology Journey Maps

Technology Journey Map: ARTIFICIAL INTELLIGENCE

Potentials:

- AI is transforming many aspects of human lives, such as working life, consumption and learning.
- AI can make many mundane tasks easier.
- AI applications aid in making better decisions and navigating complexities of the modern world.
- AI might be able to share ethical values with humans in the future.
- AI can interact with human intelligence in ways that enrich our capacities.
- AI is learning to create culture and art, traditionally believed to be exclusive to humans.

Risks:

- AI might reduce need for human workforce in many areas, leading to unemployment.
- If not understood and regulated well, AI might steer societal discussions and political realities in directions that enforce divisions.
- AI and language generation that leaves the original (human) sources of information invisible hold risks for eradicating trust in society, as facts and fabrications become more difficult to differentiate.
- AI technologies might become so good at interaction that it will be impossible to differentiate AI from humans. This might also have implications to how we treat our fellow humans.
- AI might contribute to technology-driven bubbles that can lead to increasing loneliness and isolation.

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Technology Journey Map: ARTIFICIAL INTELLIGENCE

Research

AI develops at an unprecedented pace in many application areas. This phase includes the translation of technological capabilities into concrete AI applications where different application areas and opportunities of utilizing AI are considered.

Ecological considerations

- Use high-quality environmental data in the AI modelling to enable ecologically impactful and optimized outcomes.
- Use AI to make more ecological processes and thus, increase environmental performance of technologies.

Societal considerations

- Consider future implications of technologies: the first applications can be important in creating path dependencies that either preserve or harm human values.
- Conduct research in societally acceptable and ethical way, considering and mapping public perceptions of AI use.
- Make “no-go” decision when necessary: the decision making to not develop AI applications for certain functions is essential.
- Take privacy seriously, since AI applications are often data intensive. When planning the data use, the privacy of individuals considers also the potential implications in individual data usage for training AI.

Development of concepts & products

New capacities for AI are being researched continuously. This phase includes basic research on technological capabilities and the limits of possibilities of artificial intelligence, increasing computing power and innovating new enabling hardware solutions.

Ecological considerations

- Develop ecological hardware solutions such as recycling and new materials.
- Develop efficient software solutions e.g., less computing power or moving towards representative data usage (instead of large data masses).

Societal considerations

- Balance between open source / open science and intellectual property rights. Prevent potential misuse of data or technologies and consider licensing for specific usage.
- Use inclusive research practices with diverse participant groups and active engagement that enable usable results benefiting larger groups of people.

Introduction & early implementation

New AI applications are introduced to consumers frequently. As they are unlike anything before, they can receive high level of public interest on their release. For example, generative AI is discussed and explored by many users and yet, new applications are often hard to understand.

Ecological considerations

- Monitor environmental impact of new AI applications and their industrial contexts.

Societal considerations

- Protect vulnerable target groups, such as children and elderly, from harmful use of AI. Make it obvious for them when they are using AI (as opposed to chatting with a human) and what that means e.g., from the data collection and usage point-of-view.
- Differentiate humans and artificial intelligence since AI applications can resemble human interaction and thought patterns in a believable manner. Treating artificial intelligence in a similar way as humans can lead to deep issues and have implications to even human rights.
- Prevent biased decision making by understanding how the models are trained, which data is used and what that data describes. The existing society and related data tend to omit human biases and they need to be both understood and corrected.

Scaling-up & fine-tuning established technologies

As technologies become normalized part of our everyday practices, their basic premises are usually not questioned. However, it remains important to stay aware of the ethical, ecological and societal impacts of technologies. For example, the algorithms used by big social media platforms use AI that shapes our perceptions of the world in a powerful and unnoticeable way every day.

Ecological considerations

- Choose the most energy efficient technology for the purpose since AI can be energy intensive.

Societal considerations

- Preserve user’s autonomy for instance by enabling “opt out” from the use of AI applications that could potentially be harmful for them.
- Explainability of the widely used AI systems and applications must be publicly explained in a manner that allows users to understand their function and implications.
- Ensure human connections in AI boom to avoid isolating people in technological bubbles.

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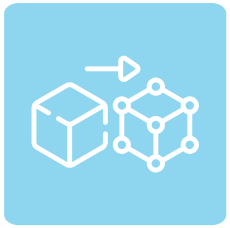

Technology Journey Map:
REAL TIME BASED DIGITAL TWINS AND SIMULATION

Potentials:

- Improved data use and new digital tools can produce better predictions and help in making better decisions.
- Virtual spaces can complement mobility, replace much of traveling and create new connections without place-dependency.
- Modelling of complex systems (even ecosystems and societies) with quantum computing can help in achieving environmental sustainability and social fairness.
- Digital avatars and working spaces might allow active life to people who can't move and be active in the physical world.
- Visualization of alternative futures through modelling holds potential for e.g. involving citizens in urban planning.

Risks:

- Living in digital worlds can lead to physical loneliness, as people will likely still crave and need physical closeness.
- Care might become more digital, as it is too expensive to keep human workforce -based system running, yet digital twins and virtual environments might not be as good in answering to human needs.
- As data use is amplified, taking care of individual privacy might become challenging.
- There is a risk of big tech companies attaining monopoly of digital twin and simulation technologies.
- The systemic implications of e.g., modeling human activities in industrial settings might ultimately be harmful to humans.

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Technology Journey Map:
REAL TIME BASED DIGITAL TWINS AND SIMULATION

Research

Simulations and digital twins are based on ongoing vast research efforts, and the potential complexity of modelled entities gets greater. Research phase includes development of computing potential for more complex systems and researching on new immersive simulation technologies as well as sensor development to enable information collection and develop a digital twin of a physical system.

Ecological considerations

- Develop solutions that are less intensive in terms of computing power and electricity and do not develop solutions that could replace more efficient existing practices.

Societal considerations

- Respect individuals' right to data privacy, even if it creates limitations to the research.
- Create inclusion with new immersive and interactive solutions by paying attention to usability, functionality and affordability to all groups.
- Focus on purpose and consider the fundamental motivations and drivers behind technology development. Enable discussion to define shared and desired visions for the society.

Development of concepts & products

As new capabilities emerge, new visions and application areas are developed. The challenge is how to bridge the gap between the virtual and real worlds, and recognizing the economic, social, political, psychological etc. constraints.

Ecological considerations

- Model environmental impacts when developing models for application areas and industries that have impact on the environment. Environmental optimization with high quality data and enough variables can lead to considerably more eco-friendly results.
- Evaluate the distribution of work between automation and human workforce from the energy use point-of-view. Sometimes using modelling and AI applications can be more energy intensive than using human labor.

Societal considerations

- Ensure openness and enable licensing when developing new products based on modelling or digital twin technologies especially regarding the data used and the functioning of the application. Generally, openness is considered to lead to more democratic technology environment as consumers can get information about the technology they use.

Introduction & early implementation

Digital twin and simulation technologies are entering many new industries. There is a strong need for multidisciplinary foresight units in both business and the public sector to understand the implications of new technologies, using e.g., science fiction prototyping.

Ecological considerations

- Avoid suboptimisation effects with high-quality and comprehensive environmental data covering all important environmental issues in the environmental modelling. If a system is optimized only for its carbon balance, for example, it may still end up producing other type of environmental damage.

Societal considerations

- Ensure inclusivity and accessibility when testing new solutions with users and starting a scale up to make sure the solution serves various needs and groups.
- Develop new solutions as experiments and maintain older back-up systems long enough. A complex modelling technology might reveal unintended features when used in large scale and it's only fair to the users to choose between test-phase or existing solutions.
- Grant privacy and data security of users and organizations as data intensive applications are taken up in new sectors and environments.

Scaling-up & fine-tuning established technologies

As new technologies become mainstream solutions, they reach more people and have more impact than before. They can also become invisible and unnoticed, yet there are many important responsibility factors to consider.

Ecological considerations

- Replace travelling and mobility where digital twin and simulation technology enables conducting many tasks without physical presence.

Societal considerations

- Balance virtual solutions and physical needs in scale up. In some domains it might be better not to have a virtual solution at all, and in other domains it might be good only as supplementing the physical work.
- Acknowledge that societies and "reality" change, hold various meanings and are heavily impacted by the novel ways of being in the augmented worlds.

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Technology Journey Map:
CYBER SAFE DATA TRANSMISSION STORAGE AND ANALYSIS TECHNOLOGIES

Potentials:

- Strong regulations about data safety and privacy are needed, as life moves more into the digital realm. Well justified, strong regulation is likely to be widely accepted.
- Data ownership can be decentralized and consequently, there is potential for new, more distributed data economy that benefits people more widely.
- With adequate education, individuals can be more active in taking care of their own privacy and data security.
- Safe online environments ultimately enable digitalization and new, virtual realities.

Risks:

- With data accumulation, also power is centralizing to few big players. People might not realize what this means for them and how to prevent or protect from the effects.
- Societies are becoming dependent on a few critical virtual infrastructures, and cyber-attacks to those systems could cause enormous harm. Cyber-attacks can even be used as a weapon in warfare.
- If code efficiency is not carefully planned for, this could lead to excessive energy use.
- With increasing data available for powerful players, dissident voices may be at risk.

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Technology Journey Map:
CYBER SAFE DATA TRANSMISSION STORAGE AND ANALYSIS TECHNOLOGIES

Research

As the pace of development in cyber security and data management is very high, even keeping up with criminals and hackers can be a challenge. As digital systems are vital to modern societies, cutting-edge research holds enormous importance.

Ecological considerations

- Influence the amount of energy used by the cyber security and data management processes e.g., by improving code efficiency.

Societal considerations

- Balance open science with concerns of security, ownership, licensing and financial utilization. Openness usually aids in taking up novel technologies in different sectors and can lead to faster development.
- Base safety and security solutions on the principle that the mechanism is so good that even if it is known to the other party, the counterparty still cannot violate it.

Development of concepts & products

As new breakthroughs are made, they still need to be turned into practical products. Packaging the new solutions in a responsible manner can sometimes be a challenge when talking about data intensive products.

Ecological considerations

- Identify material's role and reality in digital solutions. Even digital solutions require a material basis that consists of computers, batteries, wires etc. As new digital software solutions are developed, their effect on the need for this material basis can be considered through e.g., capacity needed and suitability of software to existing (and old) hardware.

Societal considerations

- Develop fair and inclusive models for individual data ownership that offer opportunities for real agency for users. Many apps and companies collect data about individuals and sell it further. These models are likely to be restricted in the future as legislation evolves.
- Move from reactive to anticipatory risks modeling. Instead of identifying and fixing security vulnerabilities as they are discovered, identify and address risks before they can be exploited.

Introduction & early implementation

With digital services and products, there are often novel things entering the markets. Consumers can't always keep up on the newest trends in data management and digital solutions, even when they are directly affected by the changes.

Ecological considerations

- Gathered environmental data carefully and ensure its security and truthfulness. As new data intensive solutions are taken up the role and protection of environmental data should be considered along with human-centric values.

Societal considerations

- Create opportunities for autonomy. Data management can be built in ways that offer people opportunities for agency regarding their own data. Asking for consent is often not enough, as this does not give users a real chance to choose.
- Go beyond privacy legislation. There is already a rather strict data privacy legislation in the EU and when launching new functionalities or services to users, data handling must be in line with these laws and rules, or preferably go beyond the mandatory levels.

Scaling-up & fine-tuning established technologies

Digital and data intensive solutions have become essential for daily lives in modern societies. As these solutions are scaled and more people are using them, they start also having different impacts.

Ecological considerations

- Use energy efficiency as criteria when making decisions on which solutions to take up. Digitalization consumes a significant portion of all electricity used in current societies, and data handling can be intensive in terms of needed processing power. Minimizing energy waste by e.g., using the heat generated by data centers can be a good solution.

Societal considerations

- Provide easily accessible and understandable education for users to keep up with the rapidly evolving field of data use, management and protection.
- Protect important digital infrastructures with frequent updates and resilience against cyberwarfare threats, since digital spaces play an essential role in satisfying the very basic human needs on daily basis. • Ensure understandability and thus, provide people with a real chance to give their consent for transferring data, be independent of literacy and see internationally understandable solutions e.g., with icon-based visualizations.

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Technology Journey Map:
BIO BASED INSPIRED TECHNOLOGIES AND SMART MATERIALS

Potentials:

- Taking inspiration for innovation from natural ecosystems we can harness human resources for the good of the planet while gaining better technologies for use.
- New materials with active (e.g., sensing, responding) and passive (e.g., antibacterial) functionalities can enhance the quality of life for many.
- New solutions to persistent issues can be found from new materials, such as “buildings functioning as batteries”.
- New, emerging materials can play a role in replacing crude oil and moving towards use of recycled and reusable items.
- New materials and bio-sensing provide possibilities for health care.
- Utilizing materials that are currently treated as waste or pollution might offer interesting business opportunities.

Risks:

- New materials require substantial investments to mature to usable solutions and to mitigate unintended consequences.
- Excessive use of raw materials needs to stop, and new materials should not be excessively produced or used carelessly.
- New innovations lead to the surplus of the old, and old materials or technologies might end up as waste.

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Technology Journey Map:
BIO BASED INSPIRED TECHNOLOGIES AND SMART MATERIALS

Research

This phase includes scientific explorations with different raw material possibilities, material structures and properties. Research does stretch the limits of possibility, even if the usability might not yet be tested outside of lab environments.

Ecological considerations

- Combine different materials wisely. Artificial components can be added to make new materials last and enhance their properties, but the implications for e.g., recyclability or compostability must be carefully considered and communicated.
- Start from the nature. Traditionally, research processes start from the needs of humans but when aiming for a better balance with natural ecosystems, waste materials or invasive species, for example, might offer interesting opportunities for material sciences.

Societal considerations

- Prioritize for impact and reasonable funding. As researching new materials is often based on trial-and-error type of testing and the results of any experimental branch can not be guaranteed going forward with material sciences needs proper funding and prioritization.
- Be holistic with costs. When considering the costs of new materials, not only their current monetary value pays a role, but the emphasis on the whole costs to ecosystems and the society.

Development of concepts & products

As new materials emerge from the scientific field, their application areas and use properties still need to be refined. As they are turned into products, they become parts of multiple entities: the product, production chains, recycling properties, etc.

Ecological considerations

- Promote reuse, recycling and circular economy with new materials and their production methods such as using recycled raw materials or ensuring the recyclability of the materials or changeability of product parts.

Societal considerations

- Consider both the pros and cons of licensing with new solutions. Licensing might enable attaining funding or selling the idea to bigger companies and thus, scaling the solution. On the other hand, it might limit the growth and use of the new solution as grass-roots hobbyists, for example, might not be able to experiment with the new material.
- Map and analyse consequences of the innovation scaling up: How the wider use could change everyday practices and is it for better or for worse?

Introduction & early implementation

As the new materials mature, they will eventually reach the consumers. As the consumers encounter the new materials, their safety and rights need to be considered.

Ecological considerations

- Use multi-criteria evaluation. Materials that make it to user testing phase usually have positive effects to at least some sustainability values but the sustainability should be assessed from multiple perspectives and different environmental values, such as climate change, biodiversity and toxicity.
- Evaluate the real benefits of new materials, products and solutions since changing for more sustainable materials is usually a good decision from environmental perspective but their environmental footprint still exists, and if the use can be avoided altogether, it can be even a better alternative.

Societal considerations

- Provide users with knowledge about the products they are using in simple enough language and when testing smart materials that have functionalities affecting the users or their direct environment, ensure their user rights and privacy.
- Evaluate harm also in time scales of use: If a solution is perfect for 5 minutes of use but harmful for long periods of time before and after, the actual benefit of the product might be questioned.

Scaling-up & fine-tuning established technologies

If a new material or solution proves to be useful, it might enter the scaling phase. In this phase, the solution gains popularity and becomes more common. With larger production and wider user base, new responsibility considerations become essential.

Ecological considerations

- Ensure that the raw materials of solutions that will be taken up in large scale can truly be produced sustainably in the locations of production.
- Limit the overall consumption and the use of virgin raw materials. Even as new materials might be less ecologically harmful than traditional materials, their use still consumes limited natural resources.

Societal considerations

- Distribute inclusively and fairly the opportunity to benefit from the scientific advancements regardless of e.g., financial situation and especially in the context of health care system. New materials can offer life-enhancing opportunities for people with disabilities, the elderly, or other special groups.

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Technology Journey Map:
HUMAN CENTRIC SOLUTIONS AND HUMAN MACHINE INTERACTION

Potentials:

- New technologies hold significant potential in healthcare, from digital solutions improving efficiency to nanotechnology applied in human bodies.
- Technology and AI can help humans express their creativity with less effort and in a more accessible way.
- Multidisciplinary teams in technology development can lead to human-centric solutions.
- Technology and human enhancements can lead to completely new definitions of learning or education: There is no need to know so many things by heart and understanding and interpretation become central in expertise.

Risks:

- Data should not be confused with knowledge, understanding or wisdom, even though it can lead to these outcomes.
- Unequal access to technology can deepen inequalities.
- Inserting technology to human bodies can leave people vulnerable to cyber attacks on themselves.
- Bodily enhancements can potentially become necessary for certain jobs or positions.

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Technology Journey Map:
HUMAN CENTRIC SOLUTIONS AND HUMAN MACHINE INTERACTION

Research

The research phase of technologies that humans will use is a wide field with various practices. As technology-focused research is done, the human and environmental aspects of technology should already be present, guiding the choice of new technologies to research and new capabilities to create.

Ecological considerations

- Re-use, repair, and recycle. The possibilities for environmentally wise behaviours can be created and boosted, such as re-using old technology, repairing broken gadgets or re-cycling products part by part.

Societal considerations

- Utilize multidisciplinary teams when technologies for humans are developed. Social scientist and experts familiar with human behaviour should be included in the processes. This does not include only ease of use considerations, but also perspectives like creating a healthy cognitive environment and avoiding harm to human minds.

Development of concepts & products

When practical products and applications of technology are developed, the human dimension becomes even more central. Technological capacities can be used in various manners to build products for the immediate use of humans.

Ecological considerations

- Focus on effects for human behaviour towards nature or natural resources. Technology can alienate human from the nature, or it can bring more wisdom into the way we act with natural resources and protect the natural systems on our planet.

Societal considerations

- Build ways for smooth interaction between technology and human cognition. Technologies most often work alongside humans, complementing and not replacing human intelligence.
- Ensure inclusion of different user groups. Often digital solutions can produce significant life-enhancing solutions for people with disabilities and the elderly, for example, if adequate efforts are made to adapt the solutions for their needs.

Introduction & early implementation

As technologies are released and first used by real humans, data about their effects can be gathered. At the same time, the rights of people using the new technologies become more imminent.

Ecological considerations

- Study resource use and ecological consequences when adopting new technologies. If technology is clearly a more resource-intensive or environmentally harmful, the necessity of it should be carefully considered, aiming to find a more environmentally friendly alternative.

Societal considerations

- Create clear rules on intellectual property rights and claiming authorship in the era where humans produce content, including text, music and visual arts, in collaboration with computers and machines.
- Respect user rights as new solutions come to existence and humans come into contacts with them. The user's right to refuse the use of certain technologies or giving up their personal data must be allowed.

Scaling-up & fine-tuning established technologies

As technologies become normalized, often also dependency is formulated. Wide user groups bring a multitude of different users, and this diversity should be recognized.

Ecological considerations

- Use nudging towards ecological behaviour to shape the behaviour of masses. This can mean encouraging people to fix their old technologies instead of buying new or discouraging excessive online shopping of environmentally harmful products.

Societal considerations

- Ensure cyber safety and minimize individual risks. Individuals are increasingly dependent on technologies that hold their personal information (e.g., biometric identifiers and even attachments to their bodies), which leave people vulnerable to personal cyber attacks.
- Clarify the roles of data and understanding. When scaling computer systems, data should not be confused with understanding, even though having high quality data can lead to new insights. Human considerations and wisdom can still not be outsourced.
- Ensure the possibility of opting out and comprehensively understand the technologies that become necessities in the society.

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Technology Journey Map:
TECHNOLOGIES FOR ENERGY EFFICIENCY AND TRUSTWORTHY AUTONOMY

Potentials:

- New, sustainable energy forms can revolutionize industry, leading to a zero-carbon path.
- Individuals can take a more active role in their energy use e.g., by setting up energy communities.
- Technological solutions to reduce and reuse energy waste are under development e.g., using excess heat, smart energy grids and energy storages.
- Through financial incentives and taxes, energy use could be steered towards clean energy and decreasing energy use in both industrial and individual levels. Carbon market or similar solutions can make clean energy even more profitable alternative.

Risks:

- Increasing population most likely equals with increasing energy demand.
- Energy scarcity leads to conflicts. Energy can also be weaponised.
- Unequal access to electricity can lead energy being a persisting form in inequality.
- Some industrial sectors can be very hard to turn sustainable in their energy use.

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Technology Journey Map:
TECHNOLOGIES FOR ENERGY EFFICIENCY AND TRUSTWORTHY AUTONOMY

Research

With energy technologies, research phase consists of exploration of new potential energy sources and properties of different materials, for example. Ecological and societal considerations should be present already in this stage.

Ecological considerations

- Use ecological guide to find many potential routes to less harmful end products, more production efficiency and when deciding what to research. Looking for more ecological alternatives to current energy technologies can take many paths, and at the research state this multitude should be embraced.

Societal considerations

- Aim for fair energy systems even though at this stage the research can seem detached from surrounding society, the seeds of fair and just energy systems are often already laid up.

Development of concepts & products

After new potential energy solutions are recognized, they need to be turned into products that can be used by the public. For example, small scale nuclear power plants are being conceptualized as potential power sources in many different areas.

Ecological considerations

- Minimize or avoid the use of rare minerals, metals and materials that can be environmentally harmful to produce or use.

Societal considerations

- Give the users more power to choose and impact their own energy use. Autonomy and empowerment of users can be a good choice from both sustainability and marketing point of view.
- Investigate the openness of licensing, since the new sustainable solutions have more impact potential if they can be picked up in different places without expensive licenses.

Introduction & early implementation

New energy solutions introduced to the system usually have some sort of friction at first, as they are entering the energy grids. Many solutions start off-grid in small scale.

Ecological considerations

- Pay attention to total energy use. When energy is used more efficiently the total energy use will not decrease, since there will be more usage. Further, when picking up new more efficient technologies to achieve sustainability gains, it is important to make sure the savings achieved do not add to energy use elsewhere.

Societal considerations

- Ensure equal access and distribution of electricity as new electricity grids and solutions are built i.e., no areas are left behind.

Scaling-up & fine-tuning established technologies

As new energy solutions turn from niches to important infrastructures, new types of possibilities and potential problems arise. For example, windmills and solar energy are taking up a bigger role in the energy infrastructure and influence the whole energy systems.

Ecological considerations

- Use multi-criteria decision making as new energy technologies are scaled and their impact on multiple different environmental issues are considered. Solutions that are good for carbon balance, such as the use of biomass, can be harmful for other matters, such as biodiversity, if they are scaled up too quickly or widely.
- Beware to scale, since problems possibly arise with volume. In small scale, many solutions can have no negative effects, but with scale their waste, burning product or some other part of the process might become problematic. For example, burning oil was not harmful before it was scaled across the globe.

Societal considerations

- Engage local communities and ensure fairness as new distributed energy solutions are built. The processes should be fair for the local communities near the production sites, and communities should be engaged in the planning phase.
- Ensure security as modern societies are very dependent on electricity and energy production is a potential target when seeking to disturb societies.

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