TECHETHOS

FUTURE ○ TECHNOLOGY ○ ETHICS

Multi-stakeholder evolution of TechEthos scenarios on ethical issues in climate engineering, digital extended reality and neurotechnologies

D3.1 | PU

D3.1 Evolution of advanced TechEthos scenarios			
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Lead Partner	AIT		
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Ethical review and approval were completed for all data collected and reported in this document in accordance with De Montfort University's Research Ethics Committee. This includes activities related to horizon scanning; expert scenario engagement; and stakeholder and citizen workshops with the TechEthos game.

Short project summary

TechEthos is an EU-funded project that deals with the ethics of the new and emerging technologies anticipated to have high socio-economic impact. The project involves ten scientific partners and six science engagement organisations and runs from January 2021 to the end of 2023.

TechEthos aims to facilitate “ethics by design”, namely, to bring ethical and societal values into the design and development of new and emerging technologies from the very beginning of the process. Technologies covered are “climate engineering”, “digital extended reality” and “neurotechnologies”. The project will produce operational ethics guidelines for these technologies for users such as researchers, research ethics committees and policy makers. To reconcile the needs of research and innovation and the concerns of society, the project will explore the awareness, acceptance and aspirations of academia, industry, and the general public alike and reflect them in the guidelines.

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Definitions and abbreviations

Table 1: List of Definitions

Term	Explanation
Awareness	Citizens' awareness of the TechEthos technology families and associated technologies has been investigated in the context of the citizen engagement activities (Glaser and Strauss 1967/2006; Timmermans 2009). TechEthos question: "have you heard about this technology?"
Attitudes & Acceptance	Citizens' attitudes towards the TechEthos technology families and associated technologies have been investigated as a person's mental state referring evaluative or affective to an object, action or event (Allport 1935, Blumer 1969/1986, Fishbein and Ajzen 1975, Pestello 2009). TechEthos question: "how excited/concerned are you about possible future developments of this technology?" Excitement and concern as two extremes of a spectrum point also to the participants' **acceptance** of the technologies covered.
Innovation ecosystem	Evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor, or a population of actors related to a technology family.
STEEPV approach	Analytical approach to gain an insight into past, current and future of the external environment developments during times of uncertainty, times of information overload and times of disruptions. STEEPV stands for Social, Technological, Economical, Ecological, Political & Legal and Value developments.
Values	Across disciplines, there are many ways that "values" are defined and identified. Sociological definitions of value relate to concepts of what is or is not desirable; economic notions of value relate to questions of "how much" objects are desired; linguistic concepts of value reference the meaning of words within larger systems of understanding (Graeber 2001). In TechEthos, we operate with a sociological definition, informed by psychology research (Schwartz 1994; Kraatz et al. 2020). Specifically, we draw on a definition of values from science and technology studies: what an individual or group, "**considers very important, because they refer to legitimate interests, mutual obligations and/or views of the good life**" (Boenink et al 2010). Citizens' values towards the TechEthos technology families and associated technologies are the result of an analysis of their reflections uttered in the course of the scenario game workshops.

Table 2: List of Abbreviations

Term	Explanation
aDBS	(Adaptive) Deep Brain Stimulation
AR	Augmented Reality
BECCS	Bioenergy Carbon Capture and Storage
BMI	Brain Machine Interaction
CE	Climate Engineering
CDR	Carbon Dioxide Removal
CCS	Carbon Capture and Storage
DAC	Direct Air Capture
LLM	Large Language Model
LTP	Linked Third Parties
NLP	Natural Language Processing
NT	Neurotechnologies
SAI	Stratospheric aerosol injection
SRM	Solar Radiation Management
STEEPV	Social, Technological, Economical, Ecological, Political & Legal and Values
tDCS	Transcranial Direct-Current Stimulation
TMS	Transcranial Magnetic Stimulation
VR	Virtual Reality
WP	Work Package
XR	(Digital) Extended Reality

Executive Summary

Scenarios are used in TechEthos to explore the awareness, attitudes, and values of various stakeholders towards ethical implications of new and emerging technologies. This report describes the methodology and the results of the multi-stage & multi-stakeholder enrichment of TechEthos scenarios on ethics in climate engineering, digital extended reality and neurotechnologies.

Given the uncertainty accompanying the development path of emerging technologies, and the challenge of dealing with diverse stakeholder groups involving different levels of understanding and perspectives on the ethics of such technologies, a multi-stage & multi-stakeholder methodology has been developed and applied in TechEthos. This methodology uses scenarios as a backbone, whereby different societal groups' reflections about ethical issues were stimulated by scenario narratives on the one hand and are enriching them on the other. This enrichment of the TechEthos scenarios engaged expert stakeholders as well as citizens across Europe in three succeeding stages.

First, based on the elaboration of innovation ecosystems for each technology of the TechEthos portfolio, three basic scenarios have been developed. That is, "plausible" and "contrasting" scenarios have been created by the TechEthos team using STEEPV (social, technological, economical, ecological, values) factors for structuring the basic scenario creation as well as scenario narratives.

Second, within the next stage, information about innovation ecosystem stakeholders as well as basic scenarios were used together to surface expert stakeholders' attitudes to ethical implications of the TechEthos technology families (i.e., expert enrichment). The results of expert workshop deliberations are described in D3.5 "Policy note: Analysis of expert scenarios addressing ethical implications of the selected technologies".

The third stage in the evolution of TechEthos scenarios - capturing citizens' awareness, attitudes and values (i.e., citizen enrichment) - consisted of three main components. Starting with the development of the game-based participatory methodology (i.e., "The TechEthos game: Ages of Technology Impact", D3.2). Followed by the recruitment of citizens to a series of science cafes hosted by science engagement organisations involved in the project as Linked Third Parties (LTPs). Finally, the engagement of citizens in a series of 20 workshops across LTP countries (Austria, Spain, Serbia, Czech Republic, Sweden, Romania) one for each technology family selected by the TechEthos project (D1.2).

The synergies of all three stages – i.e., the evolution the TechEthos scenarios via multi-stakeholder enrichment – are discussed and summarized in the final chapter "scenario evolution overview". The main findings are listed for each technology sorted by the six STEEPV dimensions. These findings will lead into the development of ethical guidelines for each technology family. Beyond the individual results, we highlight three overarching ethical issues: equity, reliability and environmental sustainability. Each is discussed within the context of the technology family and should be considered for the responsible development of emerging technologies.

Beyond these results, the report offers a contribution to the empirical study of ethical issues at the intersection of foresight and ethical assessment of emerging technologies.

1 Introduction

Scenarios are used in TechEthos (WP3) to explore the awareness, attitudes, and values of various stakeholders, including the research community (academia and industry) and the broader public (citizens), towards ethical implications of the identified new and emerging technologies. This report describes the scenario evolution conducted as a multi-stage & multi-stakeholder enrichment process.

1.1 Evolution of TechEthos scenarios

Given the different levels of understanding and perspectives related to ethical issues of emerging technologies, a multi-stage & multi-stakeholder methodology has been developed and applied in TechEthos. It consists of three stages, starting with the creation of basic scenarios, followed by a scenario enrichment by various experts (expert engagement), and completed by a scenario enrichment by citizens (public engagement) (see Figure 1).

The approach will better enable stakeholders to express their attitudes, values, and expectations in regards with the ethical dimension of somewhat uncertain (new and emerging) technologies. Additionally, the multi-stage & multi-stakeholder scenario approach allows for the integration of the different levels of understanding and perspectives.

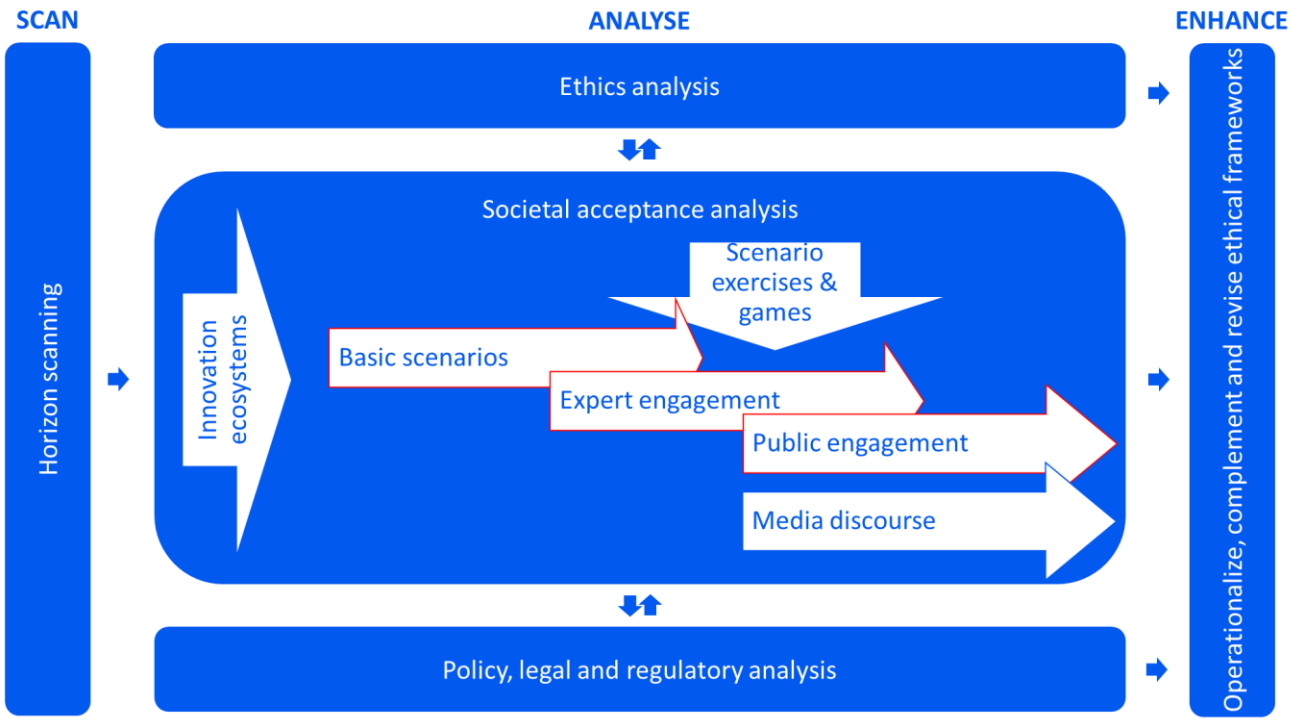

Figure 1: TechEthos multi-stage & multi-stakeholder scenario methodology

The overall methodology of the societal acceptance analysis (WP3) includes supporting elements of the multi-stage & multi-stakeholder scenario approach: innovation ecosystems mapping, scenario exercises and games development. In the following, all elements of the societal awareness & attitudes analysis are briefly described:

- **Mapping innovation ecosystems**: on the basis of the horizon scanning in WP1, for each of the selected technology families their respective innovation ecosystem has been mapped as a starting point for the scenarios.

- **Building three basic scenarios for each selected technology family**: these scenarios form the basis for the further exploration of various stakeholder attitudes regarding the selected technology families.

- **Developing scenario exercises and games**: co-creation of tools with science engagement professionals who interphase between citizens and R&I actors that have been used to capture expert and public attitudes & awareness in the advancement of the basic TechEthos scenarios (see deliverable 3.2).

- **Exploring expert attitudes**: using the basic scenarios as a starting point to obtain experts' reflections on the ethical implications of the selected technology families, resulting in an expert scenario enrichment.

- **Exploring public awareness, attitudes, and values**: engage with citizens of six European countries to get insights concerning their perspective on ethical implications of the selected technology families and their attitudes and awareness of these technologies resulting in citizen scenario enrichment.

1.2 Structure of the report

According to the logic of the societal awareness & attitudes analysis (WP3) and its multi-stage & multi-stakeholder scenario approach the report will initially outline the mapping of the innovation ecosystems of the three selected technology families (Section 2). For each technology family, a description of the technologies involved in it, identified case studies, stakeholders and institutional contexts will be provided.

Section 3 focuses on the scenario creation process up to so called basic scenarios. For each technology family of the TechEthos portfolio – climate engineering (CE), neurotechnologies (NT), and digital extended reality (XR) & natural language processing (NLP) – the three basic scenarios which have been created will be presented.

On this basis the results of the next scenario-stage – advancement through consultation with experts – will be described (Section 4). This includes reflection on ethical issues associated with the technology families as presented in the scenarios and enriched by the experts. Expert proposals on solutions to these ethical issues are described in D3.5.

Section 5 provides information on the forthcoming steps of capturing citizens' awareness and attitudes. This includes preparing exercises to be used in science cafes and game workshops as well as insights into the results of these exercise.

We provided separate deliverables for details of scenario exercises and games, for results of the media discourse analysis and for a detailed description of the expert engagement (D3.2, D3.3, D3.5).

The report will conclude with the discussion of main results and lessons learned from conducting the multi-stage & multi-stakeholder evolution of TechEthos scenarios on ethics in climate engineering, digital extend reality and neurotechnologies.

2 Mapping the innovation ecosystems of TechEthos' technology families

2.1 Methodology

"*An innovation ecosystem is the evolving set of actors, activities, and artifacts, and the institutions and relations, including complementary and substitute relations, that are important for the innovative performance of an actor or a population of actors.*" - (Granstrand and Holgersson, 2020)

The map of the innovation ecosystems presented in this section is based on identifying the different stakeholders involved in each of the three technology families selected: **climate engineering**, **digital extended reality** and **neurotechnologies**. For each technology family, an overall (but brief) description of the family, the technologies involved in it and identified case studies, and stakeholders is provided. In describing the technology families, considerations of the technological and institutional context are included. Moreover, the mapping method, which is the core of TechEthos task 3.1, includes:

- Technological context: describing case studies, areas of application and innovation ecosystem perspectives (relationship with TechEthos WP1).
- Relevant stakeholders: researchers, technological, economic, legal, ethics experts, science engagement professionals and civil society actors (including vulnerable populations) (relationship with TechEthos T3.4 and WP6, WP7).

The following categories (derived from the TechEthos communication plan) are used to classify the type of stakeholders relevant for each innovation ecosystem (only to list them):

- **Researchers, tech & economic experts**: public research, industry and business; academia, researchers and innovators in different disciplines; research institutions and infrastructure; public R&I organizations; development; technology owners and developers; companies; technology centres; innovation clusters; R&D partners; suppliers; manufacturers; sectoral and industrial associations; retailers and other R&I and business partners; services; distributors; equipment; public and private investors.
- **Legal and policy experts**: government departments and agencies; policymakers and regulators at international, EU and national levels (especially in countries chosen for analysis), standard-setting bodies.
- **Ethics experts**: research ethics committees and integrity bodies (e.g., EUREC members)
- **CSOs, public & media**: end-users and citizens; civil society organisations investigating impacts of new technologies; labour associations and trade unions; environmental organizations; advocacy groups; media; local communities; consumers; vulnerable groups.
- **EU-funded projects**: other European projects in the context.

2.2 Relationship with other WPs

The map of the innovation ecosystem is part of TechEthos Task 3.1 and links with other WPs by taking up their results, completing where necessary and integrating them in an innovation ecosystem perspective per technology family: Links to WP1 (horizon scan), WP2 (ethical analysis), WP4 (policy/legal) dimensions), WP6 and WP7 (the latter two are about stakeholder engagement). Task 3.1 was used to develop task 3.2 which started with identifying trends, drivers and 'wildcards' for each selected technology family (based also on desk research and a WP-team workshop). This was followed by the development of the basic scenarios together with all the project partners. The basic scenarios will primarily be detected potential future pathways reflecting on the ethical implications of the selected technologies and only secondarily address proposals or solutions. This task continuously integrated the evolving results of Task 2.2, especially the results of the three "levels of ethical analysis" (technology level, artefact/product level, and application level).

2.3 Climate engineering innovation ecosystem

Climate engineering is a set of technologies aimed at mitigating climate change crises on a local and worldwide scale. They represent a group of technologies that can act on the Earth's climate system by reducing greenhouse gases in the atmosphere and other anthropic emissions or directly changing physical or chemical processes in the biosphere to achieve direct control of climate. As illustrated in Figure 2, this technology family includes, for example, technologies for carbon dioxide removal applications that can reduce the anthropogenic carbon dioxide from the air with consequences on the planet's temperature regulation. Solar geoengineering technologies are a further example, raising the possibility of modifying the Earth's interaction with solar radiation by, for example, creating a layer of particles in the stratosphere to reflect part of the solar radiation. Despite their high research and industrial relevance, ethical concerns arise around these technologies: who can access these technologies? Will these technologies have an effect locally or globally, and who is going to decide about their implementation? What could be the future environmental consequences of their applications? How should we ethically evaluate irreversible transformation with uncertain outcomes?

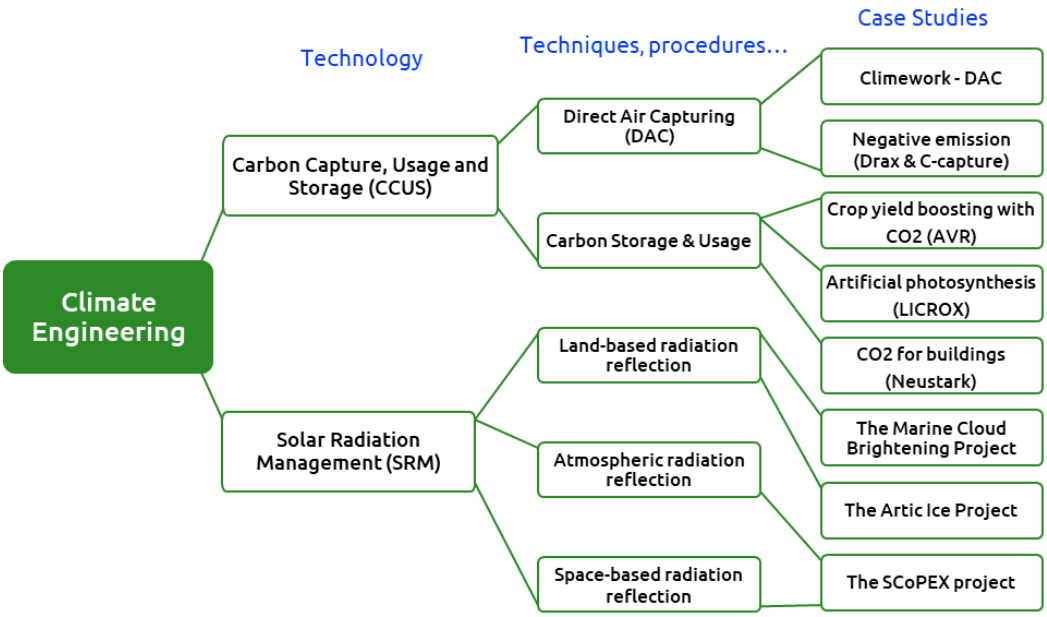

Figure 2: Mind map of climate engineering technology family

2.3.1 Carbon dioxide removal (CDR)

Carbon dioxide removal is a group of technologies, techniques and approaches that involve the removal, separation and sequestration of carbon dioxide and subsequent storage of it in natural sinks (e.g., oceans and geological reservoirs) or in usable products (e.g., fuels and cement). The capturing of CO2 can be applicable in large power plants and involves compressing the CO2 and transporting it to be durably stored in large storage sites like the ocean/seabed or transformed into products. The main technologies within CDR are (IPCC, 2022):

- **Direct air CO2 capture and storage (DACCS)**: It captures and permanently stores carbon dioxide directly from the atmosphere (and not from specific CO2 point sources).
- **Land-based CDR:** It employs natural sources and agriculture practices (e.g., afforestation, reforestation, ocean fertilization and enhanced weathering) to capture CO2.
- **Bioenergy with carbon capture and storage**: it captures and stores the CO2 generated by producing energy from biomass.

CDR is considered one of the practical approaches that can be adopted to reduce global warming and its effect on humanity and other living species. The application of these technologies directly impacts the cost of energy being generated and thus the pace at which the technology is commercialized. CDR can be used for large-scale carbon removal, carbon sequestration or fixing (e.g., turning carbon into construction materials) and microbes for CO2 capturing as their sole carbon source as the main applications. Table 3 presents a few examples of CDR applications.

Carbon dioxide removal (CDR) cases studies

Table 3: Carbon dioxide removal (CDR) cases studies

Case studies	Description
Climeworks AG **(CH)** Carbon dioxide removal (CDR) or Direct Air Capturing (DAC)	The most representative example of **CDR applications** comes from the Swiss start-up Climeworks, which captures the CO2 from the air and stores it underground in form of rocks or stones. Climeworks' technology is based on the direct capturing of air that is then filtered through a heated reactor. During the filtering process, the reactor surface collects only the CO2 molecules through the adsorption-desorption process to form a CO2-based compound and releases the remaining air. The collected CO2 is then stored underground with gas and water where it reacts with basalt and turns to stone in less than two years. To heat the reactor (which requires high levels of energy), Climeworks operates mainly in areas with high renewable energy availability, e.g., geothermal sources in Iceland. The Climework Carbon Capture plant ORCA (in Iceland) started operating at the end of 2021 and targets to capture 4.000 tons of CO2 per year.
Drax and C-Capture **(GB)** Bioenergy Carbon Capture and Storage (BECCS)	**BECCS** is a carbon removal technique that depends on two technologies: Biomass (the "bioenergy" step) and carbon capture and storage (CCS) technologies. Biomass is an organic material that can be converted into heat or electricity. The CO2 emissions from this bioenergy conversion are captured and stored or used (**carbon neutral approach**). However, since the biomass absorbs CO2 from the atmosphere as it grows, BECCS can be a **negative emissions technology**. Drax is working with C-Capture Company to develop negative carbon emission technology by capturing the CO2 from wood-burning. Their technology absorbs the CO2 by flushing it through a flue gas chimney covered with a chemical agent (amines or specific solvents) that is used to anchor the CO2 molecules. Then, the mixture is separated by heating, the chemical agent is re-used, and the CO2 is stored or used. This process would yield about one ton (1.1-ton) of CO2 stored per day.

Neustark AG **(CH)** Carbon dioxide utilisation for buildings	The Swiss company, Neustark developed a technology to remove CO2 from the atmosphere and store it permanently in building concrete. The Neustark technology starts by mixing concrete aggregates obtained from building demolition with CO2 captured from the atmosphere. The CO2 is permanently bound to aggregates through mineralisation, i.e., the CO2 turns to limestone. They can currently store about 10 kg of CO2 per cubic metric of fresh concrete, avoiding 20 kg of new CO2 emissions in the production process by reducing the amount of added cement. Their objective by 2025 is to release truly carbon-neutral concrete to the market.
LICROX Project **(EU)** Carbon dioxide utilisation for fuel production	The LICROX project aims at producing artificial photosynthesis (artificial leaf) that mimics the natural process of photosynthesis by converting sunlight, water and CO2 into energy. This artificial leaf is a photoelectrochemical cell based on a multi-layered device. Its first layer uses a material that absorbs sunlight, which is then transferred in the form of energy to subsequent layers, where water and CO2 are transformed into CO and H2.
AVR **(NL)** Carbon dioxide utilisation for Crop yield boosting	The Dutch AVR company is working in a pilot plant to capture the CO2 produced by the same company to be used as a fertilizer for crops in the local community. CO2 can be used to enhance yields of algae production and crop cultivation in greenhouses. The application of CO2 with low-temperature heat in industrial greenhouses is the most mature yield-boosting application today and can increase yields by 25% to 30%.
Liquid Wind **(SE)** Carbon dioxide utilisation for fuel	Liquid Wind develops, finances, builds and manages commercial-scale facilities to convert carbon dioxide (CO2) emissions into green electro fuel. Each facility provides large-scale investors with stable and sustainable long-term investment opportunities. Each facility will produce 50,000 tons of eMethanol per year and provide a secure and sustainable long-term investment opportunity. They are currently developing the first commercial-scale facility FlagshipONE in Örnsköldsvik, Sweden and plan to establish 10 facilities by 2030. Liquid Wind proposes a circular economy approach where its facilities will be positioned to utilise waste resources (CO2) from local industry to produce more eMethanol. They are looking to establish a viable and cost-effective solution to enable the efficient capture and handling of eMethanol emissions (CO2) to convert them back into fuel.
Carbon Engineering ltd **(CA)** Direct Air Capture (DAC)	Carbon Engineering Ltd technology is based on Direct Air Capture (DAC) technology that works by capturing atmospheric air, then through a series of chemical reactions, extracts the carbon dioxide (CO2) from it while returning the rest of the air to the environment. The captured CO2 can either be stored underground (known as carbon capture and storage) or converted into carbon-neutral fuel using renewable energy sources (by a process that the company calls Air to Fuels). The company is running a pilot plant in Squamish, British Columbia, removing CO2 from the atmosphere since 2015 and converting it into fuels since December 2017.

2.3.2 Solar radiation management (SRM)

Solar radiation management (SRM) refers to methods of modifying the rate at which the Earth absorbs solar radiation to lower global temperatures. While solar geoengineering is expected to reduce global temperatures, it would not reduce the volume of greenhouse gases in the Earth's atmosphere. Certain predictive models indicate solar geoengineering could return global temperatures to pre-industrial levels. The main sub-technologies in SRM are:

- **Atmospheric solar radiation management**: technology used to create a mirror-effect in the Earth's atmosphere. It works by spraying fine particles in the air (e.g., sulphur dioxide or calcium carbonate nanoparticles), to reflect solar radiation back towards space, limiting the solar radiation entering the Earth. The atmosphere could also be made more reflective by spraying clouds with droplets of seawater. The seawater would make the clouds whiter and more reflective.

- **Land-based solar radiation management:** the solar radiation is reflected by reflectivity artefacts positioned on the Earth's surface. Some land-based reflection ideas include using reflective materials on building roofs, installing reflectors in subtropical countries, or genetically modifying flora to produce lighter-coloured species. To be most effective, these land-based reflectors would need to be in zones that receive substantial sunlight.

SRM could be used to immediately begin to counteract the earth's heating by reducing the amount of solar radiation that the Earth receives and, hence lowering global temperatures (Barrett et al., 2014). The modification of the biosphere interaction with solar radiation could potentially be achieved at a global scale (e.g., stratospheric aerosol scattering) or locally (e.g., heat reflection to protect and restore snow or glaciers).

Solar Radiation Management case studies

Table 4: Solar radiation management (SRM) case studies

Case studies	Description
SCoPEX Project: **(US)** Atmospheric-based solar radiation management Budget: $20 million; Period 2017-2024 (of research activities)	The SCoPEX (Stratospheric Controlled Perturbation Experiment) project is a scientific experiment looking to improve the fidelity of computer simulations and broaden the knowledge about aerosol and nanoparticle interaction with the background stratospheric air, and with solar and infrared radiation. The SCoPEX project aims of using aerosol suspended in the air to reflect incoming solar radiation back into space and thus contrast the global increase in temperature. In addition to computer simulations, the project plans to launch a high-altitude balloon to lift an instrument package approximately 20 km into the atmosphere. Once it is in place, a very small amount of material (100 g to 2 kg) will be released to create a perturbed air mass roughly one kilometre long and one hundred meters in diameter. The test is aimed to enrich data and confirm simulations about changes in the perturbed air mass, aerosol density, atmospheric chemistry, and light scattering.
The Marine Cloud Brightening Project **(US)**	The MCB academic project aim at using spray nozzle technology to generate controlled volumes and sizes of seawater sub-micrometre salt in sufficient numbers to increase the local brightness of low clouds in a marine environment. The suspended seawater salt particles in the air serve as a nucleus to generate water droplets inside clouds, making them brighter. The "whitened" clouds could reflect sunlight back to space, producing cooling effects locally, and over time, in larger areas.

Atmospheric solar radiation management Budget: $16.3 million; started 2018	
Arctic Ice Project **(US)** Land-based solar radiation management Budget: $1 million (fundraising - 2020)	The goal of the Arctic Ice Project is to slow climate change by protecting arctic ice with eco-friendly materials that reflect away the sun's radiation. The project is a non-profit organisation with the objective to "preserve arctic ice by spreading eco-friendly sands, protecting the ice below". The most promising solution proposes to deploy a thin layer of very small hollow glass microspheres across strategically chosen small regions of the Arctic to improve the reflectivity of sea ice, mimicking natural processes to reflect solar energy out of our atmosphere and restore the Arctic. The project hopes to "deploy a medium-scale test area of their material solution on Arctic ice, where the material can have the greatest impact on saving ice and lowering the risks of climate change" and conduct a large-scale launch in the Fram Strait or Beaufort Gyre 2021.

2.3.3 Innovation ecosystem of climate engineering

The innovation ecosystem for climate engineering involves many actors, including primary stakeholders (those who are directly involved in the work to develop the technologies, applications and approaches), and other actors classified according to the level of interest/influence in the technology family, as schematised in Figure 3.

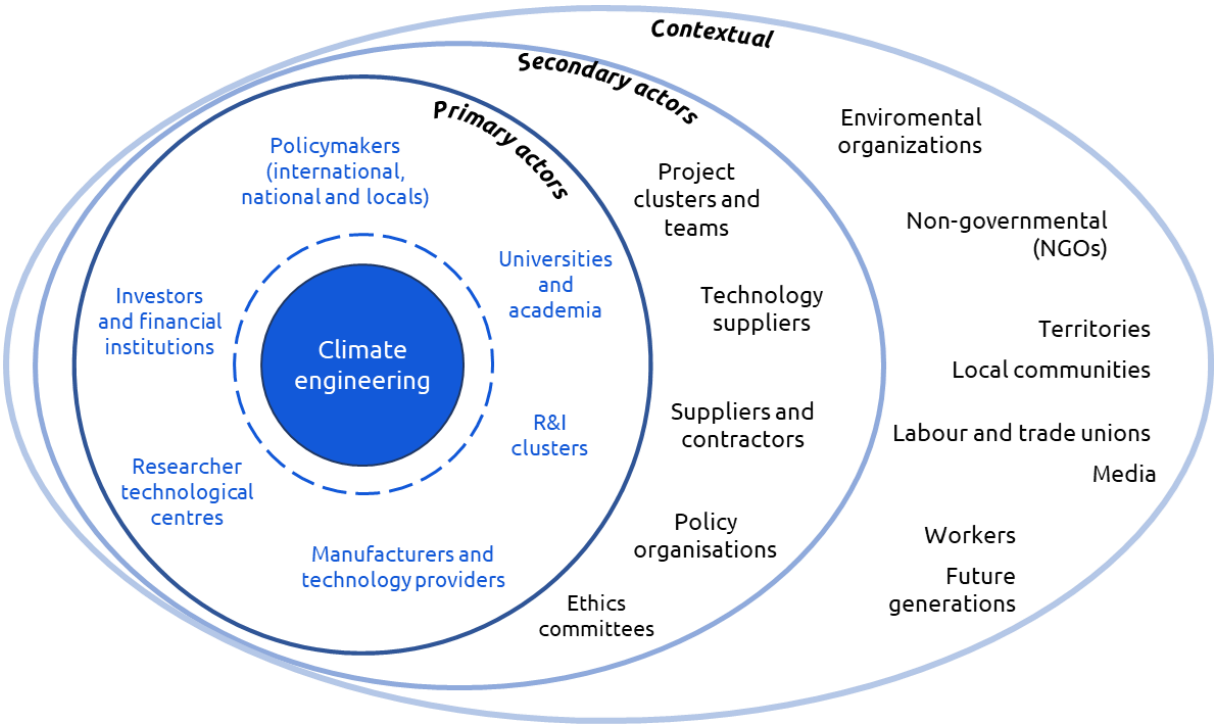

Figure 3: Innovation ecosystem of climate engineering technologies

Some of the actors involved in developing, designing, promoting and regulating climate engineering technologies are shown in Table 5.

Table 5: Actors involved in the Innovation ecosystem of climate engineering.

Type of stakeholders involved	Examples of stakeholders
Researchers, tech & economic experts, from public research, industry & business	Helmholtz Association of German Research Centres (Germany); French National Centre for Scientific Research - CNRS (France); Swiss Federal Institute of Technology Zurich – ETH Zurich (Switzerland); University of Colorado Boulder (USA), California Institute of Technology (USA); Harvard University (USA); GEOMAR Helmholtz Center for Ocean Research
	Climeworks AG (CH); Drax and C-Capture (GB); Neustark AG (CH); AVR (NL); Liquid Wind (SE); Carbon Engineering ltd (CA)
Legal and policy experts, from policymakers & regulators	UCLA Emmett Institute on Climate Change and the Environment; International Risk Governance Center; Swiss Federal Office for the Environment; Carnegie Climate Governance Initiative; The Institute for Carbon Removal Law and Policy
CSOs, Public & media: End-users and citizens, communication	AirClim; Climate Action Network; R20 Regions of Climate Action; Carbon Tracker Initiative; CDP Worldwide (Carbon Disclosure Project); Solar Impulse Foundation; Climate Alliance; VOX; Youth Climate Movement; ICLEI – Local Governments for Sustainability (formerly known as International Council for Local Environmental Initiatives); WEF; OECD; Practical Action; Africa Climate and Environment Foundation (ACEF); Climate Smart Agriculture Youth Network (CSAYN)
Ethics experts from ethics committees and research integrity bodies	Carnegie Council for Ethics in international affairs; World Commission on the Ethics of Scientific Knowledge and Technology; Carnegie Council for Ethics in International Affairs (CCEIA)
EU-funded projects	Gov4Nano project; GENIE project; FlexiGroBots project; HR-Recycler project; CO2Fokus; SCoPEX Project; The Marine Cloud Brightening Project; Arctic Ice Project; LICROX Project (EU)

2.4 Digital extended reality innovation ecosystem

Digital extended reality is a technology family that combines advanced computing systems (hardware and software) that can change how people connect with each other and their surroundings through the interaction with virtual environments. As illustrated in Figure 4, it includes AI-based digital technologies emulating or connected with human cognitive functions (e.g., voice, gesture, movement, emotions, psychological dispositions), as well as human-digital machine interaction technologies and data processing technologies to reproduce, replace, adapt, and influence human actions. A potential field of application includes people's remote assistance for educational, medical, and training purposes through virtual and digital devices (e.g., mobile phones, computers, autonomous systems). Advanced computing can be used for Natural Language Processing (NLP) applications, to process and analyse a vast quantity of human natural language information (e.g., voice, text, emotional data), extracting the most relevant data to profile and influence behaviours. Potential ethical repercussions of such technologies include cognitive and physiological impacts as well as behavioural and social dynamics, such as influencing human behaviour, misinformation, monitoring and surveillance, privacy, security and sensible data management. There exist also radically new applications, such as chatbots imitating dead persons, that require ethical and regulatory guidance and frameworks.

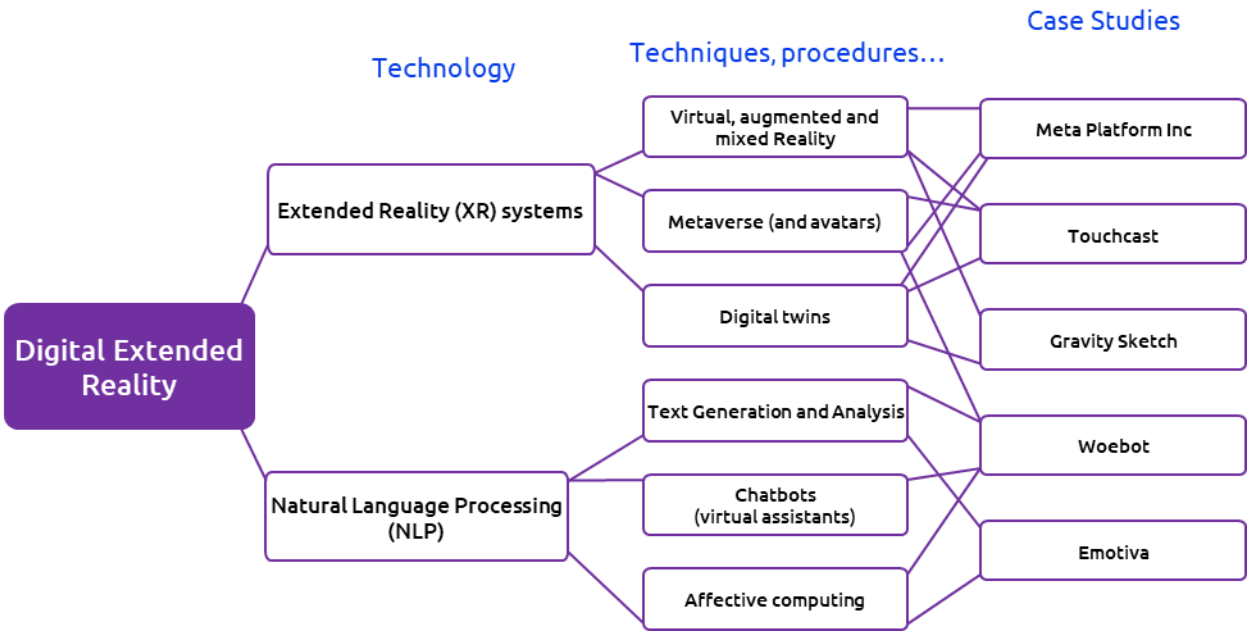

Figure 4: Mind map of digital extended reality technology family

2.4.1 Extended reality (XR) systems

Extended reality refers to all real and virtual environments combined, where users can dive into a digital world and interact with virtual environments through informatic interfaces and wearable devices. Such a virtual world is perceived as very realistic, and the degree of immersion mainly depends on the possibility and the way of interactions in the digital environment. XR technologies consist of a combination of virtual reality (VR), mixed reality (MR) and augmented reality (AR) and other specific technologies:

- Virtual reality (VR): it creates a fully computer-generated 360°-environment where users can completely immerse themselves into the virtual world (using headsets or glasses) and interact with it, while the real world is hidden from view.

- Augmented reality (AR): it expands or extends the real world by inserting virtual objects, items and information (e.g., images, text, and animations). The perception still centres around the real environment.

- Mixed Reality (MR): It works by combining elements of AR and VR, and hence, it combines our real world with virtual environments, creating new surroundings. The user simultaneously interacts with the real and virtual environments, e.g., physical objects in the real-world influence digital elements.

- Avatars: is a set of expansive networks of persistent, real-time 3D virtual spaces and simulations where an effectively unlimited number of users, each with an individual sense of digital presence, interact with one another. Users do not have to be in the same physical space - their presence in the metaverse is a virtual representation of them (an avatar).

- Digital twins: are an accurate virtual representation of physical, biological or information entities digitally linked (often in near real-time) to the original object or system, supporting predictive analytics, experimentation, and assessment.

XR might change the ways in which people communicate and interact in immersive and digital environments. It could impact business and society with a more connected and digital world (Doolani et al., 2020). Some of the current and future applications and uses of XR are related to training and educational purposes, e-health application, remote or smart work, romantic relations and social networking as well as gaming and long-distance communications (Palmas and Klinker, 2020).

2.4.2 Natural language processing (NLP)

INLP refers to the branch of computer science and artificial intelligence concerned with giving computers the ability to recognise, understand and generate text and spoken words in much the same way human beings do. NLP combines computational linguistics (rule-based modelling of human language) with statistical, machine learning, and deep learning models. Together, these technologies enable computers to process human language in the form of text or voice data and to 'understand' its full meaning, complete with the speaker or writer's intent and sentiment. Using cutting-edge computer technology and algorithms, NLP might enhance the way in which computers interact and interpret human language making it more similar to the way humans do. It may impact multiple sectors: medical, pharmaceutical, finance & legal. Some of the main applications and uses of NLP technologies are:

- Text generation and analysis, where text and information are structured into human language.

- Chatbots (virtual assistants) are computer programs that use artificial intelligence (AI) and natural language processing (NLP) to simulate and process human conversation (either written or spoken), allowing humans to interact with digital devices.

- Affective computing is the study and development of systems and devices that can recognize, interpret, process, and simulate human affects, for example, by analysing human feelings and emotions through cues such as facial expressions and speech.

Other specific uses of NLP are related to education, care and psychiatry, decision-making for human resources; fake news generation and detection in journalism, medical advice and follow up, customer service, legal advice, creativity, social media sentiment analysis and user profiling (Stewart et al., 2021).

Extended reality (XR) and natural language processing (NLP) case studies

Table 6: Extended reality (XR) and natural language processing (NLP) processing cases studies

Case studies	Description
Touchcast Metaverse **(US)** Keywords: Metaverse as a service; AI; Cloud computing; Mixed reality	Touchcast has developed a platform aimed to help companies to produce virtual conferences and other events in the metaverse without much technical heavy lifting. They propose a Metaverse as a Service (MaaS) solution to host virtual events. Touchcast is a sort of intersection between mixed reality (virtual and augmented reality) and artificial intelligence to recreate customized immersive and online events, collaborations, commerce and learning experience based on customer requirements and preferences. Their technology is based on using AI and Cloud GPUs (from NVIDIA and Microsoft) and includes features like real-time language translation, 3D images and videos, and customisable virtual spaces.
Gravity Sketch **(UK)** Keywords: AR; VR; 3D modelling	Gravity Sketch is an intuitive 3D design platform for cross-disciplinary teams to create, collaborate, and review their work. Their platform is AI-powered where people, using VR and AR headsets and tools, can generate virtual representations or digital twins of a product and can be modified in real-time between the collaborators. Gravity Sketch platform can be used for educational purposes for businesses, industries, colleges and universities and engineers and architects.
Virtualitics **(US)** Keywords: AI; VR; AR; ML; NLP; data science	Virtualitics is an advanced analytics company that proposes AI-based online platform solutions to help enterprises and governments make faster and better decisions with ready-to-use AI algorithms. Their AI platform can process, analyse and understand different complex data into powerful multi-dimensional graph visualizations, and forecast future business outcomes with clear, explainable no-code AI-based modelling.
Emotiva **(IT)** Keywords: AI; Analytics; Computer vision; Machine learning; NLP	Emotiva developed a computer vision approach and machine learning algorithm to detect and classify in real-time face muscle activations of users to read and interpret human facial expressions and emotions. Their proposal is a software-as-a-service (SaaS) platform based on a cloud computing service for data processing. Emotiva analyses people's facial expressions while they are watching online videos, online publicity and Ads, using their PC webcam (and under user consensus). The data obtained is then processed and evaluated looking to determine the peak of people's attention while seeing such videos. Their marketing slogan is: We collect emotion. You receive data.
Meta **(US)** Keywords: AI; AR; VR; XR; Social Networks; I; NLP; deep learning; computer vision; avatar	The US company Meta Platform Inc (Previously Facebook, Inc) is working to bring the metaverse to everyone's reach. The company's position is to create 3D spaces in the metaverse to allow people to socialize, learn, collaborate and play in a more immersive environment using virtual reality, augmented reality and other tools. Among the different services, Meta proposes solutions for individuals and groups to use AR, VR and MR (hardware and software) based on AI-driven contextual digital assistants and using a SuperCluster of AI supercomputers for NLP and computer vision processing and deep learning operations. The Builder Bots is an AI self-learning virtual assistant that can generate virtual and immersive environments using the user's voice.

Woebot **(US)** Keywords: Virtual assistant; Chatbot; AR	Woebot is a digital personal chatbot developed to help people to improve their mental health. Woebot works by using cognitive-behavioural therapy (CBT), interpersonal psychotherapy (IPT), dialectical behaviour therapy (DBT), artificial intelligence (AI) and natural language processing (NLP) to deliver scripted responses, therapeutic support and clinically validated approaches to users. Woebot personal chatbot interacts with users (listen, learn and delivers message) by creating close relationships and trusted bonds with people in any place and 24/7. Over time, Woebot can create an emotional model of users and can see the pattern of their moods and learn about their sentiments and emotions. Woebot was tested on 70 college students dealing with depression, demonstrating significant benefits.
Roblox **(US)** Keywords: Virtual assistant; Chatbot; AR	Roblox is an online game platform and game creation system where users can program and play games created (freely) by other users. Roblox is free to play (with in-game purchases available through a virtual currency called Robux) with over 164 million monthly active users, including more than half of all American children under 16. Although Roblox has received generally positive reviews from critics, it has faced criticism for its moderation, microtransactions, and the financial exploitative practices directed toward children to develop further games. Other concerns are related to the presence of inappropriate games, content and messages in an environment where children from 10 years old can play.
NASA and AEXA aerospace **(US)** Keywords: Telemedicine; mixed reality; holoportation	NASA and AEXA Aerospace have recently "holoported" a team of doctors and specialists from Earth into space. Using the Microsoft Hololens Kinect camera and a personal computer with custom software from Aexa, ESA (European Space Agency) astronauts had a two-way conversation with live images of doctors from the Earth placed in the middle of the International Space Station. This was the first holoportation handshake from Earth in space. Holoportation is a type of capture technology that allows high-quality 3D models of people to be reconstructed, compressed and transmitted live anywhere in real-time. When combined with mixed reality displays such as HoloLens, it allows users to see, hear, and interact with remote participants in 3D as if they are present in the same physical space. Holoportation has been in use since at least 2016 by Microsoft, but this is the first use in such an extreme and remote environment as space.
CAP_ABLE **(IT)** Keywords: AI, facial recognition; profiling	Cap_able is looking to address the issue of privacy, highlighting the importance of protection from the misuse of biometric recognition cameras. Cap_able's mission is to raise awareness of the risks associated with the improper use of facial recognition technology. The company developed a set of garments - The Manifesto Collection - that can protect the wearer from unauthorized biometric data acquisition. The garments were designed using AI to fabricate dresses with specific patterns that can limit personal biometric acquisition from cameras during image recognition. As Cap_able states, the biometric data of people wearing their technology cannot be stored by current facial recognition technologies, limiting personal data storage and citizen profiling.

2.4.3 Innovation ecosystem of digital extended reality

The different categories of stakeholders identified for digital extended reality are shown in Figure 5 and are grouped according to the level of influence/interest in the technology family.

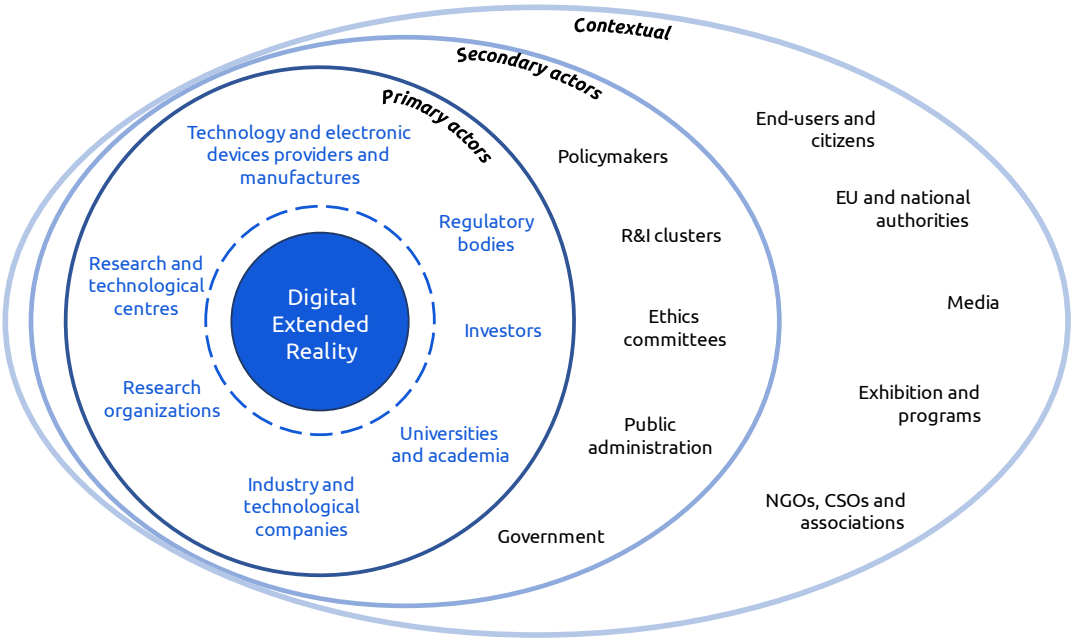

Figure 5: Innovation ecosystem of digital extended reality

Some of the stakeholders involved in developing, designing, promoting, and regulating digital extended reality technologies are shown in Table 7.

Table 7: Actors involved in the Innovation ecosystem of digital extended reality

Type of stakeholders involved	
Researchers, tech & economic experts, from public research, industry & business	Charles University (Institute of Formal and Applied Linguistics); Fondazione Bruno Kessler (Human Language Technology); CIIRC – Czech Institute of Informatics, Robotics and Cybernetics; DFKI – German Research Center for Artificial Intelligence; Lab for Computer Graphics and Virtual Reality; WAI: Virtual Worlds, Visualisation and Artificial Intelligence research group; VRVis Zentrum für Virtual Reality und Visualisierung Forschungs-GmbH
	META, Google, Touchcast; Gravity Sketch; Virtualitics; Emotiva; Meta; Woebot; Roblox; NASA and AEXA aerospace; JPMorgan Chase; IHS market; NielsenIQ; Zulily; Nexocode; Deeper Insights; DataRoot Labs; Maruti Techlabs
Legal and policy experts, from policymakers & regulators	Council of Europe; P&S Legal; Columbia human rights law review; OECD; European banking authority (EBA)
CSOs, Public & media: End-users and citizens, communication	CSO; Access Now; Bits of Freedom; Chaos Computer Club; D3 - Defesa dos Direitos Digitai; Electronic Privacy Information Center (EPIC); Hermes Center; Homo Digitalis; Iuridicum Remediu; Metamorphosis Foundation; Panoptykon Foundation; Privacy International; Statewatch.

Ethics experts from ethics committees and research integrity bodies	International Bioethics Committee of UNESCO; the French National Consultative Committee on Bioethics; Carnegie Council for Ethics in International Affairs (CCEIA);
EU-funded projects	Robotics4EU project; Assitance project; PopAI project; Starlight project; ARLENE project; SHERPA project; SIENNA project; PANELFIT project; e-SIDE project

2.5 Neurotechnologies innovation ecosystem

Neurotechnologies represent a group of technologies used for directly monitoring, assessing, mediating, stimulating, manipulating and emulating the structure, functions, and capabilities of the human brain and neural systems. Neurotechnology uses neural interfaces to read or write information from/into the central nervous system (CNS), the peripheral nervous system (PNS), or the autonomic nervous system (ANS) facilitated by machines or computer communications (brain-machine interfaces). These technologies offer possibilities to improve health and well-being. As illustrated in Figure 6, they are expected to change existing medical practices and redefine clinical and non-clinical monitoring and interventions. For example, patients with degenerative motor conditions can be treated efficiently by using neurodevices, enabling neuron regeneration by stimulating certain brain zones, helping them to overcome such critical situations. Such neuro-devices are still being an object of research for treating Parkinson's patients who have suffered a stroke, Alzheimer's disease, severe trauma, and many other conditions. Nevertheless, neurotechnologies raise concerns about personal data privacy management, integrity and responsibility, access to these systems, and potential off-label and misuse of such technology.

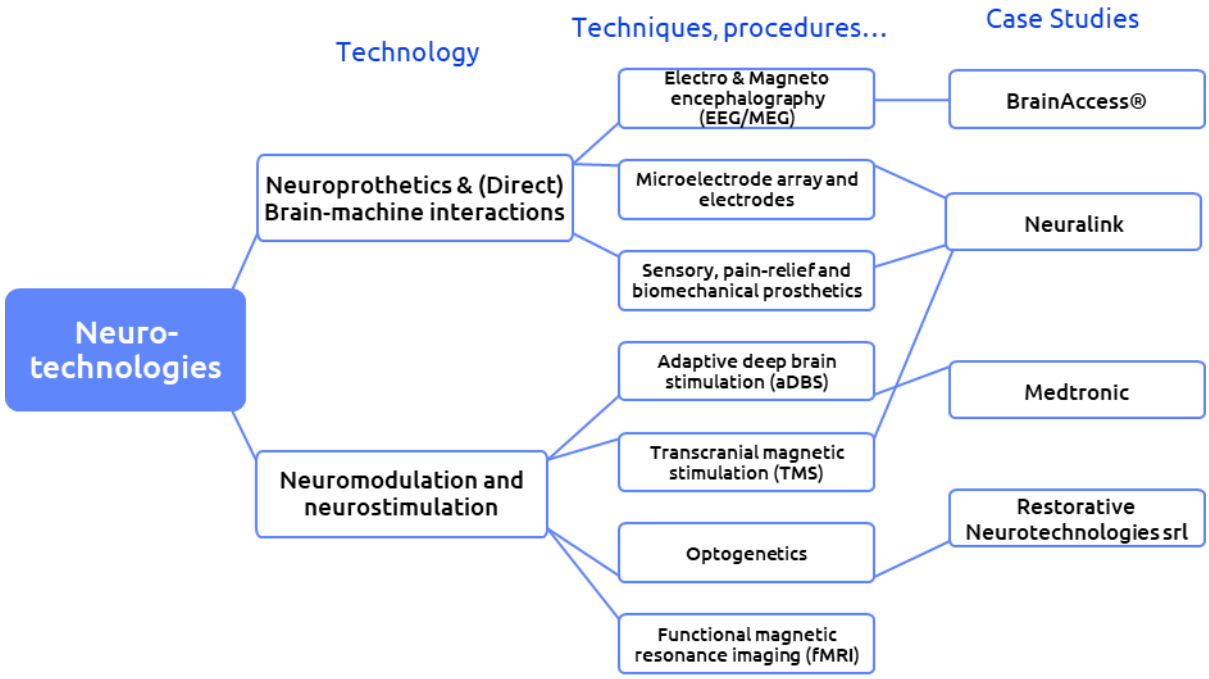

Figure 6: Mind map of neurotechnologies technology family

2.5.1 Neuroprosthetics - (direct) brain-machine interactions (BMIs)

Neuroprosthetics is a set of technologies and disciplines to read and/or write information from/into the brain, with the result of enabling users to control external or implanted devices or prostheses through the direct communication between the brain and specialized brain-machine and brain-device interfaces. It might help people to interact and control devices by using only brain signals or through specific interface between machine, devices and brain. Neuroprosthetics might be enabled by using 1) invasive approaches (electrodes are placed on the brain or the skull) and 2) non-invasive methods (electrodes are placed on the scalp) to connect with external devices, machines or prostheses. Imaging techniques are essential to monitoring brain activities before, during and after the prosthesis or electrodes implantation.

- Non-invasive:
    - Electroencephalography (EEG): methods to record an electrogram of the electrical activity of the brain on the scalp.
    - Magnetoencephalography (MEG): a neuroimaging technique for mapping brain activity by recording the magnetic field produced by electrical currents during brain activities.
    - Electrooculography: a technique for measuring the cornea-retinal standing potential that exists between the front and the back of the human eye.
- Invasive:
    - Microelectrode array: devices containing tens to thousands of microelectrodes through which neural signals are obtained or delivered.
    - Electrocorticography (EToG): a technique for measuring the electrical activity of the brain by positioning electrodes directly on the user's scalp or skull.
- Prostheses (devices or artefacts):
    - Visual prosthesis: they can create a sense of image by electrically stimulating neurons in the visual system.
    - Auditory prosthesis: devices or electrode array implanted in the cochlea, the lower brain stem or in the inferior colliculus to restore auditory.
    - Pain relief prosthesis: Prosthesis is accurately positioned to stimulate the nervous system of the user to achieve pain relief.
    - Biomechanical prosthesis: mechanical artefacts to replace a missing human limb controlled by brain activity.

In general, the potential of neuroprosthetics can be seen in medical context such as restore motor, sensory, or cognitive modality of patients, visual prosthetics, auditory prosthetics and prosthetics for pain relief, prosthetics for conscious control of movement (tetraplegia and sclerosis), biomechanical prostheses as well as for education, sport and workplace purposes, like restoring learning, physical and cognition abilities.

2.5.2 Neuromodulation and neurostimulation

Technologies that use invasive or non-invasive medical devices to stimulate the nervous structure and hence influence the brain activity look to relieve, restore and enhance brain functionalities by altering or modulating the nerve system.

- Invasive:
    - (Adaptive) deep brain stimulation (aDBS): DBS is a neurosurgical procedure involving the placement of a neurostimulator (neurodevice) on the patient skull, which, through implanted electrodes in the brain nucleus, sends electrical impulses to specific targets in the brain. In DBS, the patient is delivered with a constant amount of current that is regulated by the operator. Adaptive DBS is a closed-loop system that adjusts the stimulation parameters according to the patient's clinical state.
    - Spinal Cord stimulation: is a therapy for chronic pain management that delivers mild electrical pulses to the spinal cord of patients.
- Non-invasive:

- Transcranial magnetic stimulation (TMS): is a method that uses a magnetic field to generate a change of electrical current in the nervous system (electromagnetic induction) and stimulate specific areas of the brain. Transcranial Direct-current stimulation (tDCS) refers to when direct low electrical current is delivered on the head (rather than a magnetic field)
- Optogenetics: is the ability to manipulate and control individual neuronal circuits and cells by using light through the expression of light-sensitive elements in cells.
- Functional magnetic resonance imaging (fMRI) + Artificial Intelligence (AI): fMRI is a widely used technique that measures brain activity by detecting changes associated with blood flow and oxygen levels which in turn is associated with neuronal activations. fMRI combined with AI approaches can provide a rich characterization and interpretation of brain information and data to reveal and even predict patient conditions.

In general, this type of neuro approaches can be used in medical applications, for treating tremor in Parkinson's diseases, treating chronic conditions (Alzheimer, depression, and chronic pain), dystonia, obsessive-compulsive disorder (OCD) and epilepsy, recovery treatment in stroke cases. Other applications involved educations and workspace by aiding in enhancing learning and cognition among students, trainees and workers. Furthermore, in military or national security by enhancing physical abilities, e.g., coordination or motor skills in military activities, in sports by potentially helping monitor physical well-being and in consumer applications through providing features like a thought-to-text writing function, or virtual and augmented reality devices assisted by brain control for purposes of entertainment.

Neurotechnologies cases studies

Table 8: Neurotechnologies cases studies

Case studies	Description
Restorative Neurotechnologies **(IT)** Keywords: Healthcare; Medica Device; Psychology; Wellness	Restorative neurotechnologies is focusing on the development of medical devices for rehabilitation that runs through digital platforms and devices for patients' neuropsychological evaluations. Their technology for cognitive rehabilitation is based on digital therapeutics, neuroscience and biomedical approaches. The company developed a non-invasive neuromodulation technology, called MindLenses, to stimulate patient's brain to carry out effective behavioural cognitive rehabilitation. MindLenses is a pair of glasses with a specific prismatic lens created to stimulate the patient's brain and enhance cognitive functions. The company also created *Serious Game*, which is a set of adaptative exercises and games (from a dedicated mobile app) for specific cognitive functions based on a patient's brain capacities. The patient's medical records and therapy monitoring are stored in the *cloud*, allowing the patient to visualise their data at any time.
Medtronic **(IE)** Keywords: Biotechnology; healthcare; health diagnostics; therapeutics	Medtronic launches an innovative Adaptive Deep Brain Stimulation (aDBS) tool for Parkinson's Disease patient treatments. Their device, called ADAPT-PD (Adaptive DBS Algorithm for Personalized Therapy in Parkinson's Disease), was mentioned in a study that demonstrated its ability to automatically adjust brain stimulation based on the patient's clinical state. This patient-specific therapy aims to manage symptoms of Parkinson's disease. The trial was conducted across 12 research centre sites in the USA, Europe, and Canada, and showed promising results for movement disorder treatment. The company states that currently approved DBS systems deliver stimulation manually within limits defined by physicians. In contrast, aDBS therapy has the potential to individualize and optimize PD therapy by automatically adjusting stimulation within physician-defined limits, based on brain signals detected by the DBS system. It's

	important to note that the aDBS feature is still under investigation and has not been approved for commercial use. However, the Medtronic device, when using cDBS, received approval from the US Food and Drug Administration (FDA) in June 2020.
NEUROtechnology **(LT)** Keywords: Bioinformatics; technology; healthcare; health diagnostics; therapeutics	NEUROtechnology's core offer is algorithms and software development products for biometric fingerprint, face, iris, voice and palm print recognition, computer-based vision and object recognition to security companies, system integrators and hardware manufacturers. With millions of customer installations worldwide, Neurotechnology's products are used for both civil and forensic applications, including border crossings, criminal investigations, systems for voter registration, verification and duplication checking, passport issuance and other national-scale projects. The company develop BrainAccess®, which offers EEG solutions for the brain-computer interface, human-machine interface and other applications. BrainAccess products feature dry-contact EEG electrodes, wireless connection and compact form factor allowing for truly portable applications. Solutions come with software development kits supporting multiple programming languages allowing easy integration into the user's application. The provided BCI library comes with AI-enabled BCI algorithms providing immediate connection of your brain to the computer. BrainAccess Standard Kit is currently available for purchase on the BrainAccess website.
Neuralink corporation **(US)** Keywords: healthcare, medical device, neuroscience, robotics, software	Neuralink corporation is a neurotechnology company developing implantable brain-machine interfaces (BMIs). The mission is to design the first neural implant that will let people control a computer or mobile device by inserting Micron-scale threads into areas of the brain that control movement. Each thread contains many electrodes and connects them to an implant – The Link (a partial-invasive device). The Link device is implanted into the brain to process, stimulate and transmit neural signals. Another device produced by the company is NEURAL THREADS, which are the small and flexible thread that contains many electrodes for detecting neural signals. Both devices will allow people to control mobiles or computers using brain activity through Neuralink mobile and desktop apps. The main application of their technology is to let people with paralysis communicate more easily (via text and speech) and perform independently some tasks, such as typing or internet searching.

2.5.3 Innovation ecosystem neurotechnologies

Stakeholder categories identified for neurotechnologies are shown in Figure 7 and are grouped according to the level of influence/interest in the technology family.

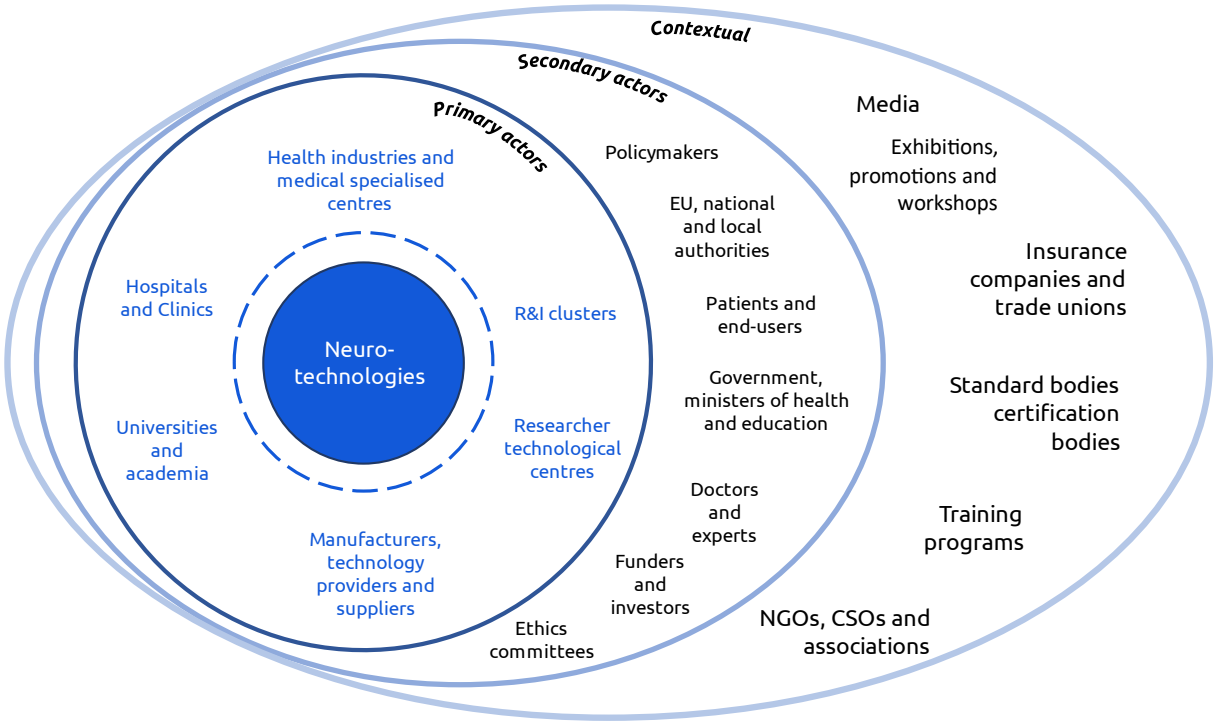

Figure 7: Innovation ecosystem for neurotechnologies

Some of the actors involved in developing, designing, promoting and regulating neurotechnologies are shown in Table 9.

Table 9: Actors involved in the Innovation ecosystem of neurotechnologies

Type of stakeholders involved	
Researchers, tech & economic experts, from public research, industry & business	The European University of Brain and Technology; IBM research lab; The Jacob laboratory; Radboud Universiteit (Netherlands); Rheinische Friedrich-Wilhelms-Universität Bonn (Germany); FirenzeNeuro: Computational Neuroscience Lab
	Neuralink; Neurable; Emotiv; Kernel; NextMind; MELTIN MMI; BitBrain
Legal and policy experts, from policymakers & regulators	Council of Europe; P&S Legal; Columbia human rights law review; OECD

CSOs, Public & media: End-users and citizens, communication	CSO online (USA); Center for International Relations and Sustainable Development; UNESCO
Ethics experts from ethics committees and research integrity bodies	International Bioethics Committee of UNESCO; Carnegie Council for Ethics in International Affairs (CCEIA)
EU-funded projects	SATORI project; SYNCH project; CONBOTs project; NIMA project; B-cratos project

3 Creation of TechEthos basic scenarios

Basic scenarios are the first stage of the TechEthos multi-stage-scenario-methodology (see introduction). Followed by a second stage in the form of scenario enrichment by various experts, and a third stage in the form of scenario enrichment by citizens. This section deals with the methodology of scenario creation and presents the resulting nine TechEthos basic scenarios (T3.2).

3.1 Methodology: Scenario creation

The TechEthos scenario methodology follows a stepwise approach combining a proven expert driven part[1] (T3.2 and 3.4) with citizen engagement (T3.5). Section 3.1 focuses on the scenario development process up to so called "basic scenarios". It consists of five steps starting from identifying trends and drivers and resulting in three scenarios as narratives (Figure 8) for each of the three technologies of the TechEthos technology portfolio[2].

The following agreements have been made within TechEthos WP3 team:

- Developing "plausible" scenarios: concrete, consistent and coherent narratives
- Developing "contrasting" scenarios: alternative assumptions for each narrative
- Use STEEPV (social, technological, economical, ecological, values) factors for structuring the basic scenario creation process as well as scenario narratives

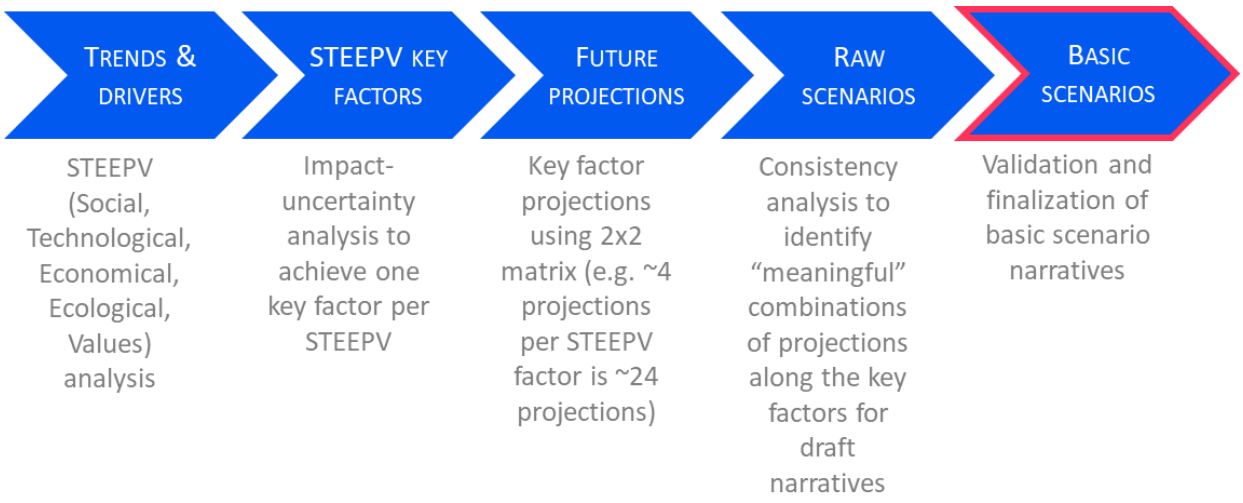

Figure 8: TechEthos basic scenario development[3]

[1] See e.g., Theis & Köppe (2018), Haraldsson & Bonin (2021), Sessa et al. (2021), Schoemaker (1995), Walton et al. (2019).
[2] TechEthos technology portfolio comprises climate engineering, digital extended reality, and neurotechnologies (see D1.1, D1.2 and D1.3).
[3] Adopted especially from Theis & Köppe (2018), Haraldsson & Bonin (2021), and Sessa et al. (2021).

3.1.1 STEEPV approach

STEEPV is an analytical approach to gain an insight into past, current, and future of the external environment developments during times of uncertainty, times of information overload and times of disruptions. It stands for Social, Technological, Economical, Ecological, Political & Legal, and human Values developments[4].

- Social developments may include factors such as demographics (aging, urbanization, migration), inclusion/exclusion, lifestyle (health, leisure), education and community (family, peers, neighbourhood).
- Technological developments may include factors such as research and development (academia/industry), innovation & diffusion, private & public strategies (roadmaps, action plans), and standards.
- Economic developments may include factors such as industrial structures, markets (B2C, B2B) & competition, investment (risk capital, subsidies), trade, jobs, entrepreneurship, and circular economy.
- Ecological developments may involve factors such as global warming (fossil vs renewable vs nuclear energies), pollution (air, water, soil), resource depletion and biodiversity.
- Political & legal developments may include factors such as political (in)stability, regulation (law, standards, tax policies, consumer protection), jurisdiction, trade unions and lobbying (multinational companies, NGOs).
- Value developments may include factors such as: culture & subcultures, religion & ideology, attitudes of various (professional) stakeholder groups.

3.1.2 Basic scenario process steps

The first step is identification of (short, medium, and long-term) trends and driving forces (drivers) for the three technology families among which the most important trends and drivers are selected in relation to the three technologies families and ethical implications. This is done on the basis of literature review and is informed by the results from chapter 2.

- Result: overview of trends and drivers (how technologies are expected to develop in the future) according to STEEPV factors.

The second step is identification of key factors out of the list of trends & drivers. Key factors are characterized by “high impact” and “high uncertainty”. Going for high uncertainty provides a basis for differentiation (i.e., there could be different possible projections of the future).

- Result: one key factor per STEEPV factor.

[4] Also known as PEST, PESTEL, PESTLE, STEPJE, STEP, STEEPLED, and LEPEST. See e.g., Loveridge (2002), Richardson J. V. (2017), Szpilko D., Glińska E. & Szydło, J. (2020).

The third step is creation of future projections for each STEEPV key factor. A 2x2 matrix is used to structure projections by placing the key factor in the middle and selecting two (uncertainty) dimensions for consideration (see Figure 9).

- Result: e.g., about 4 projections per key factor for each technology means about 24 projections (number of projections depends on the "meaningfulness" since some quadrants may produce more than one projection, and others may remain empty).

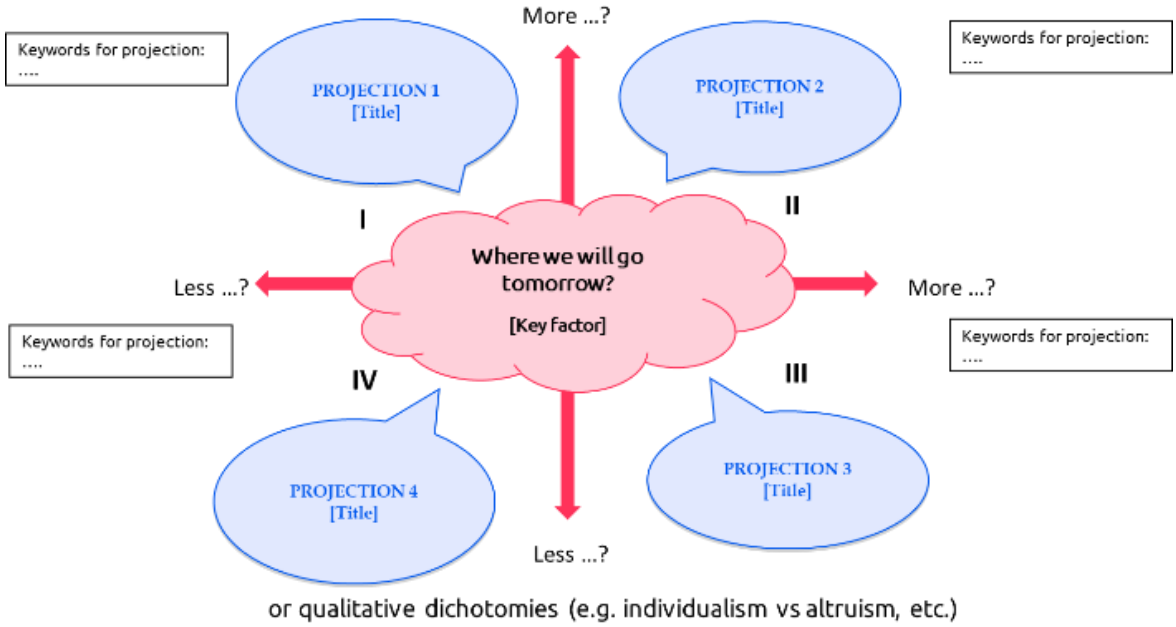

Figure 9: Template for creating scenario projections along STEEPV key factors

The fourth step is the contingency analysis following a clustering approach across the projections to come to the raw scenarios. Clustering means looking through the six key factors (STEEPV), identifying across the six key factors coherent "projections" and integrating them in contrasting raw scenarios (draft narratives). Whereby contrasting means capturing a diverse set of possible futures; however, the contrasting scenarios need to be plausible (including the possibility of widespread and unprecedented uses of a technology).

- Result: three contrasting **raw** scenarios (draft narratives) per technology.

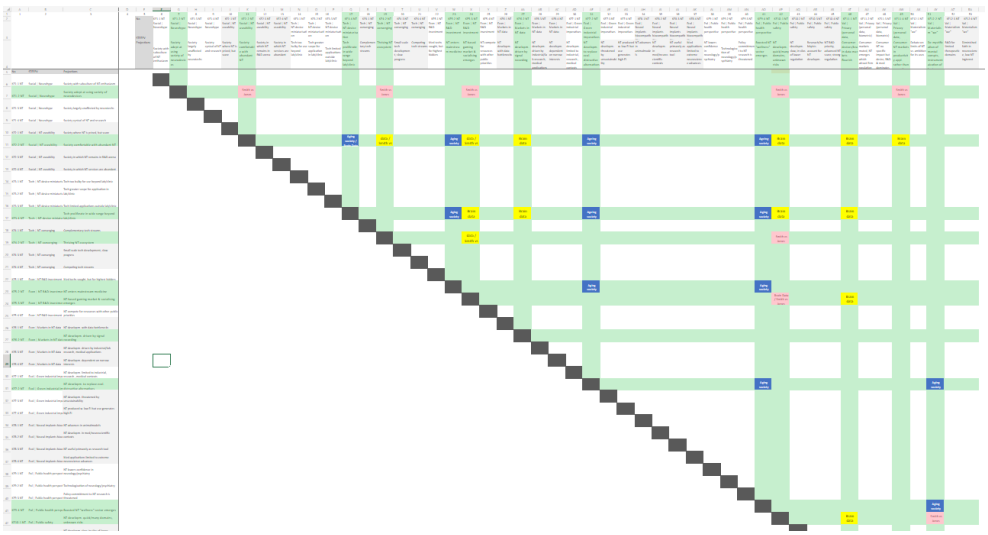

Figure 10: Example of consistency analysis indicating raw scenarios by using scenario projections

The fifth step is validation of raw scenarios by all partners and finalising narratives according to the feedback.

- Result: three contrasting basic scenarios (narratives) per technology.

3.2 Three climate engineering scenarios

3.2.1 Scenario 1: Betting on biofuels

Table 10: Climate engineering scenario 1 STEEPV factors

The scenario is based on the following STEEPV key factor projections:

- **Social:** social acceptability of climate engineering – high acceptability of CDR, low acceptability of SRM and weather impacts; Inequality worsens as larger firms capitalize on political and financial resources global carbon market regimes
- **Technical**: costs, effectiveness, feasibility at scale of CDR (BECCS) – moderate effectiveness and costs, limited feasibility of biomass production; implementation of carbon dioxide removal (CDR) is erratic; BECCS facilities face shortages, leading to development of biomass produced e.g., from seaweed and microalgae
- **Ecological**: environmental impacts of climate change and climate engineering – moderate climate impacts, high environmental impacts of biomass production; an initial rush to produce biofuels in the Global South for bioenergy with carbon capture and storage (BECCS) undermines food security, water, and biodiversity; food and water shortages and biodiversity loss contribute to political backlash against biomass production
- **Economic:** economic growth and climate impacts – moderate mitigation trajectory, economic growth; challenges with BECCS encourage investments into DAC, with national governments partnering with large corporations including fossil fuel companies who spend large sums rebranding themselves as carbon removal businesses
- **Political:** governance of climate engineering, and geopolitical context – low governance of CDR, moderate multilateral cooperation
- **Values:** materialism, anthropocentrism

Betting on biofuels

The world follows a trajectory of moderate decarbonisation, with Global North countries taking the lead in mitigation and investing heavily in BECCS and DAC to remove atmospheric CO2. The world overshoots the 1.5C warming target but remains within the budget for 2C. Several other planetary boundaries remain in a state of overshoot. Climate mitigation has uneven effects upon global equity, depending to a large extent upon domestic governance. The EU and China adopt high climate taxation and recycle the revenues collected for education and social welfare programs, while the USA buys carbon credits from South American and African nations with low emissions and limits domestic redistribution. Many authoritarian nations utilise production controls to reduce emissions instead of carbon pricing. Economic growth slows, but continues in lower- and middle-income countries, which face adjustment costs switching from fossil infrastructure to renewable energy—although with

support from multilateral development aid. The development and supply of CDR follows a market approach. There is substantial investment in expanding biomass production to replace existing fossil infrastructure and to operate BECCS facilities.

While the effectiveness of BECCS is difficult to assess at early stages, progress is made in rationalising carbon accounting under the Paris Agreement framework. While some biomass is produced in the EU, USA and China, demand far outstrips supply, and the prospect of large profits encourages political and economic elites in South America, southeast Asia and central Africa to attempt to become major suppliers of biomass. Biomass production is regulated by producers and determined by market forces, partly in response to lobbying from agribusiness. This exploitative dash for biomass encourages additional land clearance, and many growers move away from food production. Species extinctions worsen as a result, and food prices rise for basic crops, although biomass remains more profitable. This causes food shortages and a political backlash against biofuel producers, with crops being destroyed by angry and critically affected groups of people and communities. Several countries face imminent threats of starvation among their populations; anti-government protests force leaders to resign. In other countries, more authoritarian regimes enact greater violence to stifle unrest but resistance and demand for change, and reverse of biofuels production, win out. The EU and USA are forced to grow more food domestically, which also increases its price and leads to political unrest. As a result, BECCS facilities experience shortages in biomass, and less carbon is removed for several years.

These events contribute to a rethinking of reliance on crop-based biomass. Initially, city and unused commercial space, as much office work continued a transition online, is repurposed for vertical biofuel production. Over time, biomass produced from seaweed and microalgae grown off coastlines replace crop-based biomass. Due to challenges with biomass supply, DAC becomes a more viable CDR option despite its higher costs, with national governments seeking to lower costs by partnering with large corporations possessing the technical capabilities. These partnerships include former fossil fuel giants, who have spent vast sums on marketing to rebrand themselves as carbon removal businesses. While supporting the upscaling of DAC, such partnerships worsen global inequality as larger firms capitalise upon public financing and global carbon markets. Old oil and gas production facilities and pipelines are transitioned to utilisation for carbon capture and storage (CCS), as well as transport from DAC units to storage facilities. A circular economy of reused atmospheric CO2 concurrently develops, enabling cycled carbon use e.g., for building materials in construction and to make synthetic fuels for marine shipping and aviation sectors. Overall, the large-scale utilisation of CDR improves over time, and this ensures the 2C warming target remains achievable following a period of emissions overshooting.

3.2.2 Scenario 2: Who controls the global thermostat?

Table 11: Climate engineering scenario 2 STEEPV factors

The scenario is based on the following STEEPV key factor projections:

- **Social:** social acceptability of climate engineering – low acceptability of CDR, moderate acceptability of SRM, high acceptability of climate and weather impacts; climate-crisis denialists in many nations gain prominence claiming that the lack of catastrophic consequences is proof that warnings were overblown; after extreme 'wet bulb' event, climate-crisis deniers become discredited, and persecuted in some nations; climate misinformation becomes a criminal offence in many nations
- **Technical**: costs, effectiveness, feasibility at scale of SRM (SAI) – moderate effectiveness and costs, high feasibility; SAI effectively lowers global temperatures, but interrupts precipitation and lowers food production, leading to food shortages

- **Ecological**: environmental impacts of climate change and climate engineering – moderate climate impacts, high environmental impacts of SAI; global GHG emissions do not fall rapidly, and the 1.5C and then 2C carbon budgets are exhausted
- **Economic:** economic growth and climate impacts – high economic growth trajectory, low sustainability; carbon dioxide removal (CDR) is limited to due high costs and low priority given to mitigation; economic growth is prioritised, and most planetary boundaries are overshot, while species extinctions worsen significantly. Scientific debates rage about catastrophic tipping points
- **Political:** governance of climate engineering, and geopolitical context – moderate governance of SAI due to multilateral cooperation; after an extreme 'wet bulb' event killing many, India and China decide together to implement SAI to lower global temperatures, ignoring the protests of other nations
- **Values:** materialism, anthropocentrism; two factions emerge within many societies, one favouring a rapid reduction of ecological footprints, the other favouring the status quo protected from climate impacts by Stratospheric Aerosol Injection (SAI)

Who controls the global thermostat?

The world prioritises economic growth under the guise of sustainable development but fails to reign in global emissions. Many nations catch up to Global North consumption standards and environmental footprints. However, most nations fail to live up to their net zero climate pledges and the 1.5C carbon budget is soon eclipsed. Time-lags in climate impacts do not heighten the case for urgency; the 2C carbon budget is also eclipsed. Most planetary boundaries, as a result, are overshot. Species extinctions reach plague proportions, sparking scientific debates about the exact time additional catastrophic tipping points will be reached. Research and development of climate engineering technologies reflects the lack of prioritisation of mitigation: implementation of CDR remains limited to due high costs. Meanwhile, small-scale but well-funded research initiatives continue to develop sulphate aerosol injection (SAI) in several nations, where it is viewed as an emergency national security measure but publicly disavowed. These research collaborations make possible the advance of secret multi-lateral agreement among several nations to guide research and development of SAI, including clauses for potential localized deployment.

In parallel, with climate-impact time-lags, climate crisis-denying factions emerge in most countries, claiming that previous warnings about climate change were untrue and motivated by scientists' desire for research funding. Simultaneously, in the EU, UK, and USA, resentment about a perceived loss of status further fuels far-right populists (already sceptical about climate change), as economic development of China, India, Brazil, and others accelerates. Eventually, extreme climate impacts become far more pronounced, rendering the time-lag obsolete. These impacts include regular heat stress events and droughts in many regions. For decades, these impacts were successfully portrayed as natural and not linked to climate change. However, after a series of wet bulb events in Southern China, Northern India, and Central Pakistan lead to the deaths of millions of people over a period of a two weeks, perceptions drastically change. In response, China, India, and Pakistan tri-laterally deploy localized SAI interventions in a humanitarian effort to protect their populations, triggering untested emergency provisions in their previously secret multilateral SAI agreement. SAI is effective in immediately lowering regional temperatures, and extreme heat wave events become much less frequent. Despite the beneficial impact in zones of deployment, the SAI interventions effect weather patterns, particularly, as fear of further wet bulb events perpetuates a reliance on SAI, altering rainfall, regional ecologies, and seeing agricultural yields fall in India, Central and South America and unevenly across Africa.

Following the 'wet bulb' event, the UN sustainable development agenda is widely discredited, since the pursuit of economic growth is now blamed for climate breakdown. The term 'sustainability' falls into disuse. Climate crisis-deniers are now discredited and face persecution in authoritarian countries, while violent clashes between them and pro-climate groups are common across the world. Social media content denying the reality of climate change and the 'wet bulb' catastrophe is censored and spreading climate misinformation becomes a criminal offence under human rights legislation. In a fragmented geopolitical environment, bilateral and regional groupings go their own way, with the China-India-Pakistan partnership predominant due to its economic might and its control of SAI.

Following the collapse of the UN sustainable development agenda, two prominent factions emerge within many countries, one favouring a rapid reduction of environmental footprints, pointing to catastrophic risks like the historic wet-bulb event. This includes the large-scale drawdown of atmospheric CO2 through CDR technologies. Many coastal nations are now in favour of major CDR projects, since the use of SAI has not stemmed ocean acidification, which leaves their aquaculture projects much less viable (commercially viable wild fish stocks remain in a state of collapse). However, another faction favours the continuation of the new status quo of economic growth protected from climate impacts by SAI, without any intention of decarbonising or decoupling the economy from environmental impacts.

3.2.3 Scenario 3: Post-consumer societies and natural climate solutions

Table 12: Climate engineering scenario 3 STEEPV factors

The scenario is based on the following STEEPV key factor projections:

- **Social:** social acceptability of climate engineering – high acceptability of 'natural' CDR, low acceptability of SRM, low acceptability of climate and weather impacts; ethical norms of environmental stewardship spread, and the pursuit of GDP growth loses policy importance; large percentages of the population pivot to supporting a 'rights of nature' approach, changing domestic and international environmental law
- **Technical**: costs, effectiveness, feasibility at scale of CDR and SRM (roof whitening) – high effectiveness and costs, high feasibility; large-scale implementation of carbon dioxide removal (CDR) perceived to be 'natural', esp. afforestation and reforestation, soil carbon sequestration and biochar, and agroforestry, ensure significant removals of atmospheric CO2 and benefitting local livelihoods and biodiversity
- **Ecological**: environmental impacts of climate change and climate engineering – low climate impacts, low environmental impacts of CDR and SAI; emissions fall very rapidly, spurred by environmental protest movements, worsening evidence of climate impacts, and prominent climate lawsuits; bioenergy with carbon capture and storage (BECCS) based upon conventional biofuels is limited due to concerns with land clearance
- **Economic:** economic growth and climate impacts – a growth/degrowth trajectory, high sustainability
- **Political:** governance of climate engineering, and geopolitical context – high governance of CDR due to value convergence; the EU and China form closer economic and political ties, while the USA is divided into two steadily more autonomous factions, one pursuing isolationist economic growth and the other pursuing closer integration with the EU-China trading block; like-minded countries announce a multi-generational project to utilize DAC to remove all atmospheric CO2 emitted since industrialization

- **Values:** post-materialism, environmentalism, non-anthropocentrism; pro-environmental values and anti-consumerism become cultural flashpoints between younger and older generations in many societies. Generational conflict lasts decades

Post-consumer societies and natural climate solutions

Environmental protest movements and widespread evidence of worsening climate impacts and environmental degradation spur the world towards rapid decarbonization. Prominent climate lawsuits across the EU and in some states of the US increase the pressure further. Radical lifestyle changes become a cultural flashpoint, often between younger and older generations, with many among mainstream older generations clinging to ideologies of consumer capitalism and denial of responsibility for climate change. The younger generation—with support of key elders and long-enduring environmental activists—wins out, encouraging new environmentalist, post-consumer values across many societies, although these values spring from different cultural sources and have different implications. Nonetheless, generational conflict remains widespread for the better part of a decade, spurred by social media and conspiracy theories about the moral dangers of environmentalism. As a result, the mitigation challenge is steadily reduced, and global emissions peak by middle of the decade of generational conflict, and then begin, finally, to fall year after year.

There is large-scale implementation of CDR projects perceived to be 'natural', including afforestation and reforestation, and soil carbon sequestration and biochar, which also improve agricultural output and soil quality. Agroforestry practices spread worldwide, ensuring significant removals of atmospheric CO2, benefitting local livelihoods and biodiversity. While BECCS based upon conventional biofuels is limited due to concern with land clearance, water use, and biodiversity impacts, there is considerable investment and implementation of marine-based biomass production using seaweed. Across much of the EU, environmental stewardship and circular economy become normalized, and new measures of social progress and sustainability replace the single-minded pursuit of economic growth. China's economic strategy turns increasingly to high-tech innovations, while the African Union becomes a new centre of global manufacturing supported by Chinese and EU/US capital. Supported by novel pro-environmental technology transfer regimes, African Union countries break with the deadly Western tradition of industrialization at the expense of environmental and social wellbeing and model thriving, environmentally responsible global manufacturing methods. China and the EU form a strategic partnership, as the belt and road initiative establishes high speed, electrified, continental train freight to replace shipping. This collaboration fosters closer diplomatic ties with the EU, and increased trust is built upon a closer alignment on environmental and social values following continued evolution of Chinese leadership (e.g., recognizing ecosystem health and human dignity as key pillars for future party stability) while concurrently, greater European acceptance of China's chosen political system. The EU and China now form a formidable carbon trading bloc and charge external economies tariffs upon carbon intensive imports. The EU-China bloc is soon joined by many countries from still emerging economies, eager to leap-frog failed industrial modes of development. Meanwhile, the USA divides into two ever more autonomous factions, one pursuing isolationist economic growth and driven by continued fossil fuel lobbying, the other pursuing diplomatic integration with the EU and China and post-growth goals. The latter joins the carbon trading bloc, while the former ignores climate mitigation and trades with other hold-out nations from the previous fossil-fuel geopolitical order, free riding on the mitigation efforts of others.

Legal recognition of the rights of nature expands beyond early championed efforts in Central and South America, inspired by hybrid conceptions that reject the concept of 'nature' as a colonial imposition. A majority of South American nations ally under similar eco-socialist regimes, becoming a

formidable bloc in their own right, championing biodiversity conservation and reforestation by undertaking a multi-nation project to reforest the Amazon. This group of countries modelled off of the Union of South American Nations and its successor, Prosur, but with broader environmental and social aims, lobby for and receive financial support for their protection and reforestation of rainforests under a revived UN REDD+ certification scheme for forest carbon credits. These efforts contribute greatly to the stabilization of global atmospheric emissions. EU investment in afforestation and reforestation projects also increases. Research into SAI remains limited as the original rationale for deployment runs afoul of discredited and unfashionable ideas of dominating and controlling nature. However, there is widespread uptake of other forms of SRM, especially the whitening of roofs in large urban areas. As global emissions continue to fall, like-minded countries announce a multi-generational project to utilize DAC to return atmospheric CO2 levels back to what they were in the Holocene.

3.3 Three digital extended reality scenarios

3.3.1 Scenario 1: Remote work

Table 13: Digital extended reality scenario 1 STEEPV factors

The scenario builds on key factor "System Longevity and Usability" (STEEPV Technological) and projection 1 (Agile/niche: Techno-Efficient Society) that describes a society where technologies remain relevant and can be upgraded to meet new demands. It also incorporates the key factor "Mobility and Energy Consumption" (STEEPV Environmental) and projection 1 (Positive/Static: Home-Based Consumption Economy) that describes home-based XR dependency based on traditional consumption practices and positive carbon footprint.

- **Social:** Major home-based XR dependency based on traditional (over)consumption practices
- **Technological**: A version of an online, virtual "meta-verse" has strong presence in peoples' daily lives, from corporate and government presence to social interactions; A society where technologies remain relevant and can be upgraded to meet new demands
- **Ecological**: Intensive use of XR effects a large carbon footprint; urban forms change in response to the prominence of virtualization, affecting residential and commercial areas, traffic, other forms of transit; significant rural repatriation progresses as virtual workers may be able to work from anywhere
- **Economic:** Acceleration of trends toward work-from home in 'white-collar' settings, but not evenly distributed either within or across national boundaries
- **Political:** In majority of cases, remote work is even considered compulsory, but legislation forbids automatic attention control

Remote work

Beginning already in 2020, the Covid-19 pandemic has greatly accelerated the shift towards work from home. This shift greatly amplified in the following years to the extent that almost all "white-collar", i.e., non-physical, workers now work from home. Even collaborators working on the same team never meet physically. At best they will hang out together or spend a weekend in a retreat to relax, but real work is only done online. This mode of life has become a new normal.

This year, 80% of companies and public establishments (not counting a few still unautomated factories that produce material goods) require workers to use VR helmets and tools of virtual presence for work meetings. Offices with meeting rooms are not necessary anymore. Many companies do not even have a physical office: everything is done remotely or, as we now say, industry has left the material world for the metaverse. Companies are registered by virtual trade chambers, taxed by virtual tax offices, and market their goods at virtual markets. Customers are so used to living in the metaverse that metaproductivity is going up and metaeconomic numbers are excellent.

The change in the labour organization has brought about changes in the material world. Vacated office spaces have been turned into residential quarters. Downtowns have more apartment buildings than office spaces. All shopping is done online, so neighbourhoods are filled with delivery booths. Shopping malls at main transport junctions are gone, as so few people travel to work. Newly built sports facilities are available everywhere and every new residential building is complete with a swimming pool and a gym. Traffic is smooth because streets are mostly filled with utility vehicles and taxis. Despite the additional apartment buildings, people have moved to the countryside, where they can combine work with nature. Vast rural spaces have been repopulated. People go on walks or ride their bikes while wearing a combined vision system that lets them be present in the material and virtual worlds at the same time. Tiny urban apartments are long gone; most workers now enjoy living in much larger cottages and residences. People believe once again: "I have plenty of space, there's enough room for everything!" Air pollution isn't a problem anymore.

Meeting one's colleagues in person is rare and a request to do so is usually regarded as a faux pas. People hang out in the metaverse or with their personal friends. The number of physical humans one sees on a typical workday doesn't exceed the average family size. But families are bigger now: the demographic situation in countries with declining population seems to be slowly improving. New generations of workers, who have been trained to use remote environments in virtual schools and universities are now dominant. The overall happiness-at-work index across the economy is rising. It appears that not meeting too many people has helped to increase both productivity and satisfaction at work.

Labour legislation has not changed much, though. Only the geographical constraints and the requirement to be physically present in the office are gone. Everything else is still in place: strict working hours for employees, high taxes, high cost of labour, and regular checks by managers in virtual environments. New legislation was quickly put in place forbidding automatic attention control for all businesses. In general, though, humans have not changed their attitude to work very much. Being able to instantly switch from work to home chores is seen as a plus, but enthusiasm and commitment still need to be accompanied by rigorous legal and managerial checks. Leisure and work still remain two distinct concepts.

Not every country in the world and not every field of work is changing in this way. In many places manual labour and material production are still prevalent.

3.3.2 Scenario 2: Training in virtual reality

Table 14: Digital extended reality scenario 2 STEEPV factors

The scenario builds on key factor "Access and the Digital Divide" (STEEPV Economic) and scenario 1 (Techno-Oligarchy) that describes that a small group of economic elites are capable of affording the technology which, as part of a vicious technosocial cycle, gives them an even greater socioeconomic advantage. As a consequence, this increases the digital divide further exacerbating socioeconomic stratification. It also incorporates the key factor "Future

Stakeholders" (STEEPV Social) and projection 3 (Unknown Unknowns) that describes changing values for yet-to-exist stakeholders provides unique challenges for designers. Past sociotechnical systems may be incapable of handling future problems and unforeseen (or unforeseeable) stakeholders and emerging values. It also it incorporates key factor "Workplace Environment and Relationships" (STEEPV Technological) and projection 4 (Digitally Divided Workplace) that describes a workplace that requires highly skilled training to be productive, potentially creating a digital divide.

- **Social:** Potential for increased access to diverse and novel experiences made available through realistic virtual worlds; increases in the digital divide exacerbate socioeconomic stratification, expressed prominently in education and employment settings; novel and dynamic prominence and prevalence of mental health and social challenges increase associated with virtualization of life
- **Technological**: Increased access to educational resources, for those who can afford the technology
- **Economic:** Small groups of economic elites afford XR technology which reinforces socioeconomic advantage
- **Political:** Ambiguities in governance of information-based human enhancements; does public education remain a social good?
- **Values**: Changing values around human-human, human-machine, and physical-virtual interactions provide unique challenges for designers

Training in virtual reality

I'd been learning how to swim for six months before I took my first dive in real water. It felt so strange. I knew it would be something new, of course. Training to overcome new sensations was part of standard school education. But actual water on my physical skin produced a very unusual reaction by nerve endings. I had to remind myself to stick to the movements I had learned but it still took my brain a few seconds before it could get my body to work like a machine.

A couple of minutes into my swim I closed my eyes. I didn't think about it. It just happened. And it was a big moment. I had never closed my eyes before while swimming in virtual water. Seeing the markers and obstacles had always helped me to control the direction of the swim. Now a new thing has happened. The muscles continued working but I lost my sense of direction. Where was I going? Would I bump into somebody or something? In virtual reality you never actually touch other people. Was I going to feel another person's body on my skin?

And here it was. Just as I started thinking about opening my eyes again, my arms felt an obstacle. The eyes opened immediately, but I didn't know where I was heading nor what it was that I felt. Then someone screamed. I stopped moving. It was a girl. Her name was Jessica. Maybe we were destined to meet this way.

I knew that Jessica was not from my school, however within seconds my smartXR told me that her parents knew my parents. They had met somewhere in the past, likely in real life. I ignored that information. There were already too many new sensations. I couldn't think straight. But when I returned home the next morning, I asked my parents to move me to the same school as Jessica.

We can't do that, they said. You go to a public school. Like millions of ordinary students, you learn everything in VR. Jessica's parents are activists of the Old-New. They want us to do everything as if we

were in 2000. But your body and your brain can't change anymore. For you there's now only one way to learn. You need to continue what you started, if you want to graduate from school.

But I want to be with Jessica, I said.

Oh, replied my mum turning to my dad. Even these days children are exactly like their fathers. Tell him our story.

When I was a little older than you are now, Dad said, I was training to become a car mechanic. Those years were the heyday of technology. Within as little as a decade, old-style professional schools were replaced by augmented reality simulations. You could learn a profession within 120 hours just by following the instructions and doing exercises. Training was available day and night. People got their certificates much faster and the labour market was full of new specialists. Stock indices for XR firms were sky-high. I've done more than half of my course in two weeks. Then I had to do a real-world exercise. I was very confident in my skills. I went to the garage they randomly assigned on the training app and quickly fixed the car. The system approved the fix but then the screen said: Show the car to the examiner. Where is the examiner? I asked. The bot replied that it would give me a map within a few seconds. You see, I remember every detail of that day, just like you. So, the system gave me a location a couple of miles away from the garage. Well, I thought, now I have to drive this car. I felt a little hesitant. Of course, I'd just fixed it and the system said it was all correct, but was I sure enough to drive it myself? Can you guess what happened next?

Yes, Dad, I replied. The signal on my double retina was green but I didn't need help from the smartXR to predict how this would end. You bumped into somebody in the street. There was an accident and the person in the other car was Mum.

3.3.3 Scenario 3: Speakers for the dead

Table 15: Digital extended reality scenario 3 STEEPV factors

The scenario builds on key factor "Future Stakeholders" (STEEPV Social) and projection 2 (Presentism) that describes technology which is devoted to "here and now", futurism not required, people do not seek to "create a better world" for future generations or the deceased. It also incorporates "Workplace Environment and Relationships" (STEEPV Technological) and projection 3 (Digital Symbiotic Workplace) which describes real time integration of digital tools with work processes and symbiotic integration with other systems and agents. It also incorporates key factor "Trust and Transparency" (STEEPV Value) and projection 32 (Breached Social Contract) which describes that society has little trust in systems given breaches concerning personal data. (e.g., due to cybersecurity negligence, privacy infringement, etc.). Some users tend to prefer low-tech/analogue options given the fear of adopting existing or novel digital systems. Low trust because of low transparency projection. Companies hide their processes to increase profit. Some operations involve breach of privacy.

- **Social:** Society has little trust in systems given breaches concerning personal data. (e.g., due to cybersecurity negligence, privacy infringement, etc.); extended reality technologies are devoted to fixation on present, people do not seek to "create a better world" for future generations or the deceased
- **Technological**: Real time integration of digital tools with work processes and symbiotic integration with other systems and agents

- **Economic:** Companies hide their processes and exploit human data to increase profit at expense of human wellbeing
- **Political:** Ineffectual public data regulation; Increased ambiguity around the legal status of AI-enabled programs and machines
- **Values**: Some users tend to prefer low-tech/ analogue options given the fear of adopting existing or novel digital systems

Speakers for the dead

Two strange things happened to me last week. Only now have I begun to understand their meaning.

I was grading papers for a course I've been teaching for ten years now. Typically, computer science students aren't prolific writers, but this year the essays were really good. They read well and were quite original. Almost no one in this year's class simply repeated the slides. Also unusually, there were few spelling mistakes. When I was done grading, the summary sheet looked amazing: the average grade for the entire class was up by almost two points from the previous year. What a great year for computer science students, I thought. The school's reputation must have been so high that it has managed to attract the best young people in the country. It felt good to be a professor there.

A couple of days later I received a message on my personal email address that the spam filter didn't catch. It came from an address of someone — likely a robot — posing as my deceased father, so I knew it was fake. But since it landed in my inbox, I wondered what was in it. What a curious exception, I thought. How was it possible that the most advanced spam filter didn't catch it?

When I opened the message, I couldn't believe my eyes. "Hey son", it began in exactly the same way my father would write to me when he was still alive. The entire first paragraph — four lines — was unmistakably his style. I could feel it was him. But he was dead, of course, so what happened? Did someone break into my email archive? I copy-pasted the first sentence into the search field but it returned no matches. The text hasn't been copied from an existing message. My brain was beginning to catch onto the idea; however, I couldn't shake off my feelings. I kept on reading but after another paragraph it became too weird that I had to stop. I closed the message, marked it as spam, and it disappeared from my inbox. It left me with an eerie aftertaste.

Then it happened again. Next morning two more messages landed in my inbox. Neither has been caught by the spam filter. It didn't give me shivers like the previous day, but I still felt very surprised. Clearly, they need to retrain those spam filters.

Yesterday I was browsing through the news. So many people received those strange spams that it became a social media sensation. Those who have clicked on the links complained that they couldn't resist it because the text was too familiar, as if it was coming from their family member or a close friend. And the senders that were imitated were always deceased. The story made it into the mainstream news, so it must've been a huge attack.

Now I knew it was all due to that language generation software. Transformer neural nets, as they call them. They transform language so well that their outputs transform human lives. I know I've lived through some of the strangest moments of my life because of these transformers. No plagiarism since they don't do copy-paste. No copyright payments to authors or their heirs, since the outputs are not traceable. The software produces original texts that resemble real people's language very closely yet have completely new contents. This gives humans shivers. My students and the spammers have figured it out. Truth be told, there's not much I can do about it, and it bothers me.

"What can I do?" I asked a friend who works for the data protection regulator. The spammers were obviously using private conversations of deceased people to train their algorithms. "Not much", he replied. "Dead people don't have personal data. I can't help with that."

I asked the same question to the dean of studies at my school. I want students to learn to write well, human-write I mean. He thought a bit and suggested we only do oral exams from now on. Human writing is outdated, he said, maybe forever so.

"Do you still have a job?" I asked the journalist who wrote the article about the spammers. Strangely, I got a rather standard answer that everything would be fine. Most of what he wrote back to me was a cliché, but the message contained my name and referred precisely to my question. I was puzzled at first but then it suddenly became all clear: the journalist — his name was Jaromir Hladík — was himself (or should I say itself?) a transformer.

3.4 Three neurotechnologies scenarios

3.4.1 Scenario 1: Smith vs Jones

Table 16: Neurotechnology scenario 1 STEEPV factors

The scenario is based on the following STEEPV key factor projections:

Social: Neurohype [KF1-2 NT][5]; Social: Useability of neurotechnologies [KF2-2 NT]; Technological: Converging technologies [KF4-2 NT]; Economic: Research investment in neuroscience [KF5-3 NT] Ecological: N/A[6]; Political: public safety [KF10-1 NT]; Value: Materialism — 'we' are our bodies; 'we' are our brains [KF12-1 NT]. A summary, elaborated as follows:

- **Social**: Neurotechnologies are embraced by wide sections of the public, with attending narratives of technological emancipation gaining traction; neurotechnology is adopted in a widespread way, akin to the adoption of mobile device technology
- **Technological**: The Internet of Things takes on a new dimension as web and world connect with devices directly controlled by the brains of users
- **Economic:** Private companies come to lead neurotechnological developments as they seek productivity and recreational applications for consumer and business markets; profitability in the sector leads to auxiliary markets in brain data and user profiles for use in marketing and demography; volume of users and demand for simplicity of interface means device development is driven primarily by consumer/ citizen needs and desires, on a market-like basis, with low barriers to entry
- **Political:** Public debate and media scrutiny abound over who is responsible if and when false claims are made, or harms result from neurotechnology use. Policymakers feel the dilemma of protecting public safety and permitting scientific-technological advance

[5] KF1-2 NT = key-factor no 1 projection no 4 neurotechnologies; see the respective documentations "projections" and "consistency analysis".
[6] Because this scenario relies on ideas of growing consumer neurotechnology, they are focused on non-invasive devices as these are likely to be taken up by consumers. Hence, biocompatibility issues do not arise, not do green industrial imperatives.

- **Values**: Subcultures emerge in opposition to bioconservatism, with hobbyists pursuing more radical homebrew devices

Smith vs Jones

It's twenty years from now. The consumer neurotechnology market has been growing and attracting a lot of positive attention. Ever since the early days of widely available brain computer interfaces (BCIs), they have been put to use in a variety of contexts. They have been used to control hardware and software in ways exciting to the user. BCIs have been used to allow users to type text into computers and phones using brain activity recorded via electrode-studded headwear, as if directly controlling machines with the mind. BCIs have been used as toys, with brain-controlled drones providing people with fun ways to play. They have also been used in self-improvement and enhancement contexts, with users being able to view, and monitor.

BCI devices have allowed people to record and observe their own brain activity, and using the neurofeedback provided to exercise some sort of intentional control over their brain output. Other similar devices have allowed users to optimise their brain activity according to pre-set parameters, including to boost wakefulness, to deepen meditative states, or to improve concentration on tasks. These latter devices not only record and display brain activity, but influence it too, through producing magnetic and electrical fields that interact with brain activity. These *neuromodulation devices* can stimulate brain areas to be more active, and dampen others that are overactive, in order to meet users' desires. Despite some scepticism in expert circles about the effectiveness of BCI devices across these contexts, the marketing is confident, and consumers are satisfied with their devices. Regulators have taken a light touch approach, eager not to stifle the emerging neurotechnology industry and consumer market. But this hands-off approach is set to encounter a challenge, as a high-profile court case begins.

The case of Smith vs Jones involves a car accident. In this accident, each driver was wearing a neuromodulation BCI. Each claims the other was responsible for the accident. Smith claims he ought not to be considered liable for the accident because he was wearing his BCI and was therefore verifiably in a state of concentration, and therefore was taking extra care in driving. Jones claims he should not be liable for the accident because he was wearing his BCI and was therefore not in full control of his actions. On the one hand, Smith wishes to claim his BCI made him an extra safe driver so he could not be to blame. On the other, Jones claims he can't be considered as fully in control because he was under the influence of his device.

Smith's point is that BCI technology has made genuine claims about boosting users' concentration, and that he believes these claims, in good faith. Jones' point is that the claims made about BCI technology as really able to influence brain activity mean he can't be fully responsible for what he does when using it. BCI manufacturers are involved in the case as witnesses: they must defend claims made about their products effectiveness for Smith's side of the argument. But in doing so, they risk substantiating Jones' argument and suggesting that their devices are risky to use. Regulators too are concerned that their approach to neurotechnology may be questioned. If Smith wins the case, a precedent would be set regarding the enhancement possibilities of neurotechnology – one conclusion to this would be that it became seen as irresponsible *not* to use BCI devices. Ought policymakers, in this case, make their use compulsory?

But if Jones wins the case, regulators would be criticised for allowing unsafe technology to be on the market. Regulation might need to be sharpened up, leaving lots of BCI device owners unnerved. Legally too there could be ramifications. Whoever wins, a slew of prior cases could be reopened if they

involved BCI users. A variety of legal decisions might seem unsafe in the light of the verdict on this matter. Especially if Jones wins, other BCI users deemed legally responsible in the past could appeal on the grounds that they can't have been fully responsible and so should be considered innocent.

The public are gripped by Smith vs Jones, anticipating implications for their BCI devices. Like Smith, the public bought and used neurotechnology on the basis that it worked. They would feel cheated if Smith loses the case, and angry at neurotechnology companies for misleading them. They would also feel exposed to risk by regulators who ought to have been more scrupulous about neurotechnology if Smith lost. If Jones loses, however, the public at large might feel anxious to use neurotechnology more often and in more contexts. They might feel they are being dutiful in using devices to boost concentration while driving or at work. They might feel they can rely on the technology to aid them at rest too, altogether enhancing every aspect of their lives through BCI use.

Whoever wins the case, a lively debate on the consequences across a variety of contexts is sure to follow.

3.4.2 Scenario 2: Brain data

Table 17: Neurotechnology scenario 2 STEEPV factors

The scenario is based on the following STEEPV key factor projections:

Social: Useability of neurotechnologies [KF2-2 NT][7]; Technological: Miniaturisation of devices [KF3-4 NT]; Economic: Research investment in neurotechnologies [KF5-3 NT]; Economic: Markets in data: Development driven by signal recording [KF6-2 NT]; Ecological: N/A[8]; Political driver: public safety [KF10-1 NT]; Value: Privacy (personal data, biometric) [KF11-1 NT]. A summary, elaborated as follows:

- **Social**: Neurotechnology is adopted in a widespread way, akin to the adoption of mobile device technology; public debate and media scrutiny abound over who is responsible if and when false claims are made, or harms result from neurotechnology use.
- **Technological**: Development of neurotechnological applications becomes driven by those with the ability to record brain signals, with fidelity and consistency issues becoming less a concern as data processing access increases; recreational BCI boom in consumer markets as devices miniaturize and become easily wearable. Neurotechnology development becomes a user-driven endeavour, with consumer markets outcompeting lab and medical research for resources
- **Economic:** Private companies come to lead neurotechnological developments as they seek productivity and recreational applications for consumer and business markets; consumers are targeted by companies with strong technology push strategies in order to furnish data markets. Research neurotechnology development occurs in tandem, albeit reliant on private databases of brain signals and commercial algorithms; the volume of users and demand for simplicity of interface means device development is driven primarily by consumer / citizen needs and desires, on a market-like basis

[7] KF2-2 NT = key-factor no 2 projections no 2 neurotechnologies; see the respective documentations "projections" and "consistency analysis".
[8] Because this scenario relies on ideas of growing consumer neurotechnology, they are focused on non-invasive devices as these are likely to be taken up by consumers. Hence, biocompatibility issues do not arise, not do green industrial imperatives.

- **Political:** The proliferation of data for neurotechnological development highlights gaps in data protection, with implications for how brain data is taken and used to impact upon citizens; 'Wild West' development paradigm for neurotechnologies. Big claims can be made about the usefulness of devices without much scrutiny
- **Values**: Privacy dilemmas related to protecting public safety, enabling scientific-technological advance, and individual and public health

Brain data

Ada cannot sleep, so she adjusts her neuromodulation device to the 'relax' setting, dampening brain activity such that she begins to drift off at last, transitioning from a stressful to an unconscious state. Her stress levels have been peaking recently as she has had to plan a big event for work. She has been relying a lot on her neuromodulator because of this, using it to fine tune her brain activity to help keep out overwhelming stress, while not numbing herself to the urgency of her task.

Just like a heart patient might be prescribed a pacemaker for a heart rhythm issue, Ada was prescribed her neuromodulator by her doctor because she had been diagnosed with a stress disorder. She knows other who have similar devices for other conditions, including some friends with attention deficit syndrome who use their devices to promote states of increased focus. Recently, the devices have been upgraded, so they no longer need to be manually controlled. They can now run on 'automatic,' relieving the user of the burdens of self-monitoring.

These automatic devices record brain activity as it happens, across the user's whole brain using EEG electrodes in some discreet headgear. The activity is compared with exemplars of 'normal' brain activity stored in the cloud. When the activity being recorded starts to depart too much from normal, the headgear receives a signal and the electrodes emit electromagnetic waves to bring local brain activity back towards a normal state. The device software includes information on the user's diagnoses so that it anticipates the kinds of brain activity to expect and doesn't overreact to the activity characteristic of chronic anxiety or ADHD.

Ada, and her other neuromodulation device user friends, are very happy with the system. It gives them a greater sense of confidence to get on with their day-to-day activities and appears to work like magic. Behind the scenes, however, there is a more complicated story.

BrainMod industries manufacture easy-to-use neuromodulatory brain devices. The devices are essentially a platform for applications that can include the sorts of things Ada and her friends use, but a variety besides. The devices can be used to control hardware and software in pretty much any context – typing into phones or word processors, controlling toy drones, online gaming. They can be used in research as well. In fact, the accuracy of the data in the cloud relies on huge amounts of data being collected from all BrainMod devices and stored online. The vast amount of aggregated is processed according to complex mathematical approaches, and general pictures of 'brain activity' for different contexts are arrived at. For Ada, this means she can rely on her system to alleviate anxious states.

More generally, there is interest from a variety of interested parties. Marketing companies want to know about the brain states users manifest under different kinds of conditions so that they can target their ads more effectively. The 'neuromarketing' industry is growing rapidly, fuelled by insights gained from BrainMod devices. Users don't often think about it, but the ability their devices have to automatically detect and modify brain activity relies upon access to the cloud data, which means they are always locatable when their devices are on automatic mode. For marketing companies, this means ubiquitous brain recording complete with location data that allows a combined neuro-geographical

picture of users' everyday life. They buy access to the data at a premium. BrainMod's subsequent profits allow for more product innovation, which in turn permits greater data accuracy, creating an ever-evolving brain data market.

As user numbers grow, BrainMod goes on to make a strategic partnership with national security agencies. These agencies are interested in the prospect of improving disaster response through modifying the brain states of those caught up in emergencies toward calm states, responsive to instructions. Safety and security will be served well when the public remain calm under in disaster settings or under terrorist attacks. Security services have therefore bought access to the control centres at BrainMod in order to look into neural crowd control under these kinds of emergency conditions. BrainMod are glad to have the contract as it represents a very secure means of future funding, and so better prospects for continued product innovation.

One day Ada is reading a newspaper article and notices a story about BrainMod's recent growth, including its partnerships with marketing and security industries. She is shocked and feels exposed. The benefits of her device to her seem undeniable. But she feels like the use of her brain recordings in these ways should never have been possible. It feels grotesque to her. But she has benefitted from the overall market in her brain recordings. She does not know what to do: ditch her device in protest? Continue using it and feel exploited? Overall, she wishes the market in data had never been allowed to open – or that she had never found out.

3.4.3 Scenario 3: Ageing society

Table 18: Neurotechnology scenario 3 STEEPV factors

The scenario is based on the following STEEPV key factor projections:

Social: Useability of neurotechnologies [KF2-2 NT][9]; Technological: Miniaturisation of devices [KF3-4 NT]; Economic: Research investment in neuroscience [KF5-2 NT]; Ecological: Green industrial imperatives (environmental impacts (EI)) [KF7-2 NT]; Political: Public health perspective [KF9-4 NT]; Value: Materialism — 'we' are our bodies; 'we' are our brains [KF12-1 NT]. A summary, elaborated as follows:

- **Social:** Neurotechnology comes to perform a public health function, with applied neuroscience re-search playing a significant role in medical fields like neurology and psychiatry; neurotechnology competes with sectors of medicine, like neurology and psychiatry
- **Technological:** Neurotechnology adoption is widespread, akin to mobile device technology; neurotechnology development becomes a user-driven endeavour, with consumer markets outcompeting lab and medical research for resources
- **Economic:** the volume of users and demand for simplicity of interface means device development is driven primarily by market forces
- **Ecological:** Neurotechnology development is led by its possibilities for replacing more environmentally destructive alternatives e.g., in medicine, where devices can replace pharmacological approaches with their implications for chemical use and drug waste

[9] KF2-2 NT = key-factor no 2 projections no 2 neurotechnologies; see the respective documentations "projections" and "consistency analysis".

- **Political:** Policy shifts to liberalise user-driven applications of neurotechnology in a crypto-medical context; increased prominence of debates on appropriateness of neurotechnology applications; translational research, from lab to the hospital bedside, suffers from fear over transhumanism
- **Values:** Subcultures emerge in opposition to bioconservatism, with hobbyists pursuing more radical homebrew devices

Ageing society

The effects of an ageing society include a growing older community, and associated costs relating to the needs of older people. A growing gap between the numbers of those in work and those beyond retirement age places economic pressures on policymakers who need to balance budgets with decreasing levels of economic activity. At the same time, there are natural health needs that emerge as populations age, as well as growing burdens of disease. Among these burdens are Parkinson's disease, Alzheimer's disease, and dementia. These are particularly difficult and distressing elements of ageing societies that produce economic as well as personal stresses. The costs include residential or nursing care, the distress of family disintegration, and feelings of despair at the cognitive decline of loved ones. Present research into pharmacological and other treatments has not produced a silver bullet. Neurotechnology promises advances in treating neurological disease in ways that could revolutionise this difficult area, reducing the need for drug production, and the threats such production pose to water systems through contamination and plastic production.

Electrical stimulation of the brain has the potential to improve interconnectivity among brain cells. This is hoped by researchers to produce improvements in cognitive performance. Some research has already suggested this is the case, albeit for limited periods of time. The hope would be that for patients and their families living with disease like Alzheimer's, alleviation of memory loss and perhaps arrest of speedy decline in cognition could be brought about. This would make family life easier, the life of the patient more enriching, as well as cutting costs for care. Besides this, the expenses of and reliance upon drug treatments with limited effectiveness could be reduced.

Otto is getting older and has seen the publicity surrounding neurotechnology for memory improvement. He is fearful of losing his memory to old age and has already noticed forgetfulness in his everyday life. He wants to do everything he can to stay on top of this, for his own sake and that of his family. He begins shopping around for memory-boosting devices and eventually settles on one. He has been using it for some time and feels like he is less worried about memory loss. He feels like he is doing something about it, and so this brings comfort. His doctor is sure that the device is not doing anything really to improve brain function. He is well aware of advances in neuroscience but is sceptical that they can be translated into easy to use, consumer devices. But he is glad Otto is feeling less stressed. In fact, Otto had not really shown clinical signs of cognitive decline and his fears were mainly unfounded, medically speaking. But since these neurotechnological products appeared, more and more people look to them for 'brain training' or cognitive enhancement.

Sometime into the use of his device, Otto is shocked to discover the company whose headset he has been using is going to go bankrupt. The device relies upon a proprietary cloud data hosting system to personalise its activity. It also receives software and firmware updates. If the company goes bust, Otto will lose the use of the headset entirely. This prospect leaves him feeling concerned that his memory and cognitive health are at risk. Despite assurances from his doctor that the device did not really help,

and that there was not yet any real problem besides normal age-related forgetfulness, Otto cannot be consoled.

While his family are sympathetic to his distress, they are also somewhat relieved. Like his doctor, they had thought his concerns over mental decline were exaggerated. They weren't very happy with the company's marketing policy, feeling as though it preyed upon natural fears likely to be held by those getting older. The family also noted that the claims made by the company marketing the device were careful not to make health claims, but only about 'wellness' and improvements in general life. They supposed that this was a way around device regulation, and that it was a sign that the device wasn't everything it seemed. Besides all this, they also thought the money paid by Otto – for the headset, and for the monthly subscriptions for personalisation and updates – was too much.

As tech companies come and go, the prospect of consumers' neurotech devices becoming obsolete becomes real. This is little more than a hassle to those whose devices are used recreationally. But for those whose devices are used for more serious applications this creates no little distress.

4 Experts' enrichment of TechEthos scenarios

In Task 3.4, information about innovation ecosystem stakeholders from T3.1, as well as basic scenarios developed in T3.2, were used together to surface expert stakeholders' attitudes to ethical implications of the TechEthos technology families. The aims of the three expert workshops – one per technology family were to generate:

- Expert reflections to enrich scenarios
- Expert perspectives on technology families
- Expert identification of and reflection on ethical issues associated with the technology families as presented in the scenarios
- Expert identification of and proposal on solutions to ethical issues

Results of workshop deliberations were compiled, summarized, and analysed in D3.5, "Policy note: Analysis of expert scenarios addressing ethical implications of the selected technologies". Results will be used in connection with ethical analysis (WP2) and legal analysis (WP4) to support development of ethical guidelines (WP5) as well as strategic advocacy (WP7).

Each workshop used three scenarios, accompanied by participatory expert deliberation, to explore the potential social and ethical issues associated with development of the three TechEthos technology families. Each scenario discussed was designed to surface potential social and ethical issues, based on the varying future conditions presented (including diverse social, technical, economic, environmental, political and values (STEEPV) dimensions in each scenario). Workshop recruitment, methodology, and results[10] are presented, below.

4.1 Methodology: Scenario workshop recruitment and design

Recruitment for the expert workshops targeted a gender-balanced, diverse group of individuals from research performing, education, industry, and civil society organizations for each workshop. Workshop designs were cleared in advance with ethics review and approval conducted by De Montfort University. Recruitment relied upon reaching out to individuals based on a) experts identified through the Innovation Ecosystem Analysis (Task 3.1); b) experts identified by consortium members, based on personal networks; c) ADIM board members; d) identification of authors on articles conveying social and ethical issues associated with the technologies. A total of 101 individuals were contacted in the recruitment effort. The 14 members of the ADIM board were contacted separately by the leader of WP6. Of the remaining experts contacted, 39 had expertise in climate engineering technologies; 27 in digital extended reality; and 22 in Neurotechnology. The 87 individuals were contacted first with a customized mail merge referencing expertise and inviting attendance. A subsequent customized mail merge was sent in follow up. Where individuals responded and were unable to attend, they were asked to recommend colleagues or peers to attend. In this way, a total of 15 experts attended the climate engineering workshop (9 men 6 women); 8, extended reality (6 men, 2 women); and 11 (4 men, 7 women), neurotechnology. Participants were sent informed consent sheets to sign and return in advance of the workshop, documenting the workshop agenda as well as providing the scenarios in

[10] For the policy recommendations and solutions proposed by the experts please refer to D3.5.

advance to read. In addition to external experts and ADIM board members, TechEthos representatives of T3.1, T3.3, WP2, and WP4 also attended the workshops.

Workshops were conducted online, using the Zoom videoconferencing service, and Miro as a digital whiteboard. Workshops were each 4 hours long, contained one break between each scenario reading, and occurred in the last week of April 2022. Each workshop combined individual reflection, group discussion, and plenary discussion activities to collect expert feedback on the scenarios, as well as ethical issues associated with the technologies. Scenario authors were not disclosed to participants—even when in attendance at the workshop—to avoid devolution of conversation into personal criticism or derailing debates on intended versus read meaning of the scenarios. The decision was taken to support open receipt of positive feedback or criticism about the scenarios.

For every workshop, the set of three scenarios for each technology family was explored. Each scenario was discussed in-depth. The workshop started with an introduction to Miro, and a participant round table. Next, the first scenario was read aloud. Subsequently, participants were asked to silently brainstorm initial impressions, reflections, and corrections to the scenarios. These were then discussed in plenary. In the next phase of discussion, experts were asked to join randomly generated breakout groups and discuss ethical issues surfaced by the scenario. After breakout groups, participants were invited back to a plenary discussion that a) reviewed the ethical issues discussed in each breakout group and b) asked people to first individually note, and then collectively discuss, possible responses to the ethical issues identified (for the structure of the workshop see Figure 11). Participants were encouraged not to seek consensus, and rather collect wide range of expert opinions on the technology families and associated ethical issues and responses. This process was then repeated for each scenario.

Figure 11: Screenshot of the Miro board used for structuring the scenario reflection

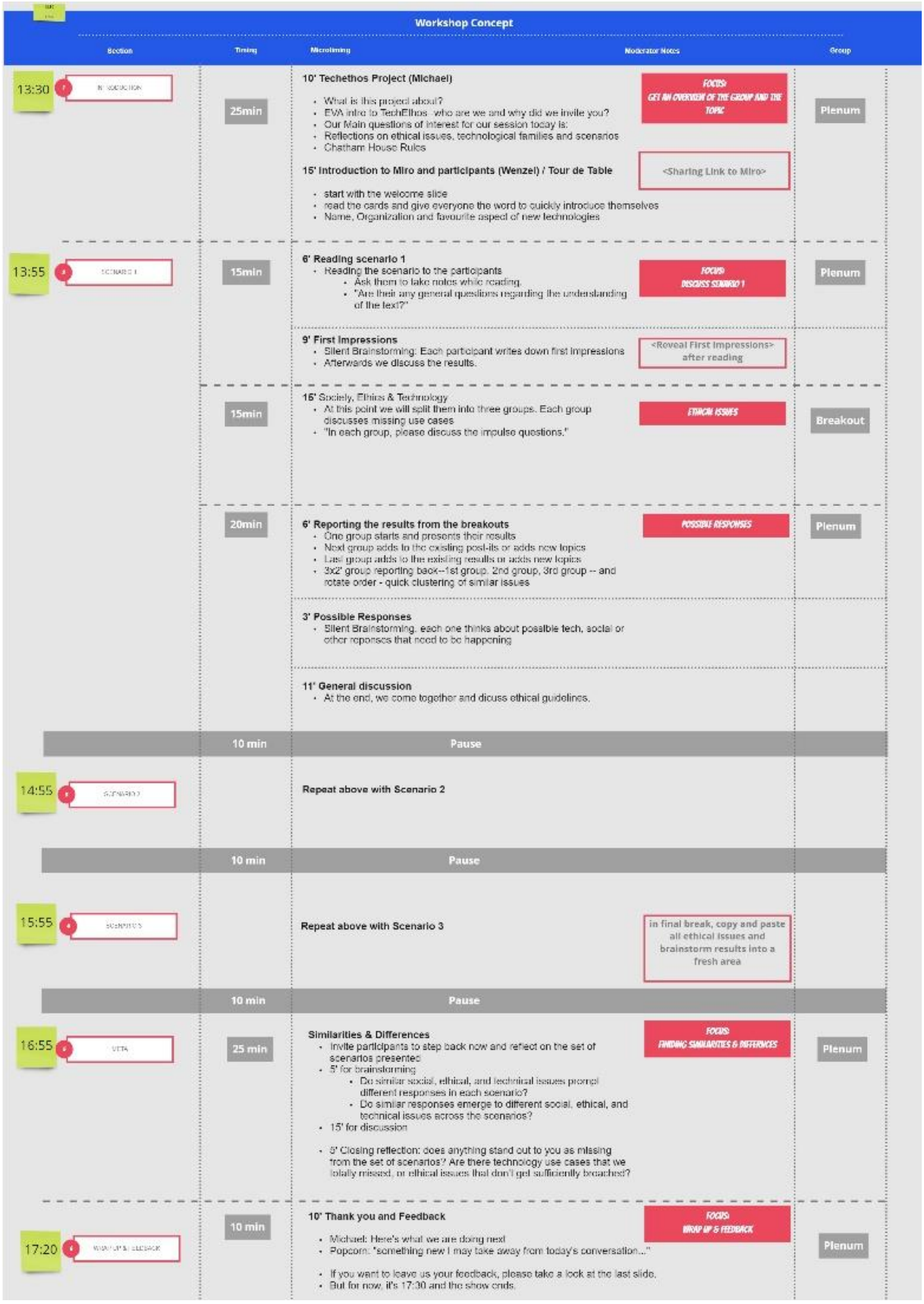

Figure 12: Scenario workshop agenda

In each workshop, there was insufficient time to conduct a closing reflection as planned, however, comparative notes across scenarios organically emerged from the conversations as review of each scenario progressed. Workshops were co-facilitated, an essential feature allowing turn-taking in facilitation roles, and robust notetaking of plenary discussions. In addition, the TechEthos members present were distributed across groups to ensure robust Miro text generation for data capture.

After the workshops, all Miro text was copied and organized into word documents. Data were sorted based on the nature of feedback. We sorted for information about the substance or presentation of the scenarios (reported in Annex 8.1 Exemplary expert feedback on the); social and ethical issues associated with the technologies; or possible responses concerning social and ethical issues. Results from each individual workshop are presented below.

Please refer to D3.5 for synthetic conclusions on overarching social and ethical issues and potential responses shared across the technology families.

As a final note before presenting the results of this exercise: reflection on ethical and social issues presented herein are to be viewed in complement to the suite of analyses conducted elsewhere by the TechEthos project (e.g., analyses of ethical issues in WP2; legal analysis WP4; and stakeholder and citizen engagement exercises T3.5, etc.), as well as the rich work of other scholars, stakeholders and publics presented in the literature.

4.2 Climate engineering: Future ethical issues

Intentional, large-scale climate interventions implied by CE technologies raise many potential novel ethical and social issues. Such issues are driven in part by problematic underlying assumptions about whether and how such technologies might play out in the world. Particularly, concerns include assuming a uniform model of development is held by all nations; implementing CE without broader reflection on decision-making approaches; and focusing on technological fixes in response to climate change. The ethical issues associated with these flawed assumptions can be addressed by opening up to alternative models of development; empowering equitable international governance and civil-society deliberations about CE; and pursuing broad, diverse, well balanced and socially considerate responses to climate change.

4.2.1 On development

Across all three climate engineering (CE) scenarios, experts touched on the problem of assuming a uniform approach to "development" across the planet. Such an assumption—that all countries by default “want” to “develop” in a singular mode of extractive, material consumption and environmental degradation as found in heavily industrialized countries—ignores varied cultural preferences about desired ways of living. Problematic too is the way it hides or side-steps the destructive aspects of economic growth contributing to anthropogenic climate change in the first place.

A number of ethical issues follow a position on assuming extractive development as a desired global norm. The position ignores concerns of distributional justice and unequal sharing of burdens and benefits of action or inaction. The costs to launch CDR and SRM technologies, and the benefits of their effects, may not be uniformly or equitably distributed. Without attention to the distributional dynamics, existing inequalities produced by current economic paradigms might worsen. Ignoring problematic approaches to economic development runs the risk of re-creating issues when deploying environmental or social “solutions” to climate change. For example, any CE requiring land use (in the case of reforestation or bioenergy with carbon capture and storage) will have to reckon with the

associated political economy of land-grabbing, dispossession, ecologically devastating monocultures, perverse incentives for old growth forest deforestation, etc.

4.2.2 On decision making

Across all three climate engineering scenarios, experts touched on the need to attend to the ethics of decision-making related to CE technologies. Questions were raised around whether to research or deploy some of these technologies, more than how or in what ways. Such questions are connected to the global and regional dynamics of climate systems where unilateral or adversarial multi-lateral deployment may have far-reaching regional and global ramifications—climatic or geopolitical. In addition, questions were raised around assumptions of incumbency in decision making structures, and whether (and how) decision making around CE might perpetuate injustices and sidestep ethical issues also associated with rapid decarbonization.

A number of ethical issues follow a concern for the ethics of decision making. There are concerns, particularly related to unilateral deployment of technologies, like stratospheric aerosol injection (SAI), where regional consequences may play out beyond the zone of technology deployment. Closely related to the issue of deploying SAI was a call, still, to consider the alternative—the negative impacts of non-deployment. Related to carbon capture and storage, social and ethical concerns arose related to carbon storage siting. These touched on whether vulnerable communities would be included and / or further disadvantaged in decision-making about where to site storage facilities for captured carbon. An additional concern relates to abuse of political economic power; for example, of multinational fossil energy companies potentially standing to profit from removal of the very pollution they profited from emitting into the atmosphere (to say nothing of government economic subsidies enacted to enable such pollution).

4.2.3 On technological fixes

Across all three CE scenarios, experts touched on the need to challenge the problematic assumption that climate change may be addressed through technological fixes alone. Such an assumption, experts warned, is dangerously misguided. First, any such technological fixes will be strongly conditioned by social forces (for example, see the 1.2.2 concerns related to perpetuation of injustices in decision making about CCS or other CDR technology). In addition, fixating on technological-fixes ignores systemic, socially-driven responses to climate change (whether through transit, farming, energy, built-environment, lifestyle or any number of others) – potent interventions in their own right.

A number of ethical issues follow from a focus on technological fixes. Using catastrophic forced-choice situations to make policies that push quick-acting, short-term technological fixes, represents a core ethical concern. Such an approach ignores potentially longer-lasting, more efficacious, non-technological and systemic interventions. Approaching CE from the lens of technological fixes means ignoring serious environmental harms and human exploitation and harm not directly associated with levels of carbon pollution—for example various forms of water, air, and land pollution or ocean acidification.

4.2.4 Ethical issues highlighted

Table 19: Climate engineering ethical issues in STEEPV categories

- **Social:** effects of armed conflicts due to environmental and geopolitical instability; storage siting issues; reaching for technology in response to socially mediated climate emergency (technooptimism issue); Intergenerational tensions; Global South and Global

North have different desires for development; lifestyle changes with reduced consumption and values of rights of nature with implications on industrial activity

- **Technological:** prevalent technooptimism about DAC and marine CDR; using catastrophic forced-choice situations to make policies that push quick-acting, short-term technological fixes
- **Ecological:** biodiversity loss; environmental justice; violation of intrinsic value of non-human species; nature-based "colonialism" of placing trees where none have been before; monoculture implications on ecology and biodiversity
- **Economic:** unfairness - abuse of economic power by companies who gained profit from the emission now benefit from storage; governance mechanism - carbon credit trading remains cheaper than emissions reduction; power imbalances between those who can participate in the market and those who suffer from the market
- **Political:** distributive justice regarding energy usage and burden sharing; power of markets and private governance, lang-grabbing - displacement of people with less economic power; lack of global discussion on SRM; lack of exploration of potential abuse of SRM; legal recognition of the rights of nature expenses
- **Values:** food choices – food prices will go up if dietary choices remain the same; human manipulation of nature; hazard of assuming universally shared trajectories of development or approach to valuing nature; not everyone may want a "developed" world; techsolutionism

4.3 Digital extended reality: Future ethical issues

The extension and augmentation of our reality through digital means can take many different facets and forms, each of which will bring different use cases and different ethical problems. Many of these problems are caused by the data used to create this extended reality. Although the digitalization of the society is not a new phenomenon, the regulation of ownership of data is an ongoing issue that will gain importance in the discussion on XR, especially when discussing the question of who owns the data and has access to it. The replacement of physical infrastructures with digital infrastructures shifts responsibilities from the public sector to the private sector. While this can improve certain situations, it often means getting caught up in techno-solution-oriented visions and seeing XR as a solution to problems that didn't exist before or are social in nature. Finally, running a prospected XR system will lead to an exponential increase in the required server capacity, causing additional CO2 emissions and increasing the depletion of rare earths, fossil fuels and other limited resources. As the experts pointed out, the environmental impact is often not considered in the debate but should not be forgotten.

4.3.1 Data ownership

Across all three XR scenarios, experts touched upon the question of data ownership. When machines start to create texts, audio, visuals or other XR media that resemble physical reality, intellectual property/ownership questions become relevant especially with regards to the copyright of the used data and the authorship of the created media. The training data used for machine learning (ML) algorithms to create these media comes from many different sources, and often without the knowledge of the sources, raising additional ethical issues about privacy and consent.

A number of ethical issues follow the issue of data ownership within the context of XR: One scenario described the application of NLP to generate communications appearing from deceased persons' accounts, sent to relatives, friends, and loved ones. Regarding the question of data

ownership, neither the deceased person nor their heirs had the possibility to intervene or contradict the use of the data required to train and deploy the natural-language programme. This extreme example highlights areas where the regulation of personal data may be inadequate; for those living and deceased. This example also raises questions like: Who owns the product or service created based on data drawn from individuals or groups of people? If a machine creates a text based on the work of multiple authors, who might be considered the author of said novel text and receive licenses or payments?

4.3.2 Digitalization of work and social interactions

Across all three XR scenarios, experts touched upon concerns related to how everyday life and social interactions may be digitalized. Digitalization may mean virtualization of everyday habits; creation of remote work environments that build upon globally available digital infrastructures; digital training, and education systems; the artificial (re-)creation of social interactions and communication practices through mediated content, etc. However, the seamlessness and consequences of such transitions of non-digital to fully virtual realities are far from clear.

A number of ethical issues follow the concern related to digitalization of work and social interactions. One exemplary set of issues relates to remote work. Such issues follow from certain types of jobs becoming increasingly possible through remote and/or virtual means. On the one hand, this might create or worsen societal divisions between groups of people who work remotely versus those requiring physical attendance. In addition, the increase of digital nomads—meaning people in sectors able to travel the world and work from anywhere with legal permission, electricity, and internet connections—may result in people working remotely for high-salaried positions but living in areas with low-cost of living. Consequently, the influx of such individuals might lead to distortions in rent, goods, and services for people working, paid, and living in areas with lower costs (currently observed, for example, in the Canary Islands in Europe or in Mexico City in the Americas).

Digitalization of work may also impact the social well-being of individuals. Working eight hours from home without meeting people face-to-face may result in diminished social units and fewer social contacts, affecting physical and mental well-being and resilience to external stressors in life. Such issues may become especially pronounced in cases where fragile digital infrastructures and associated systems (e.g., energy) fail, and no physical social redundancies exist—potentially affecting vulnerable members of society even more acutely.

Another challenge in this area relates to issues of authenticity in social interactions. As machine learning and deep fake videos become more advanced, it may be increasingly difficult to distinguish real and fake contacts, information, and data, wreaking potential havoc on interpersonal, cultural and political dialogue.

4.3.3 Tech-Solutionism for social problems

Across all three XR scenarios, the experts questioned the existence of problems that XR technologies will help to solve. The potential use-cases presented in the scenarios (and in the discourse about this technology) are often replacing already existing areas of everyday life (e.g., public education, work, social interactions) while at the same time implying that the existing structures are decaying, failing for various (mostly social or political) reasons and are therefore in urgent need of improvement. While, for example in the case of public education, it is true, that the current system needs improvement, it remains debatable if an XR-transformation represents an actual solution or, rather, a vehicle to profit of the sector, creating new problems, exacerbating existing problems, or shifting existing problems to different areas in society.

Several ethical issues follow the championing of XR as a technological solution chasing problems. Underlying the discourse of XR is the promise of a technological disruption and a replacement of

already established structures with digital solutions. These digital solutions are often driven by a monetary logic of exploitation appearing in the guise of good-will. As experts pointed out, XR technology is most of the time developed by private companies whose main interest lays in turning individual habits into collectible data or exploiting publicly available services for private benefits instead of creating solutions that benefit the public.[11] In essence, creating XR infrastructures to become the platform for social interactions or the future of education raises questions around the political and economic power of such platforms, as well as questions of who determines, programs, curates content delivered through such platforms and who owns and has access to the data that are generated on such platforms. E.g., applied to remote work, the experts mentioned that disruption from XR raises issues of how the technology may be used to monitor and control workers, undermining exchange of information and organizing rights.

4.3.4 Ethical issues highlighted

Table 20: Digital extended reality ethical issues in STEEPV categories

- **Social:** affordability of the technology; social isolation; divide between fully remote workers and in-person workers (physical separation, uneven distribution of opportunity to engage in home-based work); cultural pressures emerging from norms around work in society; what implications are there when non-living entities receive a voice
- **Technological:** the technology lacks social/haptic elements which lead to safety concerns; fear of addiction to the technology; algorithms change the way humans interact with each other (unlike static books)
- **Ecological:** Resources of ubiquitous technology; constructing and maintaining the infrastructure; rare earth mining increases; additional environmental impact of servers and energy costs
- **Economic:** divide between technological and physical education in terms of costs [impact of low-cost places from high-wage remote workers]; authenticity of work (if partially automated) – issue of patents and licenses authorship; human creative labour and value of work vs. the work of an algorithm; new business model on interactions with the deceased
- **Political:** data protection issues; issues with organizing labour unions, protests, democratic issues in the Metaverse dues to a lack of physical interaction; status of legal entities like birth and death; rights and use of data of dead people; authentication issues with fakes – legitimization issues of what is fake and what is not
- **Values:** fairness; gender bias; depersonalization, depression and decreasing of social skills; isolation becoming the norm; change in attitude towards work – some jobs become less attractive because online work offers a better work-life balance; dignity of posthumous data; understanding of privacy; taking care of digital legacy before we pass away; changes to the relation of death through the technology

[11] Similar arguments are also raised under the term “tech-solutionism” (Morozov, 2013).

4.4 Neurotechnology: Future ethical issues

Ethical issues regarding the use of neurotechnologies in the future will very much depend on the context in which this technology is used. The above examples show that the use of neurotechnology in the context of enhancing the body will raise ethical questions that call for political responses. How might society change, if neurotech-enhancements were to become a norm? What if the companies, are offering services, cannot keep up with responsibilities to maintain the devices sold? How might a neurotech-based market economy look? According to the experts, most of the questions that are debated currently can be subsumed under a term like, “Neurocapitalism” and revolve around issues of data privacy, business models, and transparency. Ethical reflection on neurotechnology cannot therefore be separated from the cultural and economic context in which the technology is imagined, developed, and deployed.

Experts also pointed out the predominance of one assumption appearing across scenarios: That neurotechnological devices might find use cases outside of medical contexts. In medicine, devices might be used to help people with disabilities communicate, move, or otherwise interact with their environment. In the current discourse, devices may also enhance people without disabilities. It is unclear whether the commodification of neurotechnology will happen or if it represents the ambitions of profit-seeking private technology companies. Moreover, discussion of the ethical issues arising from this assumption diverts attention from ethical discussions related to the actual development of neurotechnology. For example, devices may often be tested on animals (e.g., monkeys, mice or pigs), raising an ethical issue in its own right. In the future, questions may also arise around testing prototypes in human subjects. Here again, medical testing (e.g., vaccines, birth control pills, etc.) also raises ethical concerns, as the histories of drug and procedure development include many examples of non-consensual experimentation on the bodies of marginalized persons—persons often from communities who can less frequently access the benefits of the innovations made possible by their unethical treatment.

4.4.1 Neuro-discrimination and the constant optimization of the body

In each of the three neurotechnology scenarios, different devices and potential use cases are explored. Experts pointed out, across all three scenarios, an assumption that neurotechnology devices could be used beyond medical treatments to enhance human bodies. While currently, devices are used mainly in medical contexts to assist people with disabilities, there are already tendencies to pursue neurotechnologies for self-optimization and human enhancement beyond the purview of medical treatment. Devices promising human enhancement thereby create a concern that only people who can afford such a technology might benefit from its use. In addition, socioeconomic divisions related to use could lead to discrimination against those who do not have the means access to such technologies.

A number of ethical issues follow concerns about neuro-discrimination. As for the use of neurotechnology as a tool to enhance the human body, experts pointed to several ethical issues. For example, if the technology can alter the ability to concentrate / focus, the device could become a mandatory requirement for certain jobs. This challenges values such as equality, by leading to discrimination against people who are not willing, do not have access to or cannot afford to use neurotechnologies. For example, one promise of neurotechnological devices is the ability to intervene in the body's own functions and regulate emotional states such as anxiety, sadness, or stress. According to the experts, this might lead to a re-definition of such feelings. Is a little anxiety a good thing or does this already become a mental 'disease' that needs to be treated? Is stress in a work context a common feeling or considered as a handicap? Counteracting these human emotional states through technological enhancements, with the goal of optimizing one's body (or increasing one’s efficiency at work) raises questions about what constitutes a “desirable” state of consciousness.

According to the experts, this discussion might also lead to a new definition of what it means to be 'healthy' as it shifts the threshold away from what we currently define as a healthy body towards a technologically enhanced body.

4.4.2 Neurodependency and the addiction to biotechnologies

Across all three neurotechnology scenarios, experts pointed out that the use of neurotechnology may come with physical dependence on certain devices. As neurotechnology changes and affects human functions (e.g., emotional regulation), experts noted our bodies may adapt and become dependent on the technology, whether for medical treatment or enhancement. As neurotechnological devices are generally provided by specific companies, users of such devices might become dependent on said companies for regular updates or servicing. This dependency can cause major problems, as the support or the constant development of the technology cannot be guaranteed by the developer (e.g., companies go bankrupt, merge with others, change strategies, or, as in the case of monopolized motorized wheelchair manufacturers in the US, force consumers to use only approved parts and service stations marked up to near unaffordable rates). Compared to other technologies which can be easily replaced, repaired, or discontinued (e.g., smartphones), technology that becomes part of a human body may not be so easily modified, and thus carries additional risks.

A number of ethical issues are associated with concerns about neurodependency. A biotech company going bankrupt and ceasing development of its product line is a scenario that is already all too real.[12] In such a case, users that depend on the neurotechnological device would be left without the necessary support, especially if the device is linked to an external cloud system which provides the infrastructure for the usage. This also touches on another ethical problem: data accessibility. Currently, most technical systems are proprietary and do not allow data transfer between devices from different developers. In case a company cannot provide the original service anymore, it may leave users with no alternatives, as they cannot transfer their profile data from one system to another. As participating experts pointed out, the users (especially their bodies) become dependent on the technology in general, and on the company that provides the technology and the service in particular. Furthermore, even if companies persist, they may be acquired by other companies, change their direction, adopt new strategies, or adapt their business models to address unforeseen market developments. This can also impact the original function of the device. New features that users may not agree with may be installed years after the purchased device was introduced (also known as "function creep"). Due to the user's physical dependence and since the device is interwoven with the human body, the user may not be able to easily opt out.

4.4.3 Neurosurveillance and the constant monitoring of the 'mind'

Across all three scenarios, experts pointed out that devices may constantly monitor concentration levels and brain activity throughout the day. The constant monitoring and tracking raise questions about data privacy and ownership: Who owns the brain data? Are these data medical data or behavioural data? What happens to the data collected after a user dies? What will the data be used for? How private are the data, given that they represent the internal state of users' 'minds'? Finally,

[12] See for example the case of the US biotechnology company Second Sight. The company provides neurotechnological implants for customers with visual impairments. The Argus product line offers bionic eyes to help blind individuals detect light and dark shapes. In the beginning of 2022, Second Sight merged with Nano Precision Medical, another neurotech company, and since changed their strategy. Part of this change has meant abandoning the support and development of the Argus line, leaving their customers without a functioning device (Strickland & Harris, 2022).

the process of commercializing brain data and profiling based on the users' brain activity may affect people's freedom of thought.

A number of ethical issues follow concerns related to neurosurveillance. Experts noted the importance of context when assessing impacts of brain monitoring activities. In the employment context for example, a device could be used to monitor brain activities in fields where people need to be attentive and in constant focus (e.g., in medical surgery or air traffic controllers). Although devices could help focus, there is a trade-off between privacy and legitimate concerns about performance. The latter issue becomes a problem when people are monitored to assess their productivity or as a form of efficiency control. The experts drew the following scenario: Based on the datasets collected by monitoring the brain activities of different users, companies could create brain-activity-profiles, and create judgments on the individual mind of users. This profiling of brain activities might lead to new definitions of identity, privileging certain people that show better profiles than others, leading to a new premise for discrimination of people based on their brain profiles and creating new groups of vulnerable people. Here the experts compared this form of profiling to similar profiling processes based on behavioural data. These profiles become commodities that can be sold for targeted advertisements. In the case of NT, what is sold is the 'mind' of the user. What was emphasized by the experts during the discussion was the necessity of a clear definition of the data that is measured by devices: Is the measuring of the brain activity behavioural data or medical data? Depending on such definitions, different measures regarding use and commodification will be needed.

4.4.4 Ethical issues highlighted

Table 21: Neurotechnology ethical issues in STEEPV categories

- **Social:** effects on identity, self, agency and autonomy; data ownership; exclusion from labour market; workplace pressures to manage stress; issues with psychometric profiling of behaviour; issues of addiction to the technology; equality in terms of accessibility
- **Technological:** responsibility of different parties: software engineers, individual users, companies developing; the role of neurotechnology among device systems – how data can be owned, accessed and transferred; responsibility of shutting off the device(s); issues about updating and the afterlife of the device
- **Ecological:** energy usage for data storage; issues of maintenance and obsolescence; sustainability of devices
- **Economic**: the power of private companies accessing data; issue of consent for current and future use of the data; people being the product of the technology if not paying
- **Political:** governance of brain data management; legal definition of "person" and "identity"; where is the line between "tech is responsible" and "user is responsible; fundamental freedoms and rights might be impacted if brain activity is measured; neurodiscrimination; in case of misuse the issue of liability; issues of manufacturer discontinuation and data ownership
- **Values:** technology is shaped according to societal needs – values are embedded in the design; redefining terms like anxiety; mental privacy issues – neurosurveillance; right way of ageing – expectations on ageing and the role of the technology

4.5 Concluding thoughts from expert reflections

Across all three technology families, we observed several common social and ethical issues. One relates to a **fixation on technological solutions to more-than-technological-problems**. This illuminates how the industrial capitalist paradigm shaping the development of these technology families manifests uniquely in each area:

- **In CE**, this manifests as pursuing CDR and SRM sometimes independent of larger social solutions to comprehensive energy, transit, built environment, agriculture and industrial system transformation.
- **In XR**, this manifests as a seemingly headlong rush to embrace potentially profitable innovations, as well as a blurring of lines between physical and virtual worlds with little care or concern for social or political consequences.
- **In NT**, this fixation manifests as a drive toward technological interventions on human identity with little regard to consequences for social discrimination, and broader mental healthcare pursuits.

A second social and ethical issue common across the three technology families relates to **environmental concerns**.

- **In CE**, there are the potentially significant disruptive effects on land use, agriculture, terrestrial, and marine and freshwater systems, and human settlements. Such effects might emerge from climate interventions gone awry – or from being insufficient, in the end, to address the scale of climatic changes that are affecting the planet.
- **In XR and NT**, environmental concerns relate to material production energy intensity, the CO2 emissions produced by high-energy-demanding computational exercises, as well as water and land use associated with the creation, operation, and end-of-use of technological devices.

A third set of common social and ethical concerns relates to issues of **procedural[13] and distributional justice**[14].

- **In CE**, concerns relate to the way incumbent firms and governments responsible for climate pollution in various forms might end up as beneficiaries of technological solutions developed or deployed (and frontline communities deprived of vital resources to respond to climate change hazards). Alternatively, there is a concern in climate engineering with the way states might unilaterally deploy SRM or CDR, with serious negative, non-consensual consequences for neighbours or regions across the planet.
- **With XR** come problems of unilateral decisions to deploy surveillance or "labour saving technologies" that negatively impact large groups of society to further enrich ever smaller groups of economic and political actors. There are concerns with the way such technologies might distort or manipulate access to information in such a way as to strengthen minority rule or autocratic regimes.

[13] Procedural justice asks questions like, "how are decisions made and who is involved?". Procedural justice concerns include issues of fairness and legitimacy in decision making (e.g., with the marginalization or outright exclusion of key stakeholders or communities impacted by decision-making).
[14] Distributional justice asks questions like, "who benefits from these technologies; who is burdened by these technologies; do those bearing the burden also realize benefit?". Distributional justice concerns include the way benefits or burdens associated with the implementation or outcomes of a decision may be unequally apportioned across populations.

- **In NT**, there is basic concern with who might have access to potentially beneficial medical interventions, and who might rather simply access such interventions for human enhancement. There are also concerns related to altering definitions of people with disabilities or enhancements, with discriminatory consequences.
- **For XR and NT**, these issues of justices and abuse of power closely relate to concerns over data access, privacy, and valuation.

5 Citizens' enrichment of TechEthos scenarios: awareness & attitudes

Task 3.5 explores the public awareness and attitudes towards the three technology families. With this exercise citizens excitements and concerns are giving a voice, which is important for the development of ethical guidelines because it reflects the interests and values of society. Citizen engagement can help to enrich the discourse on emerging technologies by bringing in new perspectives and identifying issues which might have not come into light in the expert workshops and the development of the basic scenarios.

In this task the focus was on capturing citizen's awareness and attitudes. Analysing awareness helped to produce insight into how much citizens are familiar with the technologies discussed. Capturing the attitudes showed the reasons for excitement and concern the public had towards certain technology families prior to the engagement exercises. From the results of the citizen engagement exercise eliciting and analysing values gave a more elaborate insight into what the public finds important when it comes to the utilization of the technologies in question.

In order to engage citizens, an innovative game-based approach was taken. The idea behind this new research method was to create an interactive, engaging, and fun exercise where citizens in a rather "natural" way engage in a discussion about the technology families. The game-based method was aiming at making the complex topic of this research more accessible, encouraging participation in a less formal setting and giving space for facilitating a more open and creative discussion about the future of our society and the potential impact of the discussed technology families.

5.1 Methodology: Citizen engagement with science cafés and scenario game workshops

The third stage in the evolution of TechEthos scenarios, capturing citizens' awareness and attitudes, and consisted of three main components. First, the development of the game-based participatory methodology (D3.2). Second, the recruitment of citizens to a series of science cafes hosted by science engagement organisations involved in the project as Linked Third Parties (LTPs) to beneficiary Ecsite in six countries: Austria, Czech Republic, Romania, Serbia, Spain, and Sweden (T3.5).[15] Finally, the engagement of public persons in a series of 20 workshops across LTP countries one for each technology family selected by the TechEthos Project (D1.2).

These two aspects will be presented in more detail in the following sections.

This role of the game in the project (T3.3) set a number of expectations and constraints. The expectations are that the game will elicit awareness, attitudes, and values towards the selected technology families, provide feedback to enrich the basic scenarios and be playable by a general audience that includes vulnerable groups. The constraints to the game are that the game should generate meaningful qualitative data that can be captured for subsequent analysis, incorporate, and

[15] These countries represent a good mix of European countries (including an EU membership candidate country), reflecting diversity in terms of geographical coverage (Iberic peninsula, Northern, Central and Eastern Europe), cultural diversity, levels of income and technological development.

engage with the scenarios and ethical issues, and demand only frugal means of production and limited text to allow translation and adaptation in the national contexts of the six LTPs.

Moreover, upon considering the challenge of producing the game and the need to address three technology families, a choice was made to develop a single yet adaptable game with four variations, one for climate engineering, one for neurotechnologies, one for digital extended reality and one for natural language processing.

We first collected existing best practices and resources from the literature, the repertoire of the Linked Third Parties, which have extensive experience with presenting and discussing technologies with citizens, and the TU Delft GameLab's experience in game development using the Triadic Game Design methodology. Second, we made a first selection of games that could be expected to bring a diversity of elements to the discussion. Third, we used the selected games to kick-start a cycle of three co-creation workshops with external experts from the science engagement field, project partners and representatives of the Linked Third Parties. The three workshops provided feedback on how best to meet the requirements and arrived at a validating a game concept.

This game concept was refined by the internal Task 3.3 team to ensure that discussion sparked by the game will elicit the awareness, attitudes, and values of the participants. The basic scenarios, the knowledge gathered by the project during the identification of the three technology families (WP1), the description of their innovation ecosystem (T3.1), and the first results of the analysis of ethical issues that emerge in relation to them (T2.3) represent further sources of content during the game development process.

The game development process and current version of the game is described in Deliverable 3.7 Draft version: Tools to develop and advance scenarios dealing with the ethics of new technologies.

5.2 Conduct of citizen engagement events

- 15 science cafés involving 449 participants
- 20 scenario game workshops involving 331 participants

5.2.1 Science cafés

Science cafes are a popular format that has been used for the past decades to provide a forum for discussion of current scientific issues for anyone who is interested. In general, organisers should strive for a casual or informal gathering place (e.g., science centres and museums, galleries, bookshops, and bars) and a welcome atmosphere with snacks and drinks in which everybody feels comfortable to share, and barriers to participation are low.

In the TechEthos project, the main objective behind the science cafés is to build knowledge and interest about the selected families of technologies among citizens, thereby helping with the recruitment of participants to the game workshops (presented in 5.2.2).

As part of T3.5. (Capture public awareness and attitudes through TechEthos scenarios), Ecsite's LTPs conducted a series of science cafés in the following cities: Vienna (Austria), Liberec (Czech Republic), Bucharest (Romania), Belgrade (Serbia), Granada (Spain), and Stockholm (Sweden).

A science café methodology guideline was produced by Ecsite and disseminated to the LTPs before Summer 2022, covering aspects such as topics, venues and catering, format, moderation, recruitment of speakers and participants, budget, and reporting. Some basic details and Key Performance

Indicators (KPIs) about the science café cycle are presented in the **Error! Reference source not found.** b elow.

Table 22: Basic description of KPIs related to the science café events, per LTP

Feature	Basic description
No of events	**A minimum of 2** More events can be organised provided that LTPs remain within the budget allocated
Timeframe	**June-September 2022** According to the project logic, the science cafés should be completed before the kick-off of the workshops (section 5.2.2)
Speakers	**A minimum of 3 experts** should be engaged throughout the events More experts can be included, but it is recommended that no more than 2-3 take part per event, so as to allow a lot of interaction between them and the audience
Participants	**60 citizens have to be engaged across the two science café events** o 30% should belong to vulnerable groups o At least 2 vulnerable groups targeted, with all groups reached at least once across all LTPs
Objective	o Build knowledge (e.g., ethics, technological applications, etc.) about the selected families of technologies: climate engineering, neurotechnologies and digital extended reality o Recruit participants for multi-stakeholder events
Method	Using science café methodology, involving a mix of short pitches from invited speakers, Q&As or other forms of exchanges between speakers and the audience, energisers and ice breakers, and anonymous and informal feedback
Duration	Most science cafes last around 90 minutes
Reporting	A report from the event organisers with the event basics and some overall feedback and impressions

The science cafés took place in several locations, i.e., science centres and museums, libraries, cultural centres, galleries, and educational centres. In order to allow a greater number of participants to attend and join from different parts of the country, a few LTPs also opted for an online version, where the public could interact and ask questions via chat. The science cafés were informative and informal and LTPs strived to reach the widest possible audiences. Citizens were invited to discuss new and emerging technologies – more specifically the technology families that the project is focusing on: climate engineering, digital extended reality, neurotechnologies - with scientists, innovators, engineers, professors and civil society. Invited speakers illustrated not just the state of technological capabilities but also ethical, societal, and legal challenges. Discussions also included how these issues

related to their own work, bringing a local and topical angle to the themes that TechEthos is addressing.

From June 2022 until January 2023, the LTPs conducted a total of 15 science cafés involving 449 participants. Seven out of 15 science cafés were dedicated to the Climate Engineering technology family and addressed topics ranging from climate change and energy sources to technologies like carbon capture and storage (CSS), bio energy carbon capture and storage (bio-CCS) and solar radiation management (SRM). During the three science cafés on neurotechnologies, the audience discussed topical issues like the hyper connectivity between humans and machines, the risks to freedom of thought and the implications of neural implants. The five science cafés focusing on digital extended reality explored the ethical repercussions of new technologies like the metaverse and virtual reality on identity, freedom and autonomy. To complement their science café, in Sweden, Ecsite's LTP collaborated with a technology lab that offered hands-on science activities attracting children 10–15-year-olds, siblings and parents. During the same session, the invited speaker, manager of the Visualisation Studio at KTH Royal Institute of Technology in Stockholm, brought VR equipment which visitors could try.

As highlighted in the science café guidelines, the LTPs were invited to work with the following categories of vulnerability, identified at the proposal phase:

- socio-economic disadvantage such as youth not in education, employment or training and homelessness;
- social and physical isolation (e.g., people living in rural, remote and regional areas, isolated elderly, former incarceration);
- gender and LGBTQ+;
- minority status, including Roma communities, migrants, refugees, asylum seekers;
- learning and physical difficulties and disabilities;
- mental and physical health, including patients with chronic or incurable diseases and
- problematic patterns of alcohol and substance abuse.

Across the different science cafés, the LTPs managed to involve five of the seven categories of vulnerable people listed above, namely people with a socio-economic disadvantage, people living in rural areas, isolated elderly aged 65+, people belonging to the LGBTQ+ community, migrants, and people with physical disabilities. The recruit these participants, LTPs implemented several strategies, e.g., collaborating with associations and gatekeepers representing vulnerable communities, setting up the science cafés in areas with greater ethnic and religious diversity and where most of the community experiences socio-economic disadvantages, offering free entrances to the science centres and museums to encourage participation.

Upon conclusion of each science café, the LTPs compiled a report including the event basics (e.g., date and time, location, technology family addressed, speakers, participants) as well as feedback and impressions from participants regarding their familiarity with the topic addressed and the tone of their questions.

5.2.2 Scenario game workshops

Multi-stakeholder workshops were organised as part of T3.5 (Capture public awareness and attitudes through TechEthos scenarios) at the premises of LTPs. There were three events per country, with one LTP holding five scenario game workshops, for a total of 20 events. These workshops engaged a variety of participants, an average of 16 citizens per workshop and other experts and stakeholders. Many participants from the public, including vulnerable participants, will be known to the organisers, having previously participated in the science cafés described in section 5.2.1. The basic features and key KPIs related to the game workshops are presented in Table 23.

Table 23: Basic game workshop statistics, per LTP

Feature	Basic description
No of events	**A minimum of 3, each dedicated to a different technology family** More events can be organised provided that LTPs remain within the budget allocated
Timeframe	**December 2022 – March 2023** According to the project logic, the science cafés should be completed before the kick-off of the workshops (section 5.2.2)
Participants	**60 citizens have to be engaged across the three game workshops – approx. 20 in each workshop, playing in groups of 4-5 players** **Per workshop** o At least 15 citizens, including 30% citizens belonging to groups that have been identified as vulnerable o Possibility to organise an event solely for vulnerable groups o At least 2 vulnerable groups should be targeted, with all groups reached at least once across all LTPs o 2-3 Civil Society Organization actors o 2-3 local research and technology actors with insights into the selected technologies families
Objective	Generate information about public and civil society perceptions o Awareness and acceptance o Attitudes, values and concerns about the technology family being discussed o Enrich the TechEthos scenarios with additional insights o Provide input into the project's guidance (e.g., ethical frameworks or guidelines) for researchers, technologists, Research Ethics Committees etc.

Method	Game workshop consisting of introductory activities, one or more game sessions using the game method developed in Task 3.3 (see section 5.1) and a debrief session for further reflection and discussions
Workshop structure	**Introduction** (30 minutes) o Time for informed consent, pre-participation survey, short presentation **Warm-up** (35 minutes) o Awareness capture, getting to know each other **Game play** (45 minutes) o In groups of maximum 7 people + table moderator **Reflection** (35 minutes) o Reflection on the final world of the game, building a story from the future activity **Conclusion** (15 minutes) o Sharing further resources, events, etc., post-participation survey
Duration	Approx. 4 hours (+30 minute pre-workshop welcome)
Ethical considerations (as confirmed in the ethical review process)	o Age of majority (no minors, or under 16, as per legislation) and capacity to give consent o Information sheet and Informed Consent Form
Reporting	Data collection according to a project-level data protocol: o Pre- and post-event survey data collection sheet: to include the data gathered though the pre- and post-event surveys; o Data reporting template – including the information gathered during the game play and the activities carried out in the warm-up and reflection phases, translated and typed up in English

5.2.3 Working with vulnerable groups

Participants include members of the public, including those that might be identified as belonging to a category of vulnerability, residing in the countries of the six LTPs organisations carrying out—under coordination of Ecsite—the workshop.

Linked Third Parties could decide to hold the event on their premises (e.g., science centres, museums) or at external premises, venues where populations belonging to groups that have been identified as vulnerable could more easily access and participate in events such as community centres, the venues

of local associations, temporary/pop-up activity spaces, etc. The decision to do so needed to be made in consultation with associations providing services to vulnerable groups.

During their implementation of the workshops at a country level, each Linked Third Party was encouraged to reach citizens belonging to at least two groups that have been identified as vulnerable. Broad categories of vulnerability were listed in the grant agreement signed with the funder. As stated in the TechEthos ethics application, LTPs could involve vulnerable groups belonging to the following categories:

- socio-economic disadvantage e.g., as youth (over 18 years old) not in education, employment or training, homelessness
- social and physical isolation (e.g., people living in rural, remote and regional areas, isolated elderly)
- gender and LGBTQ+
- Minority status, including Roma communities, migrants, refugees, asylum seekers
- learning difficulties and physical difficulties and disabilities
- mental and physical health, including patients with chronic or incurable diseases

When recruiting vulnerable groups, the LTPs were invited to collaborate with trusted associations providing relevant services. No questions regarding vulnerability were to be asked directly to participants. The recruitment by the associations was a sufficient indicator of belonging to this societal group.

Additional considerations to be taken into account included:

- Special consideration for venue accessibility
- Additional support before and during the workshop from association members
- 30-minutes pre-welcome
- Also possible: smaller side event, involving only members of the vulnerable groups at a public location (e.g., the associations' premises) that is more comfortable and adapted to their needs

5.2.4 Participants' motivation for attending

During the introduction of the workshop, participants were introduced to research ethics and data collection, the context and the planning (timeline, schedule, etc.) of the workshop. Below are the points addressed during this phase:

- Goal of the day
- Getting to know each other (ice breaker)
- Informed consent & pre-participation survey
- Programme & house rules
- Intro to TechEthos & the technology family being discussed

At the beginning of each workshop, participants received a packet containing a unique, randomized ID, informed consent sheet, pre- and post-survey.

The pre-event survey was completed in written form and with the assistance of a facilitator where requested. In this document participants were asked for personal information (e.g., gender, nationality, educational background), information on how they had heard about the event and whether they had been involved in previous project activities, and their motivation to participate. Among all LTPs, we collected a total of 321 surveys. This number differs from the total number of participants, which amounted to 329. This difference can be attributed to the Swedish LTP, VA (Vetenskap & Allmänhet) which recorded a total of 75 participants, but only 67 surveys. This is due to the fact that some of the participants involved, who were representatives of vulnerable groups organizations, ended up helping other participants to complete their survey, without completing their own.

Below is some of the information that emerged from the analysis of the data collected in the pre-event survey.

When asked for their motivation to participate, participants could choose from the following options:

- Passion for the technology
- Curiosity about technology
- Desire to be involved in how technology develops
- I like the science museum
- To meet people
- Compensation
- Other

Based on the data collected, the first motivation to participate was **curiosity about technology (47.04%)**. This option was chosen by 151 participants, followed by the **desire to be involved in how technology develops (16.2%)** chosen by 52 participants. 40 participants said they took part to the workshop because of their **passion for the technology (12.46%)** addressed. In addition to motivations closely related to the project's technology families, participants also attended because they **like the science museum and the activities it offers (10.60%)**. A very similar percentage was recorded when it came to **meeting new people (10.28%)**. 7.78% indicated **other motivations** than those identified at project level such as a **passion for education**, **the possibility of expressing one's thoughts and feelings** and the **possibility of using this technology in their work**. Less than 1% of participants identified **compensation (0.93%)** as the reason for their presence.

5.2.5 Participant demographics and general overview

This session reports on the participants of the game workshops organised by the LTPs between December 2022 and March 2023. We present a general overview and demographics as collected through the pre-event surveys. In total, the LTPs organised 20 workshops (Figure 13). Five of them decided to dedicate one workshop to each TechEthos technology family: climate engineering, neurotechnologies and digital extended reality. During the latter, part of the participants was invited to play with the extended reality deck and part with the Natural Language Processing deck. This explains the difference in the number of participants in these two sub technologies. ASUR for its part

organised five workshops: two on neurotechnologies, one on climate engineering and two separate workshops, respectively on extended reality and natural language processing. The 20 workshops were attended by a total of 329 participants. Below is their breakdown by technology family for each LTP.

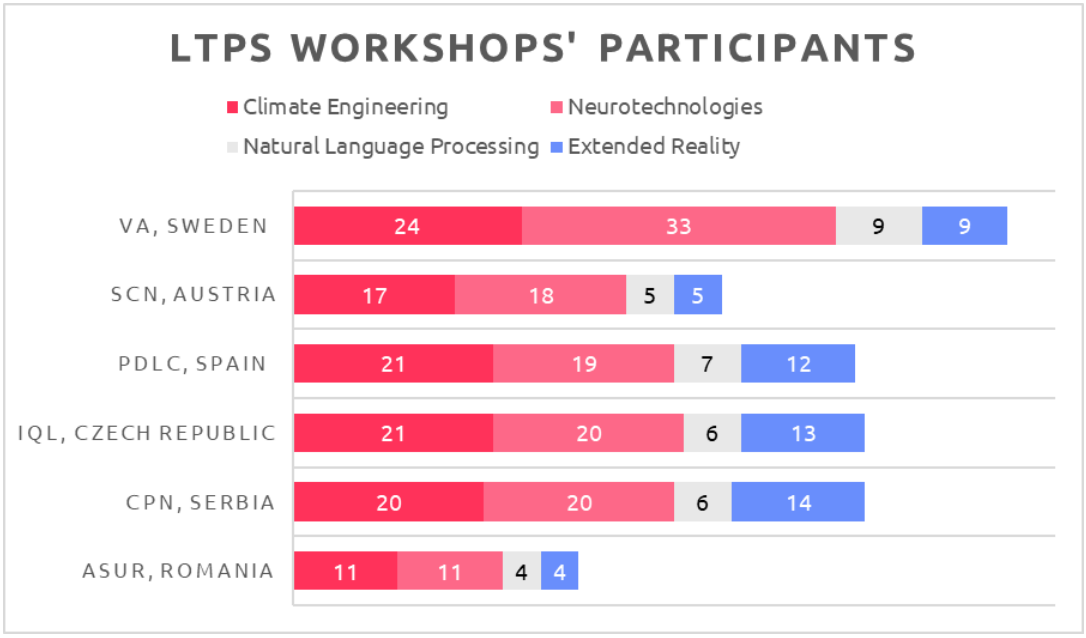

Figure 13: LTP attendance

The technology family with the most combined workshop attendees was neurotechnologies with 121 participants, followed by Climate Engineering with 114 participants. 57 participants focused on extended reality and 37 on natural language processing (combined, 94).

As agreed at the project level and outlined in the guidelines provided to the LTPs, each LTP had to involve a total of 60 participants, with 30 per cent of them belonging to at least one or several vulnerable groups. Three out of six LTPs, SCN, PdlC and ASUR were unable to reach the target KPI with respectively 45, 59 and 30 participants. IQL, CPN and VA succeeded in engaging the agreed number with respectively 60, 60 and 75 participants. This disproportion, especially in the case of ASUR, was due to the collaboration with external partners who had to cancel their commitment and language problems that prevented the involvement of vulnerable groups that were initially considered (e.g., Ukrainian refugees living in Romania). On average, the LTPs were able to achieve 91.38% of the target KPI.

When it comes to the demographics of the various participants, the pre-event surveys provide an interesting set of data on gender, educational level and nationality.

As far as gender is concerned, participants could choose from the following options:

- Female
- Male
- Non-conforming
- Neither
- Both
- Prefer not to say
- Other…

What emerges is that 58.25% of workshops audience identifies as female, whereas 40.80% of participants define themselves as male and only 0.93% do not identify with any gender or prefer not to share this information (Figure 14). Looking at the gender distribution among the workshops of the different LTPs, it is interesting to observe how in three cases (SCN, CPN and ASUR), female participation rises to 70% of all participants, reaching 88.88% in the case of SCN.

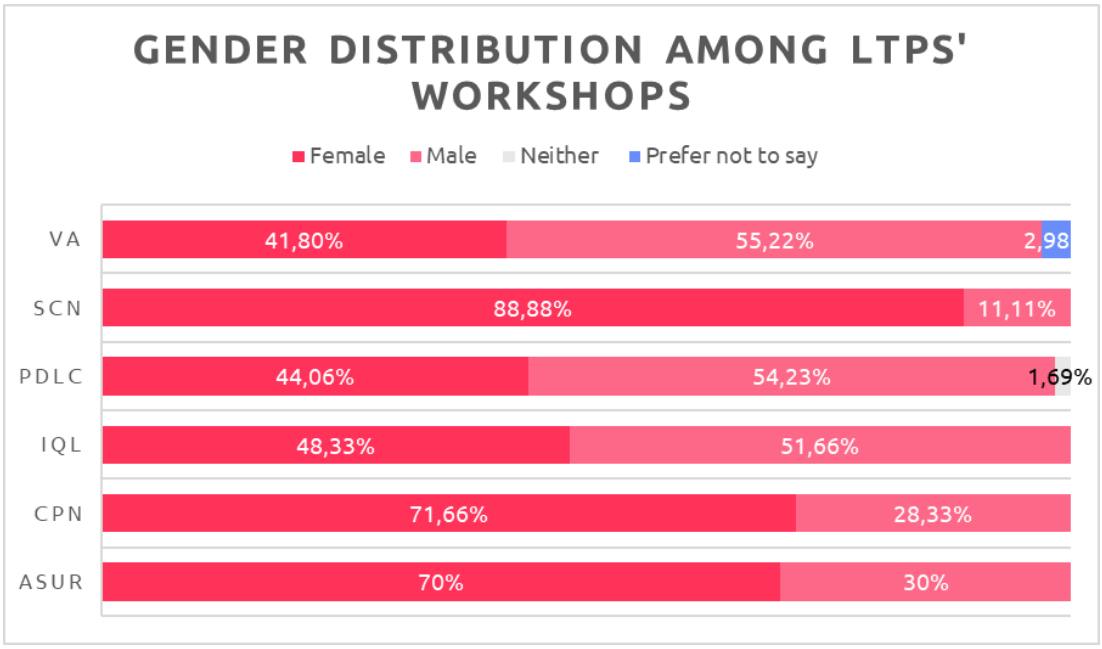

Figure 14: Gender distribution across workshops

If we take into consideration the gender representation across the workshops dedicated to the same technology family, we can notice that gender distribution is fairly balanced across all (Figure 15).

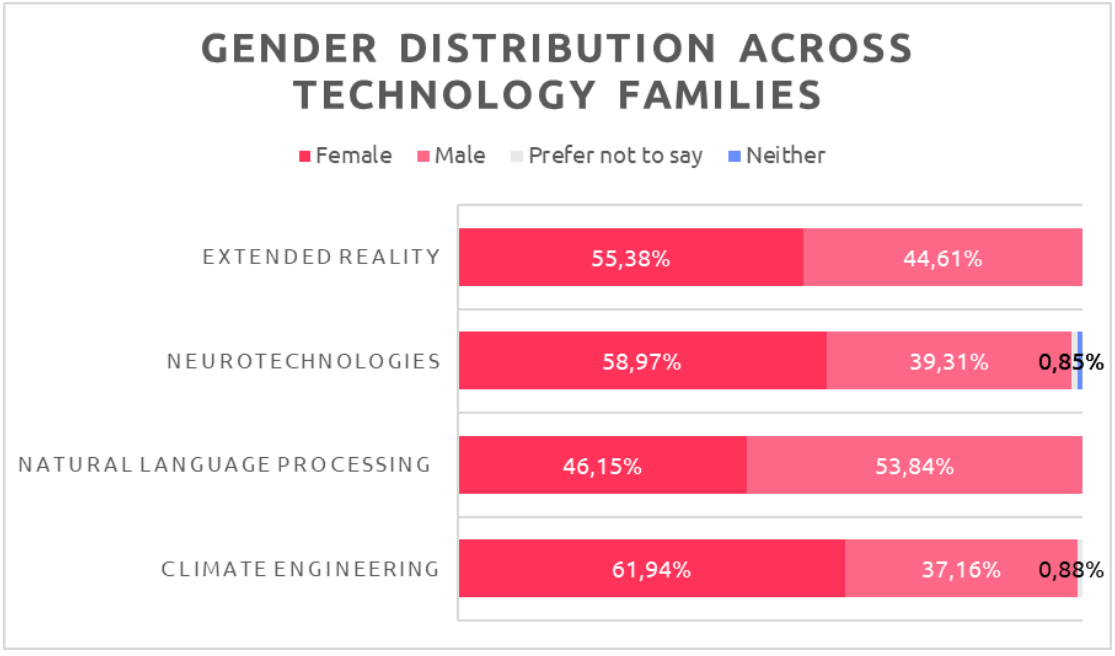

Figure 15: Gender distribution across technology families

As defined in the KPIs related to the game workshops, 30% of the workshop participants were to belong to groups that had been identified as vulnerable (Figure 16). Each LTP had to target at least

two vulnerable groups with all groups addressed at least once among all LTPs. As shown in the chart below, all LTPs managed to reach the target KPI. In two cases, VA and SCN, more than 50% of the participants in the workshops belonged to vulnerable groups (Figure 17).

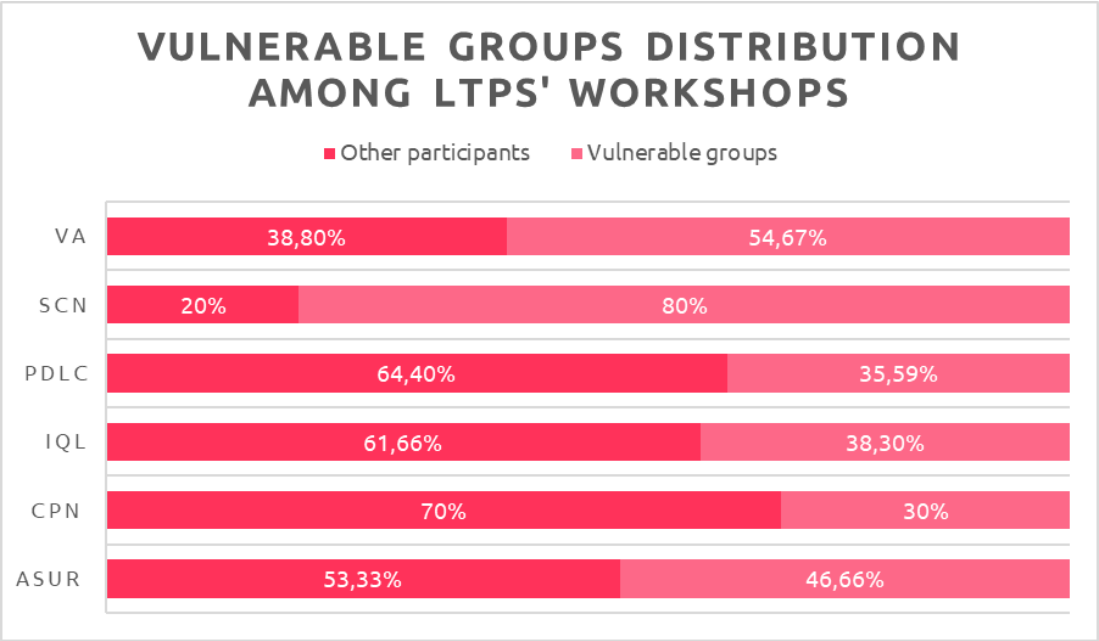

Figure 16: Participation percentages of vulnerable groups engaged across LTP workshops

With the exception of its Climate Engineering workshop, VA in Sweden managed to involve all the categories of vulnerable people identified for this task in all its other workshops. Quite remarkable is the case of its neurotechnology workshop where 26 out of 37 participants could be traced back to these groups. During this workshop participants included people with learning and physical difficulties as well as other mental and physical health issues. In the workshop, it became apparent that the language and game concept was difficult for certain players to grasp, and the moderators really had to take time trying to explain the technologies. Despite extending the game play time, players could not go through all the three rounds. Nevertheless, the nature of the discussion was very positive and revealed that some players had experienced some of the technologies being mentioned as part of their own treatment (or their relatives) so were really interested in learning about the future of these technologies and they could relate to some of technologies. They also really appreciated having been asked for their input, felt they were being listened to and empowered.

Another noteworthy case is that of SCN, where 80% of workshop participants belonged to the minority group category. In two specific cases, the Climate Engineering workshop (13 out of 17 participants) and the Neurotechnology workshop (17 out of 18 participants), the representation of this group far exceeded that of other participants. Among the minorities represented were ethnic minorities, with Afghan, Ukrainian, Serbian and Polish participants among others. Their strong involvement can be attributed to SCN's experience of often collaborating with organisations representing these groups in its various activities.

Overall, the feedback from the participants involved was very positive and many saw the game workshops as an opportunity to be involved in a type of activity in which their voices and perspectives are usually not included.

All vulnerable groups identified at project level were reached at least once across all LTPs (Figure 17). The most represented vulnerable group was the minorities one (40%), followed by participants with

socio-economic disadvantages (18%) and those belonging to the gender and LGBTIQ+ community (13%).

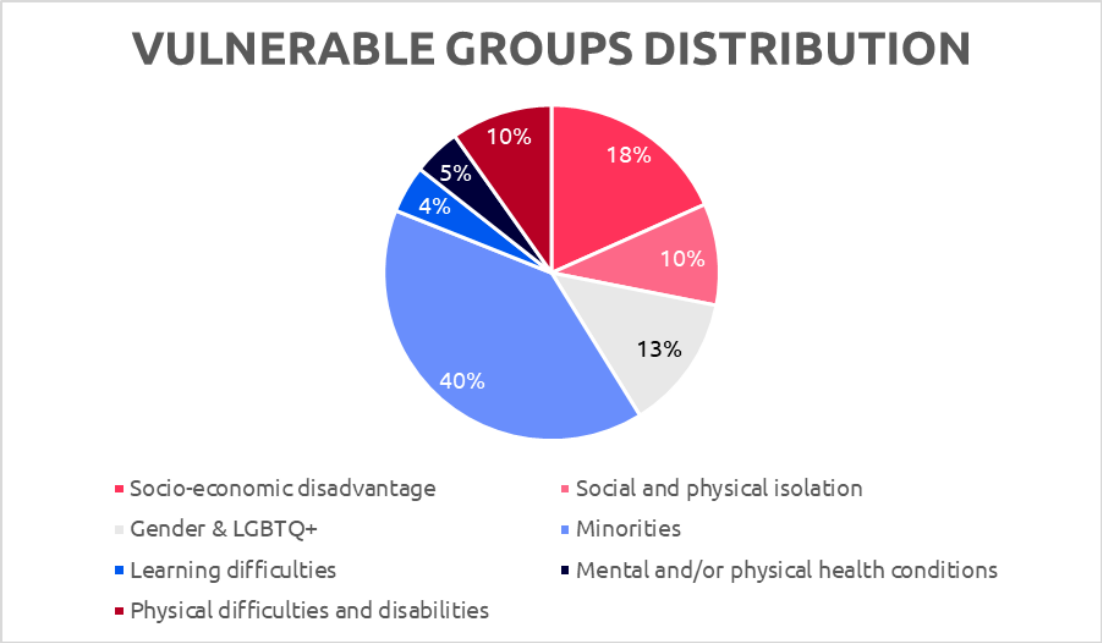

Figure 17: Distribution of participation of types of vulnerable groups engaged by LTPs

The data collected in the pre-event surveys also make it possible to outline an overview of the educational background of the workshop participants. A total of 320 participants filled in this information. Participants were asked to indicate the last education course they had completed by choosing from the following options:

- Primary education
- Secondary education
- High school education
- Vocational training
- University degree
- Advanced vocational training
- Other....

This part of the survey could be adapted to the educational structures of the different countries. The graph below attempts to group the data received under 10 macro-categories:

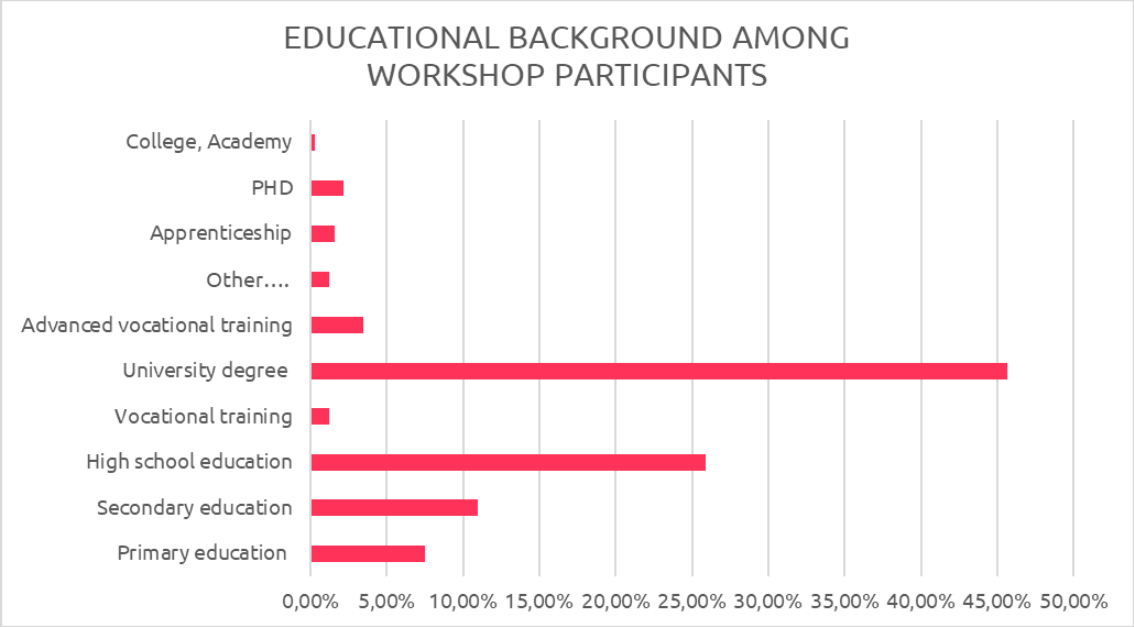

Figure 18: Educational background among workshop participants

Reportedly, 45.62% of the participants held a university degree. This category includes several qualifications such as BA, MA and post-graduate degrees, not allowing for a subdivision. 25.93% stated that they had a high school degree, followed by 10.93% who were in possession of a secondary school degree.

5.3 Results of citizen engagement exercises

This section reports on the results of the 20 multi-stakeholder workshops conducted across the six TechEthos LTP countries. Four multi-stakeholder workshops were conducted per country (with citizens, civil society organisation actors, and local research and technology actors with insights into the selected technology families, as described above) to **elicit societal awareness and attitudes** and provide input to advance the TechEthos scenarios in a further step. Together these results are discussed, and have been shared with WP5 (operationalising, complementing and enhancing ethical and legal frameworks) and WP7 (five exhibits/installations in relation to the scenario advancement workshops).

To support presentation of data collection methods and results, we present below a set of definitions that informed the TechEthos approach. Definitions are offered for clarification of what is meant by "awareness" and "attitudes". The complete script of facilitation questions in the participatory game workshop, as well as the pre-and-post surveys deployed, may be found in Appendix 8.2 – Data Collection protocols.

Awareness

- Investigations into societal awareness of the technology sought to understand whether individuals have heard of the technology family or technologies featured in the TechEthos project. This question was investigated using a Likert scale with response options "very aware," "somewhat aware," and "not really aware."
- Note: awareness was covered, as well, in D3.6, Media Analysis.

Attitudes

Attitudes in TechEthos comprise the two dimensions “acceptance” and “values”. Whereas acceptance was measured on the basis of a Likert scale, for the identification of values participants were engaged in playing the "TechEthos game: Ages of Technology Impact".

- **Acceptance** has been identified during the pre-game exercise (asking an either or questions " When you think about these technologies, do you feel excited, do you feel concerned?") and in the post-participation survey via two questions, asking for excitement and concern separately: “After participating today, how excited/concerned are you about possible future developments of this technology? The response options were “very excited/concerned”, “excited/concerned”, “little excited/concerned”, “not excited/concerned”, and “not sure”.
- **Values** have been captured via the TechEthos game. The idea behind the use of gamification was to create an interactive, engaging, and fun exercise where citizens in a rather “natural” way engage in a discourse about the technology families. It has been designed to make the complex topic of this research more accessible, encourage participation in a less formal setting and give space for facilitating a more open and creative discussion about the future of our society and the potential impact of the discussed technology families. After the game (in the post-participation survey) citizens reflected about “potential applications of the technology”, “most important issues raised by thinking and talking about this technology”, and “most important concerns about possible future developments and this technology".
- Note: Across disciplines, there are many ways that “values” are defined and identified. Sociological definitions of value relate to concepts of what is or is not desirable; economic notions of value relate to questions of “how much” objects are desired; linguistic concepts of value reference the meaning of words within larger systems of understanding (Graeber 2001). In the analysis of the participants values, we operate with a sociological definition, informed by psychology research (Schwartz 1994; Kraatz et al. 2020) and pragmatist philosophy (Dewey 1922; Coeckelbergh 2012). Specifically, we draw on a practice-based approach to values from science and technology studies: what an individual or group, “**considers very important, because they refer to legitimate interests, mutual obligations and/or views of the good life**” (Boenink et al 2010).

5.3.1 Citizens' awareness

In the TechEthos project, societal awareness sought to understand whether individuals had heard of the technology family or is respecting technologies before. During the citizen engagement activities, the awareness of the participant was asked at the beginning of the game exercise and after the participants received a general background presentation on the workshops’ main technology family (Figure 19).

Each participant was asked about the level of awareness of the three technologies that belong to the technology family. Participants indicated their awareness with sticky dots on a two-dimensional scale ranging from "not really aware" to "somewhat aware" to "very aware". The results were transcribed by the moderators and converted into a three-point scale, i.e., results that fell between two poles were weighted to one particular pole. In the following we will show the quantitative results of the awareness of the participants regarding the technology families.

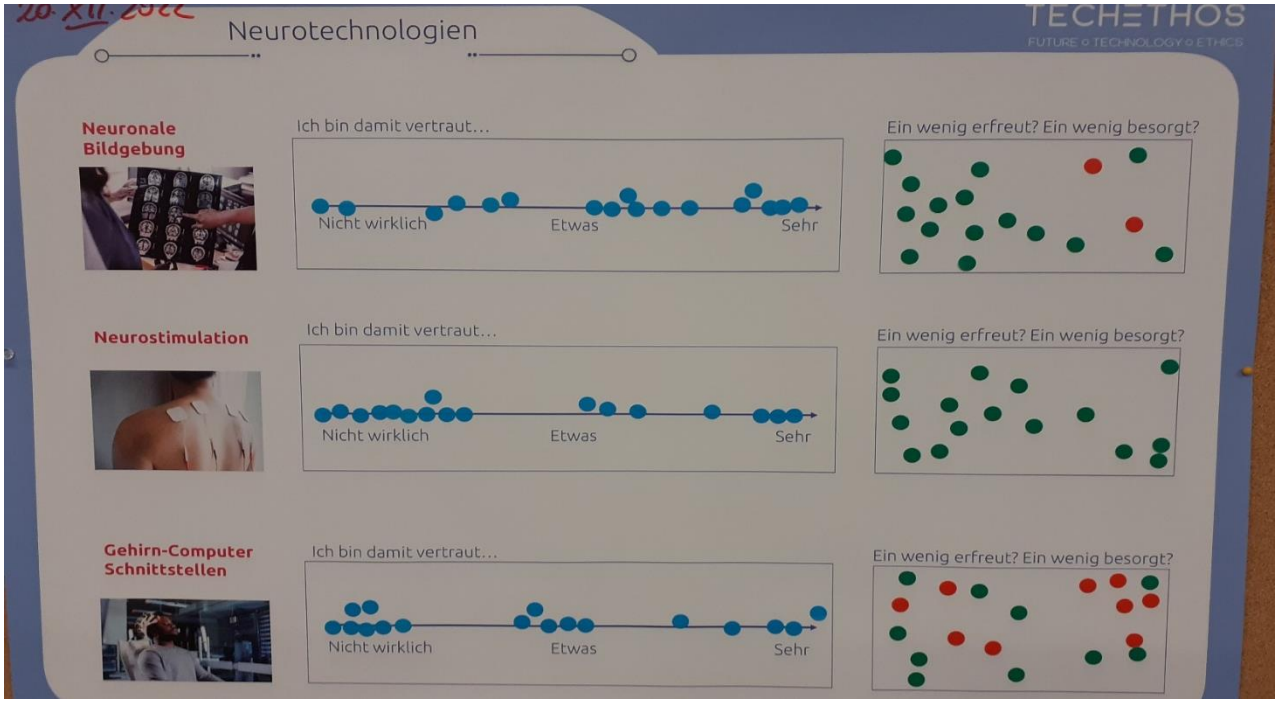

Figure 19: Awareness exercise from beginning of a Neurotechnology workshop in Austria

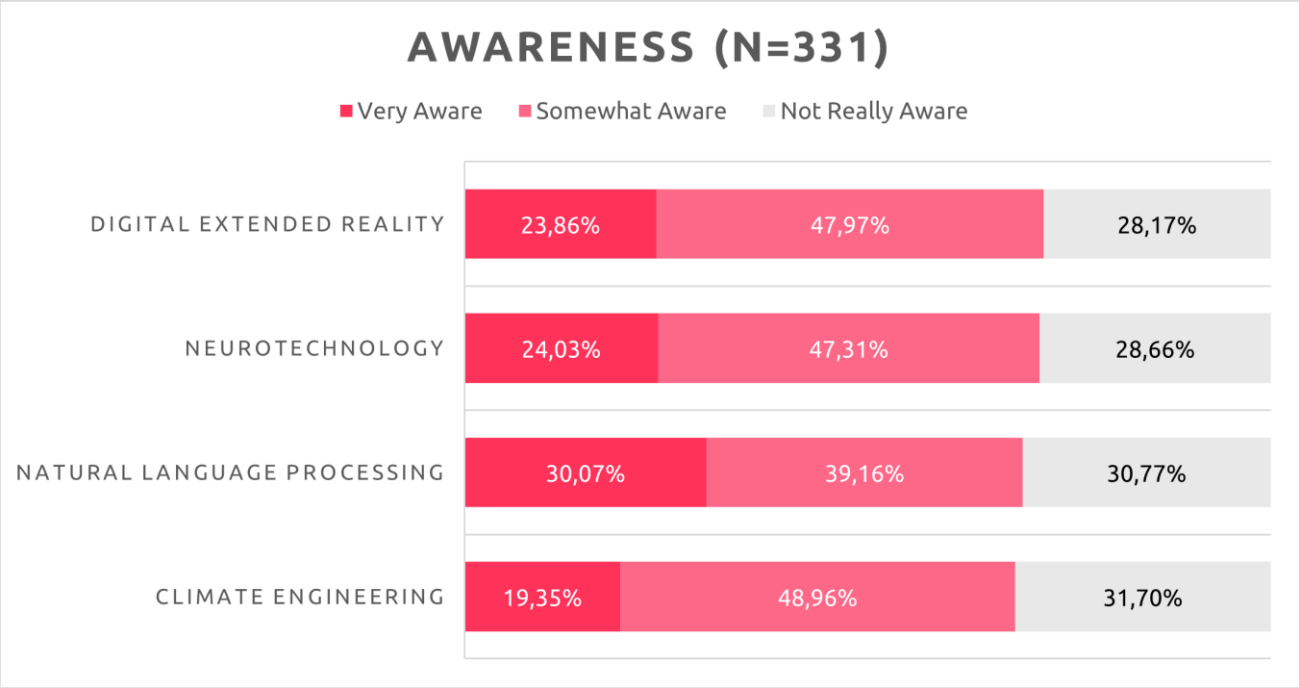

Figure 20: Overview of the awareness of each technology family

To elicit the awareness of a technology family, we asked each participant to rate their awareness of the three particular technologies from the respective technology family. For example: for the technology family of digital extended reality (XR), the participants were asked to indicate how aware they were of the technologies *virtual reality, metaverse* and *digital twins.* The sum of all three technologies depicts the total awareness of the technology family (see Figure 20).

Looking at the technologies that answered “very aware” shows a 10% difference between Natural Language Processing (NLP) and Climate Engineering (CE). 30% of all participants were very aware of NLP while only 20% were aware of CE. This might plausibly be due to the media coverage of ChatGPT, a large language model (LLM) which generates texts based on short prompts and was published shortly before the workshop was conducted. With Climate Engineering on the other hand, only 20% stated that they were *very aware* of the technology. One reason could be the lack of news coverage of the technology family. As one participant stated: "Climate Engineering today has a weak marketing, not much exposure. What advertises is what sells, and the marketing in this field is failing" (Comment 221, CE).

Citizens' Awareness of CE

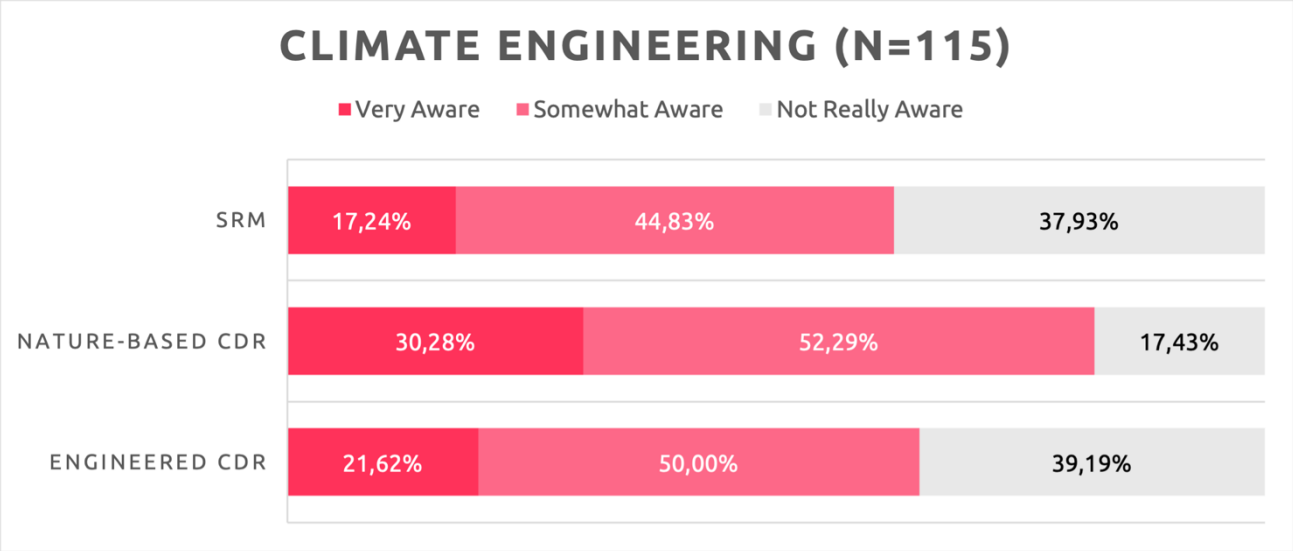

Figure 21: Overview of the awareness of Climate Engineering technologies

Within the technology family of Climate Engineering, the best known technology among the three options is *Nature-Based CDR*. Almost every third of the 115 participants stated that they were very aware of this technology. On the contrary, *SRM* and *Engineered CDR* are among the least known technologies in this family. In both cases, 40% of the participants stated that they are not really aware of them. While half of the participants said they have heard about them (somewhat aware), only every fifth (among SRM every sixth) participant said they were very aware of these technologies.

Citizens' Awareness of NT

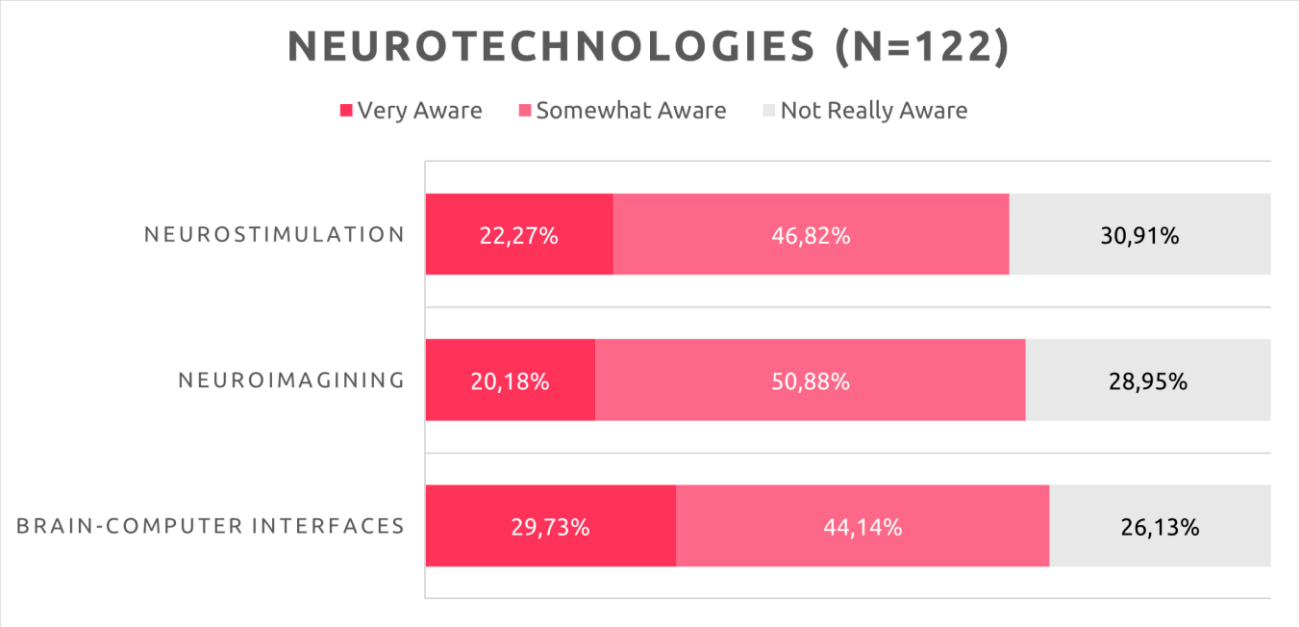

Figure 22: Overview of the awareness of neurotechnologies

When looking into neurotechnologies, the distribution of awareness among the participants seems to be rather homogenous. The majority is somewhat aware of each technology within this family, with the only exception, that Brain-Computer Interfaces are more prominent than the other technologies. Whereas only 24 of the 122 participants stated that they are very aware of Neurostimulation and Neuroimaging, almost 37 stated that they are very aware of Brain-Computer Interfaces.

Citizens' Awareness of NLP

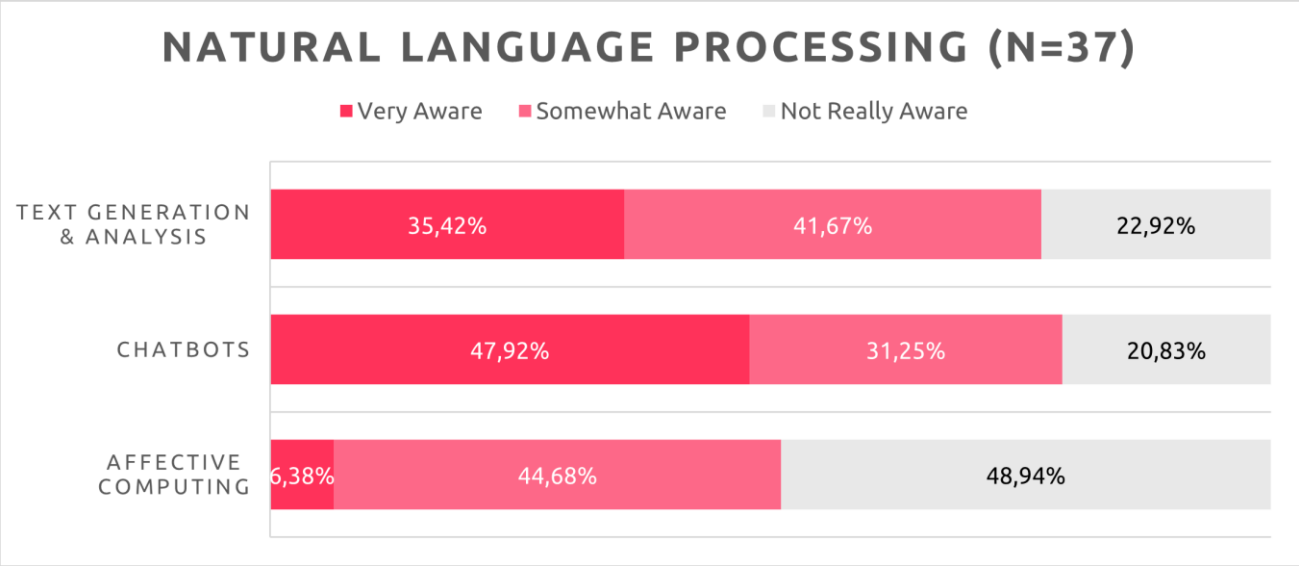

Figure 23: Overview of the awareness of natural language processing

In the field of Digital technologies, which is split into natural language processing and digital extended reality, we see a strong tendency towards those technologies already in use or currently discussed in different news outlets and media channels. In the family of Natural Language Processing the

participants were mostly aware of the two technologies *Chatbots* and *Text Generation & Analysis*. One explanation for this could be that Chatbots are already in use and LLMs (especially Chat-GPT) became popular during the time that the workshops were conducted (December 2022 through March 2023). What's noteworthy is that only 6% of the 37 participants stated that they are very aware of affective computing and roughly half of participants indicated that they are not really aware of this technology.

Citizens' Awareness of XR

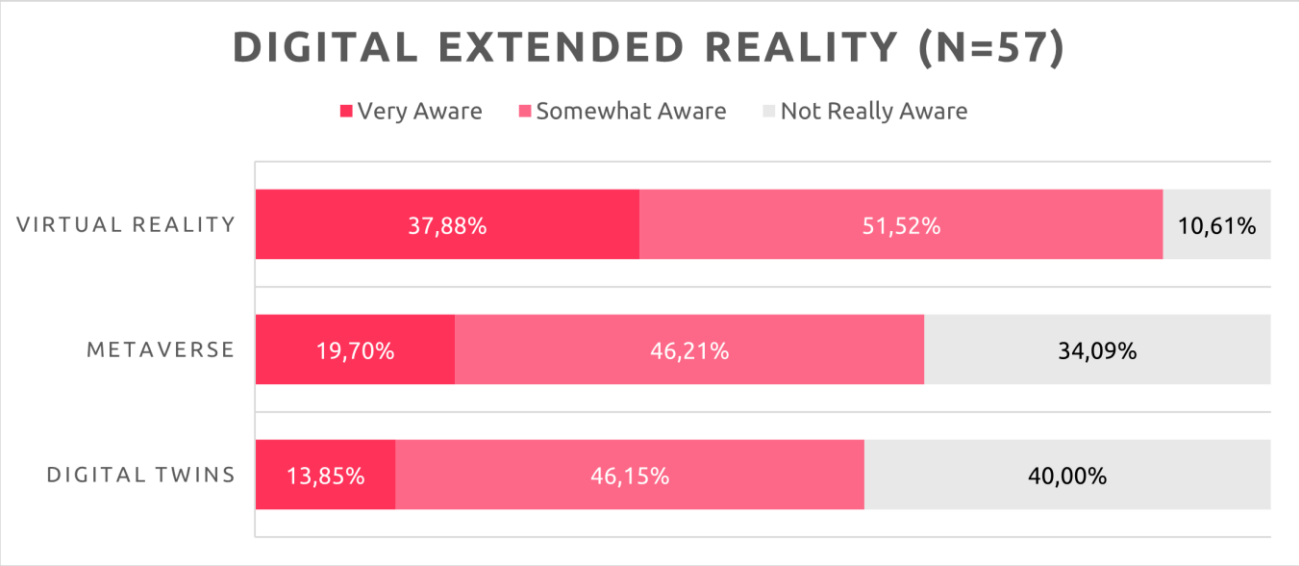

Figure 24: Overview of the awareness of digital extended reality technologies

There is a similar distribution among the technology family of digital extended reality as it is with NLP. *virtual reality*, the technology that is already on the market and discussed for almost forty years, is also the technology that the participants are most aware of. *Metaverse*, becoming a topic of discussion recently, follows, with 20% stating they are very aware of the technology. The least known technology in this family is *digital twins* with 40% stating that are not really aware of it and only 14% stating they would be very aware.

Discussion

Among all participants from the six countries, the level of awareness of the technology families is evenly distributed. 70% of all participants have heard of the technology families discussed, with slight differences between natural language processing and climate engineering. While the former technology seems to be more prevalent among participants (one in three said they knew the technology very well), only one in five of the participants said they knew the latter technology family very well.

When looking more deeply into the technology families, we see specific technologies stand out from the others as very prominent. The most prominent technology are **Chatbots**. Almost every second participant of the NLP-game session stated they were very aware of them. One reason for their prominence is the use in current applications. Within the discussion, participants referred to two use cases. The first use case mentioned were voice assistants like Apple's Siri (Comment 663, NLP) or Alexa by Amazon, the other was the use of chatbots on websites, for example with fashion retailers, as the following statement from the facilitator of the session on NLP in Austria shows:

"The participants gave examples like Alexa and the chatbot of C&A and talked about their usefulness." (Comment 435, NLP)

Besides current applications, the participants also mentioned the latest developments in this field. As an example, one participant from the Czech Republic mentioned ChatGPT, which was released shortly before the science cafes were conducted and was accompanied by a global news coverage:

"A kind of artificial intelligence similar to ChatGPT - this can make it easier for operators, salespeople and people in general who have communication as their main work activity." (Comment 298, NLP)

The second and third most prominent technologies after Chatbots were **virtual reality** (89% are somewhat or very aware) and **brain-computer interfaces** (74% are somewhat or very aware). One reason for their prominence is that both technologies are established tropes within Science-Fiction and thus part of popular culture for almost forty years. In the discussions, participants regularly referred to Science-Fiction films as a frame of reference to discuss the technologies. With regards to **brain-computer interfaces**, a participant from the Czech Republic said:

"It is not science fiction that people will be upgraded and become superhumans." (Comment 344, NT)

Another example comes from a facilitator from Spain, who hosted a session on neurotechnologies and noted that in the discussion, participants brought up "examples from movies like Minority Report" (Comment 526, NLP) and shared their fear "of becoming cyborgs" (ibid.), when discussing Brain-Machine Interfaces. The term *cyborg* also came up in the discussion in Serbia, as one participant explained when asked about their first association with the topic of neurotechnologies:

"The first thing that comes to mind is a robot. Or a cyborg. Or a super-cyborg." (Comment 156, NT)

We see a similar pattern in the discussion on **virtual reality**, also a well-established trope within the Science-Fiction mega-text[16]. As with Brain-Computer Interfaces, the participants referenced to popular culture to frame the technology and express where they heard about it. One participant of the digital extended reality session in Serbia stated that they feared "that we will stop communicating verbally and start living like in science fiction movies" (Comment 91, XR) while another participant from the Czech Republic expressed their believe that the fictional narratives have already or will become reality in the near future:

"It's like the matrix. We're already in the matrix. Every science fiction will become reality one day." (Comment 332, XR)

In the case of Digital Extend Reality and Neurotechnology, Science-Fiction is often used as a frame of reference, as participants are already familiar with the interpretation of the technology given by Science-Fiction authors and filmmakers. Furthermore, references to popular culture are also commonly used by journalists when covering development in Research and Innovation and to situate the emerging technology within a frame of reference that their audience is familiar with (see also D3.3 Media Analysis). The Science-Fiction framing does not only impact the citizens awareness of these technologies but also impacts the way the technologies are valued and perceived (see chapter 5.3.3).

[16] The SF mega-text concludes icons and tropes that appear recurrently in SF texts: e.g., time-travel, cloning, VR, brain machine-interfaces, etc. (Broderick, 1994).

The awareness between the technology families does not differ much. Looking at the technology level, we see that the **most prominent technologies** in CE are **nature-based CDR**, in NT **brain-computer interfaces**, and in NLP & XR **chatbots** & **virtual reality.**

The least known technologies within the technology families are similar distributed. Every third participant has not heard of **SRM** and **Engineered CDR** in CE, every third has not heard of **all three technologies in NT**, and in NLP & XR the least know technologies are **affective computing** and **digital twins**.

5.3.2 Citizens' attitudes

The concept of social attitudes here refers to the participants' acceptance of the technology family or the corresponding technologies and their reflection about whether **they accept the technology or not**. We operationalized the concept with two variables: Excitement and concern. Both are two extremes of a spectrum. **Excitement** is on one end of the spectrum and expresses a positive attitude towards the technologies discussed. **Concern** in on the other end of the spectrum and reflects worries or fears regarding the technologies.

Throughout the TechEthos Participatory Game Workshop there were several opportunities for the participants to express their attitudes. In the following, we will present two results. One comes from an exercise conducted at the beginning of the game, the other is the result of the Post-Survey, a survey which was filed out at the end of the exercise.

Before the game exercise the participants were given a general background presentation on the workshops' main technology family, which were complemented with a number of technology-specific or technology family use cases distributed around the room. Both activities set the stage for the game and engaged the participants to develop first impressions. To capture the impressions, the participants were asked to state their attitudes towards the technologies in a quantitative and a qualitative way:

- Quantitative: When you think about these technologies, do you feel excited, do you feel concerned? Please use a red or a green sticky dot to indicate your feeling.
- Qualitative: Is there something really exciting to you about the technology that you'd like to share? Is there something about the technology that concerns you that you want to share?

In the following chapters, the quantitative results are visualized as graphs. The N in this case is the number of votes. Each participant voted on all three technologies and also had the chance to vote for both if they were undecided or felt concern and excitement at the same time.

The qualitative examples are the first impressions of the participants before they started to play the game. They give context to the graphs and allow an insight into why the participants stated their excitement or concern. The thorough analysis of the comments from the whole game and the values stated will follow in chapter 5.3.3 Elicited values.

Citizens' Attitudes towards CE

Among all workshops and countries, the 110 participants stated an overall excitement towards climate engineering technologies. Although some concerns were stated, the general attitude towards the technology family is positive. For example, one participant stated that CE "is a fast and innovative technology that can have immediate effects" (Comment 544, CE). Others were excited that the

technologies are “globally applicable” (Comment 204, CE) and thus consider them as a promising way to “curb global warming” (Comment 563, CE).

The statements regarding concerns referred to the misuse or the unintended side effects of the technology. The technology could solve the problem of climate change but also “create new ones at the same time” (Comment 199, CE) or it could even be used as an “elitist weapon” (Comment 198, CE) or destabilize geopolitics as “these technologies can increase the inequalities between developed and underdeveloped countries.” (Comment 567, CE). Others pointed out, that “Technological solution alone can make climate cooler but does not change society in a beneficial way” (Comment 380, CE), stating that the problems for climate change are on a deeper level.

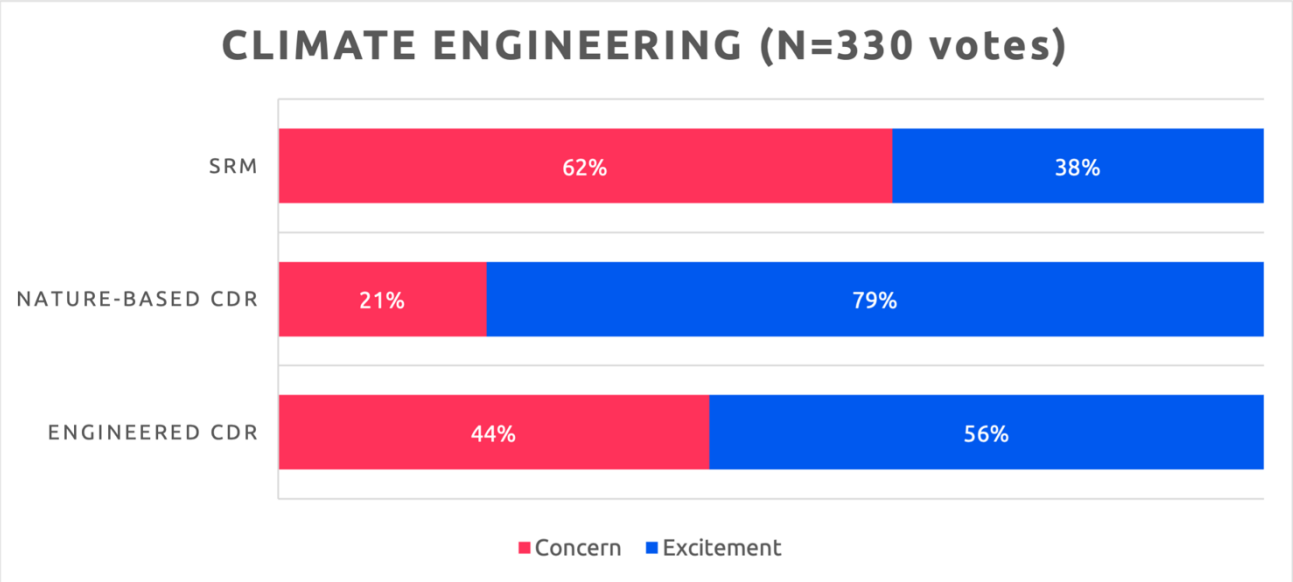

Figure 25: Participants attitudes towards the specific technologies of CE

Although the overarching position towards climate engineering is positive, the participants were mostly in favour of nature-based CDR like afforestation:

“More Trees is beneficial for the Environment and Atmosphere - Expected to work well.” (Comment 378, CE)

One participant mentioned that *“afforestation is a good idea, but only if planned”* (Comment 194, CE) while another was concerned about the implementation and the potential loss of biodiversity and the ecological balance:

“Afforestation is supposed to be good, but it also has ecological risks - Is a major intervention – not sure about the outcome, if we have only a small number of plant-species we might lose biodiversity. Ecological Balances could be disturbed through monocultures. Monocultures can cause insect die-off." (Comment 377, CE)

With the other technologies, like Solar Radiation Management or Engineered CDR, the concerns were more present. SRM for example caused concerns regarding the “impact and chemicals used.” (Comment 543, CE). The participants were concerned about the serious consequences that the application of this technology may have, especially considering the ecological footprint. They were concerned that in order to solve one problem, a more serious one is being generated.

“This technology worries me the most. - Sulfur worries me because it will result in acid rain which can cause an even bigger disaster.” (Comment 202, CE)

The **most excited** among the three technologies has **nature-based CDR**, as it appears to be the least harmful technology that is and in balance with nature.

The participants were **most concerned** about **SRM** due to the further consequences like pollution or other currently unforeseen disaster.

Citizens' Attitudes towards NT

The majority of all participants (almost two out of three) stated their excitement towards neurotechnologies. The reasons for this ranged from disease prevention (Comment 41, NT) or the current application to treat diseases – "the doctors used [Neurostimulation] to treat my back pain - it helped, it's a good method to help patients with pain." (Comment 338, NT) – until envisioned use cases that might come in the future, like the treatment of traumatic memories:

"Someone who has trauma from the war would like to have those memories erased." (Comment 145, NT)

Most of the comments on excitement revolve around medical topics such as health treatment, prevention of diseases or diagnosis. Looking at concerns, however, the thematic landscape shifts and revolves around topics like accessibility and equality:

"Rich people will be able to become 'superhumans' and have more and more power over others." (Comment 45, NT)

Another topic cluster of concern is the misuse of or the manipulation through Brain-Computer Interfaces. One participant was concerned that "Brain chips can be misused to control the human" (Comment 342, NT).

"I'm scared of the memory wipe. - Dangerous situations are not so visible but are often done behind the scenes. Usually, this manipulation is not so obvious." (Comment 144, NT)

Another participant pointed at the collected data and said that there is the potential that "companies can have essential data on individuals that serve to give them more control over them while individuals lose control over their personal data." (Comment 491, NT). In general, data usage and privacy were a concern in the context of NT:

"Privacy - Who will see/control/use the data?" (Comment 59, NT)

What can be said from the analysis of the comments is that the excited and positive statements are usually in favour of the medical use of NT while those comments that express concern do – with a few exceptions – do not mention medical usage but are rather about topics like data security, risk of misuse or hacking as well as manipulation either through a third party or by the technology itself:

"Machines start to take over control over Brain." (Comment 446, NT)

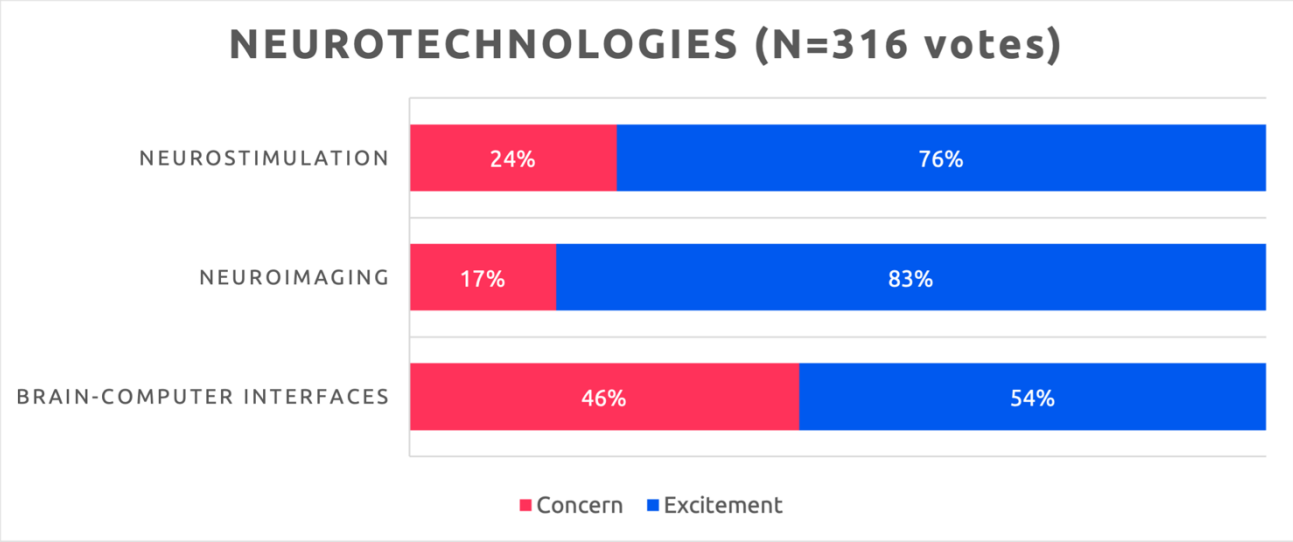

Figure 26: Participants attitudes towards the specific technologies of NT

When looking at the distribution of concerns and excitements across the technologies of the NT-family (see figure 26), we see that the majority of participants are excited about technologies like Neurostimulation and Neuroimaging, while Brain-Computer Interfaces (BCI) are causing concerns with every second participant. One reason is that, according to the comments, BCIs are more often associated with topics like hacking, becoming cyborgs, loss of privacy and manipulation than the other two technologies.

Another reason is the invasive character of BCI (Comment 489, NT), which might cause medical side effects which cannot be anticipated yet. As one participant put it:

"The brain is a complex organ - we still don't properly understand how some brain functions work, introducing chips into the brain is a risky business." (Comment 343, NT)

The participants were **most excited** about **Neuroimaging**, as it will help with diagnosis and the prevention of diseases.

The technology, which participants were **most concerned** about was the **brain-computer interface**. The reasons ranged from fear of manipulation to concerns about data protection

Citizens' Attitudes towards NLP

Similar to the other technologies, the excitement towards this technology family is larger than the concerns. Speaking in absolute numbers, of the 152 casted votes across all workshops of the technology family, 94 were indicating an excitement while only 58 stated concerns.

Looking at the specific NLP technologies, the distribution of votes between text generation and analysis and chatbots is identical, with only one in three expressing concerns in this case. In case of the third technology, Affective computing, the distribution is different. Here almost every second participant indicated that they have concerns towards this technology (see Figure 27).

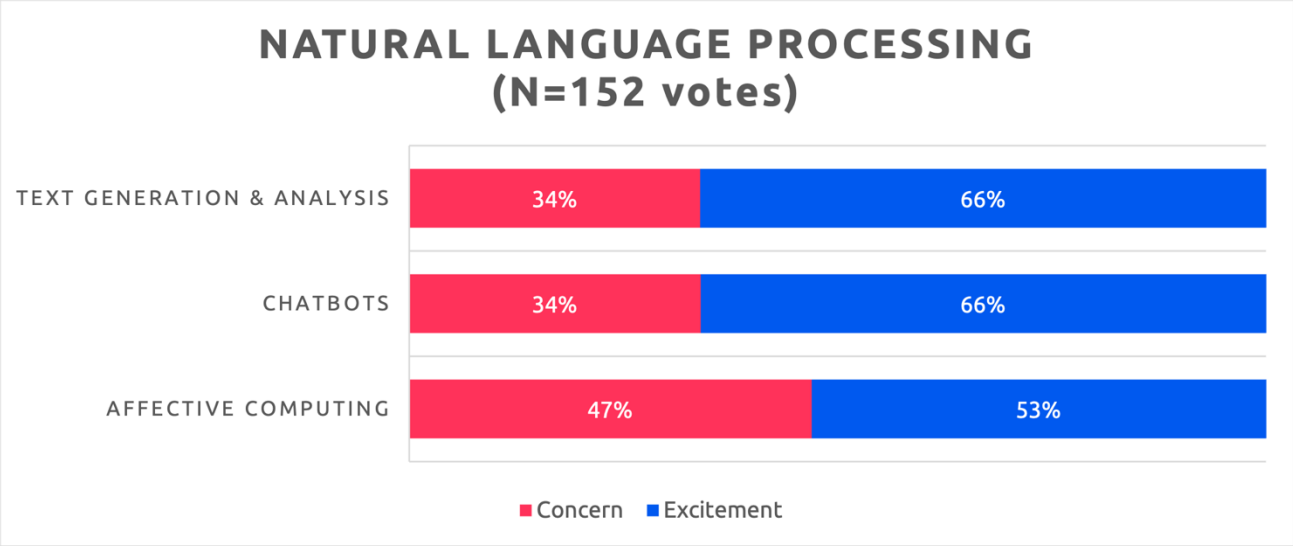

Figure 27: Participants attitudes towards the specific technologies of NLP

Just as the distribution is different between Text the first two technologies and the third, the reasons for concerns are different for these technologies as well. In the context of Affective Computing, data privacy is repeatedly mentioned as a relevant issue – "It has potential, but it is very risky. - Our personal data may be misused and given or sold." (Comment 102, NLP). Closely related is the topic of misuse. Some participants were concerned that this technology will "scan you and then wrap you around his finger" (Comment 294, NLP), causing a "centralization of power among those who will make this technology" (Comment 101, NLP). This power would come with responsibility. Therefore, the concern is that, if this technology will be controlled by "bad people and/or autocratic governments, the world will change for the worse" (Comment 71, NLP).

In the context of Chatbots and Text Generation & Analysis the concerns are touching upon different issues. There are two main topics that appear in this context. The first topic is plagiarism and copyright – "The negative aspects of this technology are plagiarism of seminar and scientific papers" (Comment 105, NLP). The participants were worried that scientific results written with programs like ChatGPT, for example, do not reflect the scientific standards anymore as the technology does not refer to the original source when showing the results: "It doesn't make quotes if you don't want them, it rewrites the meaning of the text" (Comment 296, NLP). Closely related to this topic is the concern of unemployment with participants stating that:

"People will lose their jobs and certain positions will be in trouble. What will happen to the jobs of content writers, translators and journalists?" (Comment 103, NLP)

Interestingly though, this topic also appears when stating the reasons for excitement. There, participants mentioned that "through chatbot-agents useful information can be quickly and always available" (Comment 423, NLP), or that AI "has the potential to make a lot of people's jobs easier" (Comment 292, NLP). In general, the type of work that is referred in the comments seems to be more administrative work. The reason for excitement thus follows the hope, that the technology is...

"... relieving people of mundane repetitive jobs." (Comment 422, NLP)

Among the NLP technologies, the participants were **most excited** about **chatbots** & **text generation and analysis**, as both will simplify work and make jobs easier.

The participants were **most concerned** about **affective computing** due to possible misuse and data protection issues

Citizens' attitudes towards XR

For the technology family of digital extended reality, the 57 participants casted 204 votes stating their attitudes towards the three technologies within this field. Similar to the other technology families, excitement is the prevailing attitude of the participants. 121 of the 204 votes indicated excitement while only 83 concerns were expressed. With regards to each of the technologies, the participants were most excited about virtual reality (three out of four) and digital twins (almost two out of three). With metaverse, however, most of the votes (58%) expressed concerns (see Figure 28).

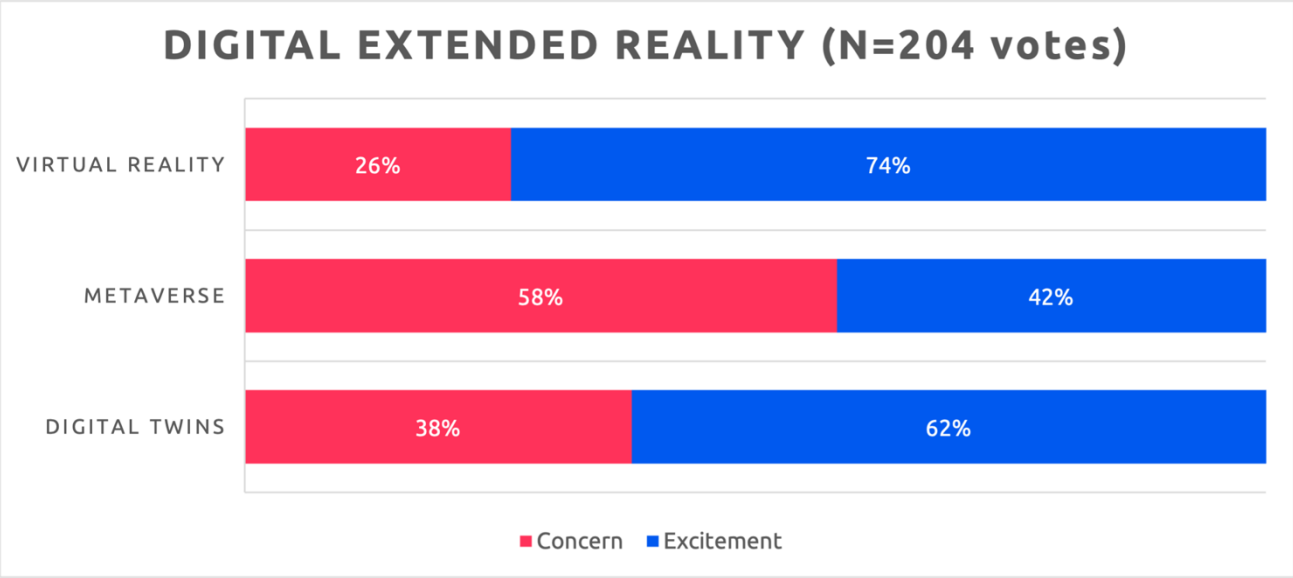

Figure 28: Participants attitudes towards the specific technologies of XR

The main reason for the concerns regarding the Metaverse technology is the mistrust in the Meta company, which the participants associated with the development of the Metaverse. When asked about the reason for their concern, one participant stated, "Facebook's data management" will cause that "personal Data might get lost or misused" (Comment 418, XR). One participant stated that "political manipulation" (Comment 93, XR), as already happened on Facebook, will also happen in the Metaverse, and way tying their concerns directly to the failures and lack of privacy that the company Meta is currently facing:

"*When you enter Metaverse, you face problems that are much bigger than the ones that exist on Facebook now. Just by shopping in the Metaverse, you will have a large number of social interactions that can be tracked. It will show exactly where your attention is directed. (...) Control in such a virtual reality is something completely different than it is now the case on Facebook.*" (Comment 93, XR).

This statement shows that the participants do not trust the companies to be able to handle the amount of data, which will be created in the Metaverse, responsibly. Regarding data and privacy, another concern mentioned was the uncontrolled commodification of personal data:

"Companies can have essential data on individuals that serve to give them more control over them while individuals lose control over their personal data." (Comment 610, XR)

Besides the lack of privacy, there was another cluster of concerns that revolves around human connection and real experiences. On the one hand, the participants were worried about fake profiles which they cannot differentiate from actual human beings anymore – "you have no way of knowing if it's a person or a program talking to you" (Comment 314, XR) – on the other hand, the participants worried about losing "the interest for the real world" (Comment 634, XR) and that "living in a metaverse bypasses important issues like experiences, sensations, feelings, etc." (ibid.). In general, they are concerned about the ability for human interactions:

"The human being can lose his ability for being social and this is his singular feature. People can be confused to identify the real world from the digital one." (Comment 634, XR)

This is a crosscutting concern that also appears in the discussion about virtual reality and digital twins. Regarding VR, the participants across all countries were worried about children's addiction to the technology as "young people can't get away from it" (Comment 312, XR) and "become more isolated if they are in a virtual world" (Comment 725, XR). The parents among the participants were worried as they one participant said: "I'm afraid that I will not [be able to] talk to my children" (Comment 86, XR):

"How will we prepare our children prepare for such a future, when even we, the adults, are not ready." (Comment 95, XR)

The concerns mentioned with regards to digital twins revolve around the topic of trust. The participants worried about relying too much on the technology, as it might mislead: "The digital world is sometimes much different from reality" (Comment 28, XR):

"*Technologies will lead us to a point where everything can be cloned, but the question is (although medical application and some other fields are positive example) – will they leave us with an authentic experience?"* (Comment 98, XR)

Concerns aside, excitement for digital twins prevails and the technology was considered to be "positive and helpful" (Comment 612, XR). Especially the aspect about education was mentioned multiple times:

"This is great, I don't see any danger. If we can practice surgical operations on digital twins instead of humans, that would be great. I don't see anything negative sides." (Comment 94, XR)

Another crosscutting topic that excited the participants was the virtual experience of "historical objects and buildings [that] are destroyed for some reason" (Comment 723, XR) or "being able to go to the south of France and meet in a [virtual] café" (Comment 720, XR).

One participant summarizes the main reason for excitement regarding XR in the following way:

"We get augmented experience of some aesthetic input, like exhibitions, movies etc." (Comment 100, XR)

> Within the technology family of XR, the participants were **most excited** about **virtual reality** (close to digital twins). As reason they stated they experience of far-off places or historical places.
>
> The **main concern** for them was the **metaverse**, as it may cause the loss of natural human connection and holds the possibility of data privacy issues.

Discussion on acceptance

Eliciting the excitements and concerns allows statements about the acceptance of the technologies. What we can say from the results before is that the quantitative data shows that the votes for excitement prevail over the votes for concerns. Thus, one result would be, that the participants accept the presented technologies. However, as also discussed before, developing an attitude towards an emerging technology is not an either-or process. Rather, most of the time the participants are both – excited and concerned. This demands a more complex consideration of their acceptance.

This is also reflected in the **post-survey**, which was handed out to the participants after the game exercises and the group deliberation of the technologies. After the participants shared their perspectives, informed each other about the technologies and exchanged excitement and concerns, they were asked to answer the following question:

- After participating today, how excited are you about possible future developments of this technology:
  Very excited | Excited | A little excited | Not excited | Not sure how I feel about the possible future developments of this technology.

- After participating today, how concerned are you about possible future developments of this technology:
  Very concerned | Concerned | A little concerned | Not concerned at all | Not sure how I feel about the possible future developments of this technology.

Across all workshops the majority (+70%) of the participants was excited or very excited about the discussed technologies (see figure 29). At the same time, the participants also expressed their concerns, as every second stated they were concerned or a little concerned about the development of the technologies (see figure 30).

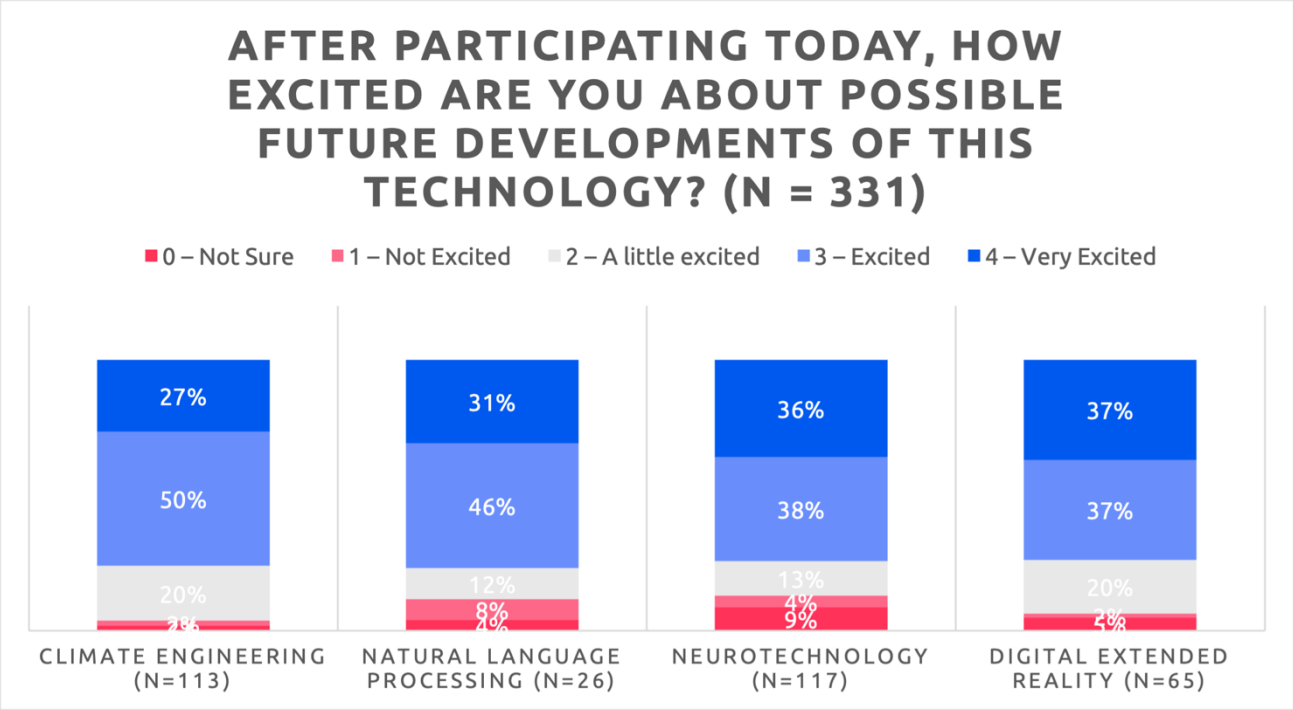

Figure 29: Post-Survey results of the participants excitement regarding the technology families

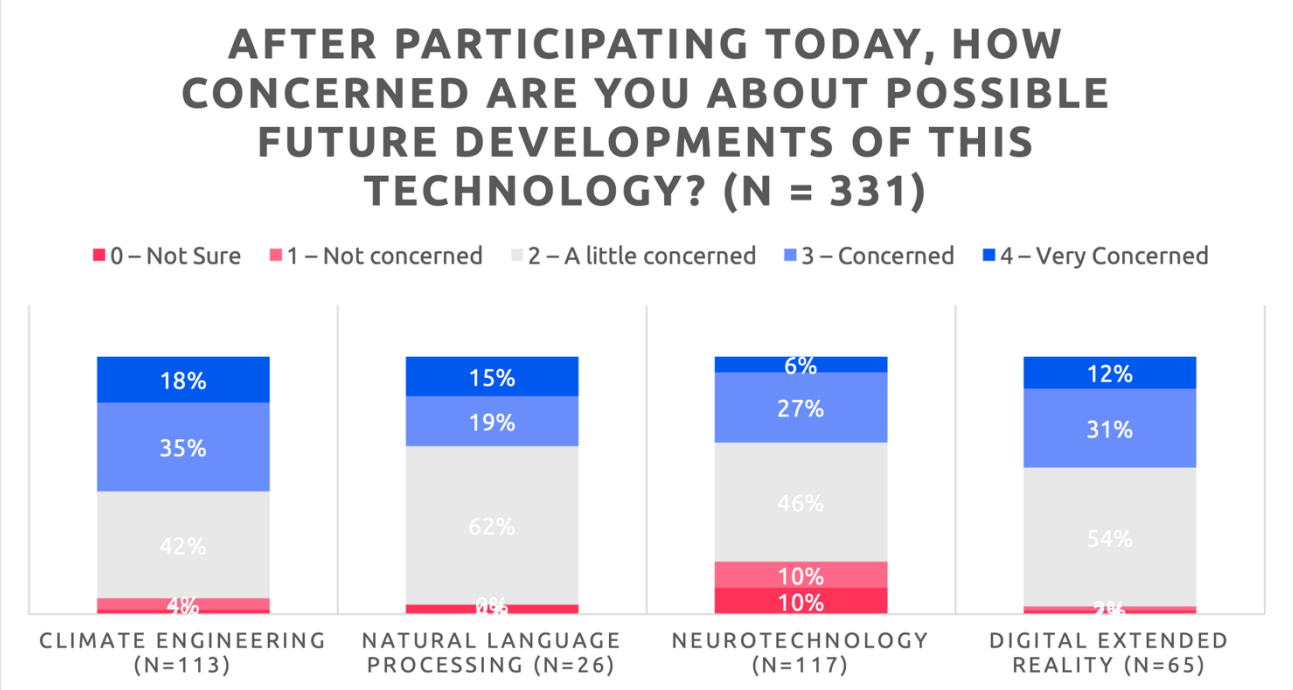

Figure 30: Post-Survey results of the participants concerns regarding the technology families

The results shows that participants are both, excited and concerned, but for different reasons. To give an example, in the case of neurotechnologies, the participants consider the technology to be exciting as it can help to improve the health of patients but are also concerned that the technology might be used to manipulate the user or to misuse the collected data.

Acceptance of an emerging technology is a complex concept, as acceptance refers to something that has not yet been created and therefore still needs shaping and is open to intervention and change. From the material collected we can say that the participants accept the technology if [X] is assured or if [Y] can be prevented. Eliciting attitudes in the way presented offers a first glimpse into a general mood. To better understand the acceptance of the technology and what conditions citizen require to accept the technology, it is necessary to understand what values the citizens share when they discuss their excitements and concerns. This has been done in the next chapter.

> Citizens are both – excited and concerned – about emerging technologies. To reflect on the acceptance of the technologies, it's necessary to reflect on what **citizen value**.

5.3.3 Citizens' values

To elicit the acceptance of the technology, we developed the TechEthos game, an exercise that engages citizens in a discussion about the emerging technologies and to reflect upon the reasons for their excitement and concern. Based on those reasons, we conducted a list of values that were mentioned by the participants. These values will feed into the ethical guidelines that will be developed in WP5. The following subchapter gives a brief overview into the methodology and the results of this game exercise. For more detailed information regarding the development of the TechEthos game: Ages of Impact, please refer to Deliverable 3.2.

In the game, the participants take the role of the **Citizens World Council**. As a groups, they have to decide which technologies should be funded, individually, everyone has to find arguments for or against the support of the technologies. Therefore, the general mode of elicitation is an encouragement to exchange arguments for or against the technology families at. Due to the construct of the game, participants faced “closed choices” with a limited set of “voting” resources. This structure on the one-hand limits but on the other hand productively focuses conversation in a manageable way. The positive framing of the voting round (“vote for the technologies you would like to have further developed”) invites the “desirable” aspect of values (i.e., that which is valued). However, the conversation is also invited on why other technologies might be better not to have developed, so the “undesirable” is also made explicit.

The game follows three rounds of game play, which are called "Tech Ages". In each round, the moderator presents different cards to the participants. Depending on the round, the content on the card focuses on a different context: (1) technology; (2) application; (3) possible societal and ethical issues.

Tech Age 1, upon voting for the technologies

- “In Age-1, you must decide which technology should be developed in your ideal future. You might decide to explain to your fellow players, for example, why Digital Twins would be beneficial in the future and why the Metaverse would be better not to be developed further. **Vote for the technology which should be developed further.**
    - Do you think the technology has the potential to benefit you or people you know/care about? How?
    - Do you think the technology has the potential to harm you or people you know/care about? How?”

Tech Age 2, upon voting for the technological applications

- "In Age-2, you must decide in which areas of life you would like the technologies selected in Age 1 to be applied. **Vote for the application areas you would like to see become a reality**.
    - What's your general attitude toward these application areas?
    - Do you think this application is beneficial or harmful? If so, in which way?"

Tech Age 3, upon voting for societal and ethical concerns

- "In Age-3, you are called to reflect on the principles and values that may be impacted by your previous choices. You must decide which ethical issues are the most important for your group to tackle, in relation to the technologies you have selected and the areas of life in which they have been applied. **Vote for the most crucial societal and ethical issues that need to be addressed so to preserve the values you believe in most**.
    - What's your general attitude toward this card? Do you think the technology is beneficial or harmful? If so, in which way?"

Table facilitators at each workshop were provided with "content packs": elaboration definitions, potential affordances, limitations, and possible issues with each technology (Age 1), application (Age 2), and societal or ethical issue (Age 3) card. These were intended to support the facilitator to respond to any participant questions in the course of the game play. Materials in the content pack were derived from TechEthos WP1 horizon scanning fact sheets as well as WP2 ethical analyses. It is important to note that cards at each age have potential framing effects that affect participant responses and thus elicited values. TechEthos game designers were aware of these framing effects and as often as possible attempted to present a balanced text. However, especially in the third level, the cards also meant to stir discussion to enable participants to disagree or agree with the content provided. In general, the texts aimed to present possibility, rather than hype; present benefits as well as challenges; and open questions with context for discussion (see for example: Figure 31, Figure 32 and Figure 33).

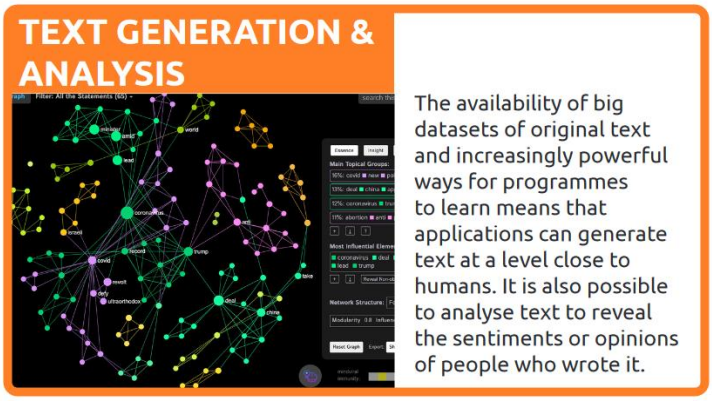

Figure 31: Exemplary Tech Age 1 Card from the NLP Deck

Figure 32: Exemplary Tech Age 2 Card from the NLP Deck

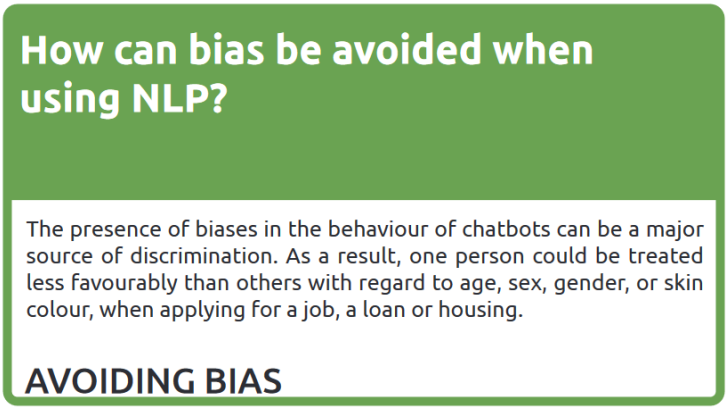

Figure 33: Exemplary Tech Age 3 Card from the NLP Deck

Qualitative coding of elicited citizen values

Each of the 20 workshops documented by the LTPs, focussing on the comments and the arguments that participants exchanged during the gameplay. This led to a total of 1700+ comments.

To elicit the citizen values, a first round of a grounded theory based approach to qualitative coding and analysis of the comments was pursued by the project team (Bryant and Charmaz 2007). In the process, four members of the author team, each social scientists from different backgrounds ages and nationalities, were responsible for coding. Each researcher began by independently open coding a subset of the data. Coders worked for approximately 20 – 30minute bursts, after which time they took a short break before reconvening to discuss. To ensure intersubjectivity, each coder then had the opportunity to present his or her subset of codes for each item followed by a discussion as a group. Open codes assigned reflected a consensus of the group. As the general set of open codes stabilized from round-to-round of coding, the team moved from discussing all open codes of their subset during a coding round, to focussing on only those codes for which they felt there was a degree of ambiguity requiring group discussion. Single statements could be linked to multiple open codes. In total, all of the 1700+ statements being coded with 475 open codes.

Next, the researchers axially coded the open codes to construct higher-level categories. A preliminary round of axial coding led to the construction of 84 from the 475 open codes. In a final consensus coding round, involving iterative discussion referencing the original statements, the first-round axial codes were re-coded into a final set of 25 citizen value categories. Definitions and exemplary quotations from each category are described below. This analysis affords a comparison abstracted values surfaced through the workshop engagement with public and other stakeholders from across six countries.

List of citizen value categories

The complete list of the 25 citizen value categories constructed is below (Table 24). For a more detailed definition of the citizen value categories, please refer to Annex 8.3.

Table 24: List of citizen value categories abstracted from grounded-theory open coding process

Aesthetics
Authentic human connection and experience
Autonomy and agency
Cultural preservation
Data privacy and security
Democracy
Economic opportunity
Ecosystem health
Effectiveness and efficiency
Equity, diversity, inclusion
Expanded opportunities for human experience
Human-centred development
Human health
Human oversight and control
Justice
Knowledge and education
Naturality
Peace
Progress
Responsible use and accountability
Safety and reliability
Techsolutionism
The Good Life
Trustworthiness
Usefulness

Distribution of citizen values across technology families

As noted earlier the same categories were used for all three technology families. In this subsection a closer view on the distribution of the citizen values will be presented across technology families. It is important to mention that these citizen value categories can, however, refer to slightly different meanings regarding different technology families. Therefore, in the coming analysis of the distribution of citizen values these differences will be highlighted for the most prevalent value categories to understand better what they capture from the citizen input for each technology family.

On the figures presented below the number of occasions (N) can be seen for how many times a certain value category was coded across the dataset. This means that if multiple values were mentioned by the citizens and therefore coded, they add to the N, even if multiple values for one comment belonged to the same value category. For example, if a comment mentions environmental pollution, but also talks about biodiversity issues it was counted twice under ecosystem health. In the following, the five most important values mentioned by the citizens will be discussed.

Climate engineering

As we can see in in climate engineering the total number of codes is close to 600. From all the value categories ecosystem health appears the most important, around 140, which means that almost every 4th value belongs to the realm of ecosystem health. The second most prevalent value category is safety and reliability with more than 110 occasions. The effectiveness and efficiency, and justice value categories follow with fairly equal distribution, but only half as prevalent as ecosystem health. The value naturality is also part of the top five value categories regarding climate engineering with almost 40 counts.

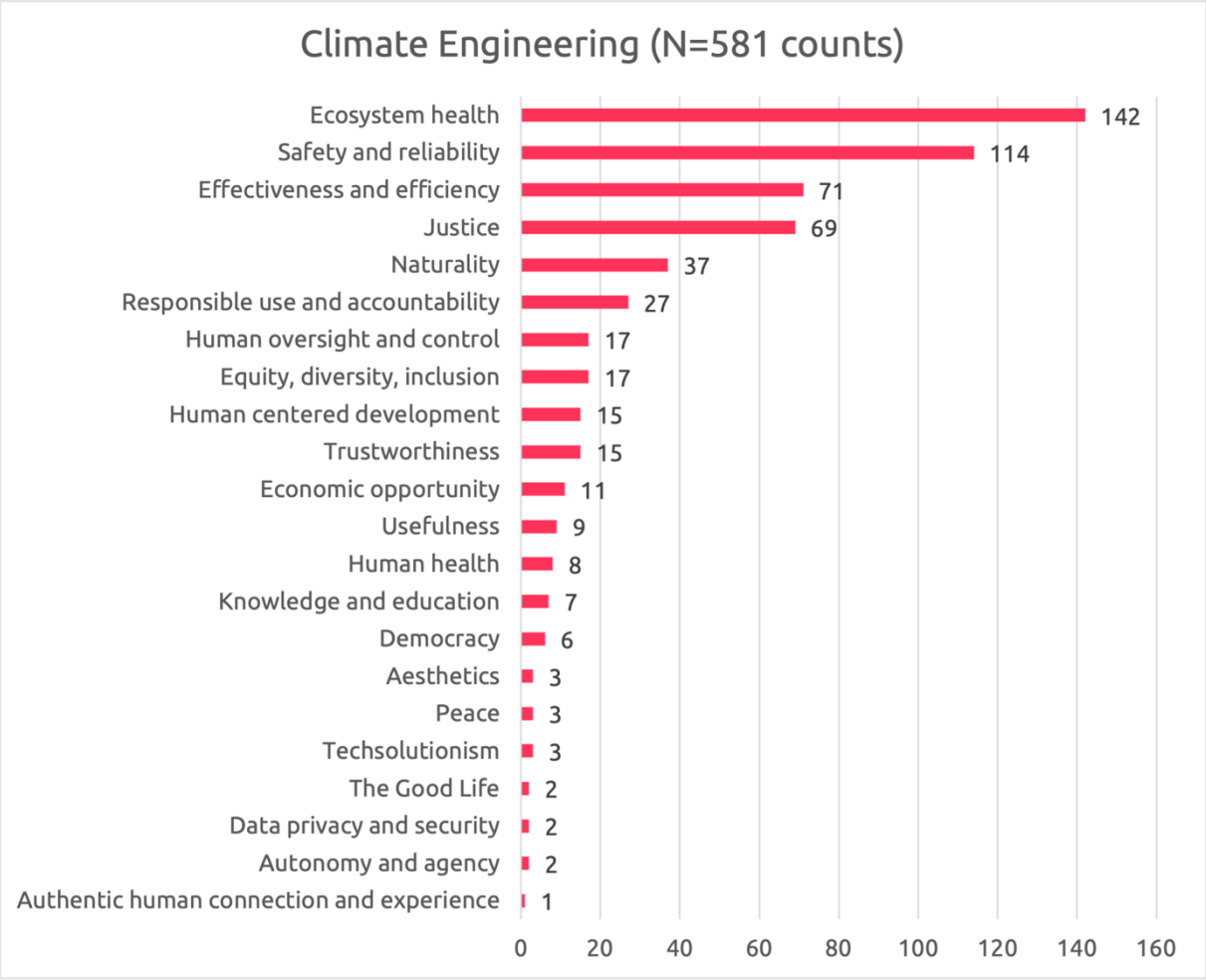

Figure 34: Value categories and number of instances coded for CE

The value category **ecosystem health** captures different values like biodiversity, sustainability, or the protection of the environment from pollution and harm:

"I don't like that it requires environmentally harmful substances, this makes it more negative for me. environmental damage can become more harmful in a short time." (Comment 706, CE)

"It is very good because the forest creates biological diversity and in the past, we had many more forests." (Comment 688, CE)

"Concern about impact and chemicals used. The participants are concerned about the serious consequences that the application of this technology may have, especially considering the ecological footprint." (Comment 543, CE)

Safety and reliability regarding climate engineering is capturing the concerns regarding the unknown effects of these technologies, whether they are posing danger onto people or whether they will fulfil their promises and not cause extra harm. Some participants were raising the issue of reliability; questioning whether these CE applications have been tested enough or not.

"Forestry is the only one that has been tested, everything else is at the experimental level." (Comment, 193, CE)

"Technology sounds inefficient and resource intensive. We cannot really imagine how this technology works" (Comment 413, CE)

"Influencing the weather has worked for decades, it's a risky attempt to have the desired impact. There is evidence but unsolved cases of weather modification for military purposes that have led to unnecessary disasters" (Comment 280, CE)

Effectiveness and efficiency refer to the effective use of technologies and possible trade-offs. In this case, participants talked about the how a certain application is worth deploying or not and if the desired impacts are sufficient or if the risks and dangers are concerning.

"Geoengineering technologies, including SRM is dangerous. This raises questions about who would be responsible for regulating the technology and ensuring that it is used in a safe and effective manner. "(Comment 267, CE)

"Use of fertilisers and pesticides: Growing crops for biofuels can require the use of fertilisers and pesticides, which can have a negative impact on soil, water and biodiversity. At that price, it is not very efficient. "(Comment 263, CE)

The value category **justice** in climate engineering is in most cases referring to global distributive justice and intergenerational justice, as well as fairness in decision making regarding the use of the technologies.

"[…] Maybe it is a good solution, but it should be available to everyone. The effects matter, everybody should benefit, no matter who can afford this technology. Rich countries can invest, but even the poor ones will feel the improvement, since the effects will be global. Yes, but poor countries do not have a vote on this matter, so the rich will decide everybody's destiny. […]" (Comment 225, CE)

Naturality in climate engineering means valuing approaches that are rather nature-based, as well as letting the environment naturally restore itself. Also, returning to earlier practices were mentioned, when the climate situation was not as bad as nowadays.

"Change of approach in sowing practices, returning nutrients to the soil, natural fertilization, these are the principles we should take back" (Comment 288, CE)

*"It helps that ecosystem to survive, and it uses natural resources." (*Comment 575, CE)

- **Social:** -
- **Technological:** The category **safety and reliability** mentioned by the participants concerns the side-effects and risks that need to be minimized before deploying.
- **Ecological:** With the values **ecosystem health** and **naturality** the participants valued the importance of ecological reflection in the development of this technology family. On the one hand, it has to ensure biodiversity on the other it should act in line with natural boundaries.
- **Economic**: The value category **effectiveness and efficiency** refers to an economical dimension in the broadest sense. The participants stated that that the technology creates the most efficient output is with regards to production costs.
- **Political:** Under the value **justice**, the citizens referred to the accessibility to the technology and the burden arise from the technology (e.g., pollution) that needs to be distributed globally and fairly.
- **Values:** -

Natural language processing and digital extended reality

In natural language processing and digital extended reality, the top five value categories are very similar with only a difference in order and one value category.

In natural language processing the value category **responsible use and accountability** occurs the most often. Approximately every nineth value belongs to this category. **Authentic human connection and experience**, **usefulness**, **effectiveness and efficiency**, and **safety and reliability** follows with almost equal occurrence in every 14th code.

In extended reality **authentic human connection and relationship** is the most prevalent, occurring in approximately in every fifth code. This is followed by **safety and reliability**, **equity, diversity and inclusion**, **responsible use** and **accountability** with an occurrence in every 12th code. Finally, the value category **usefulness** also belongs to the five most prevalent.

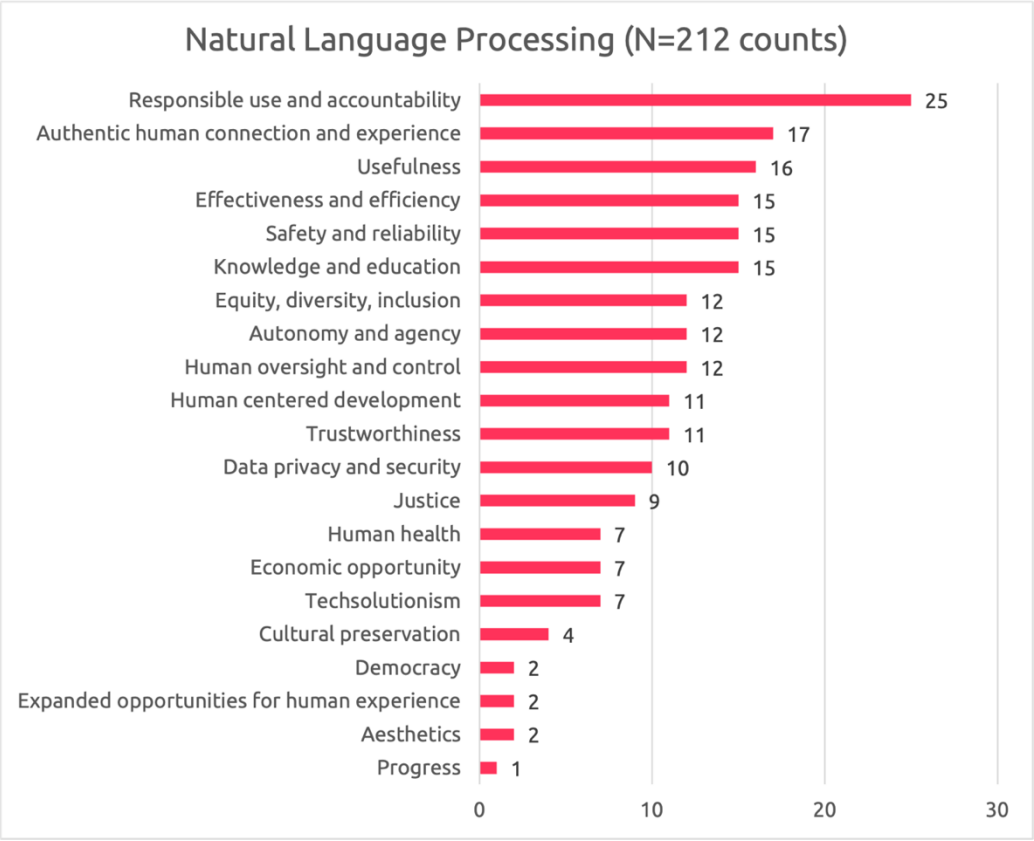

Figure 35: Value categories and number of instances coded for NLP

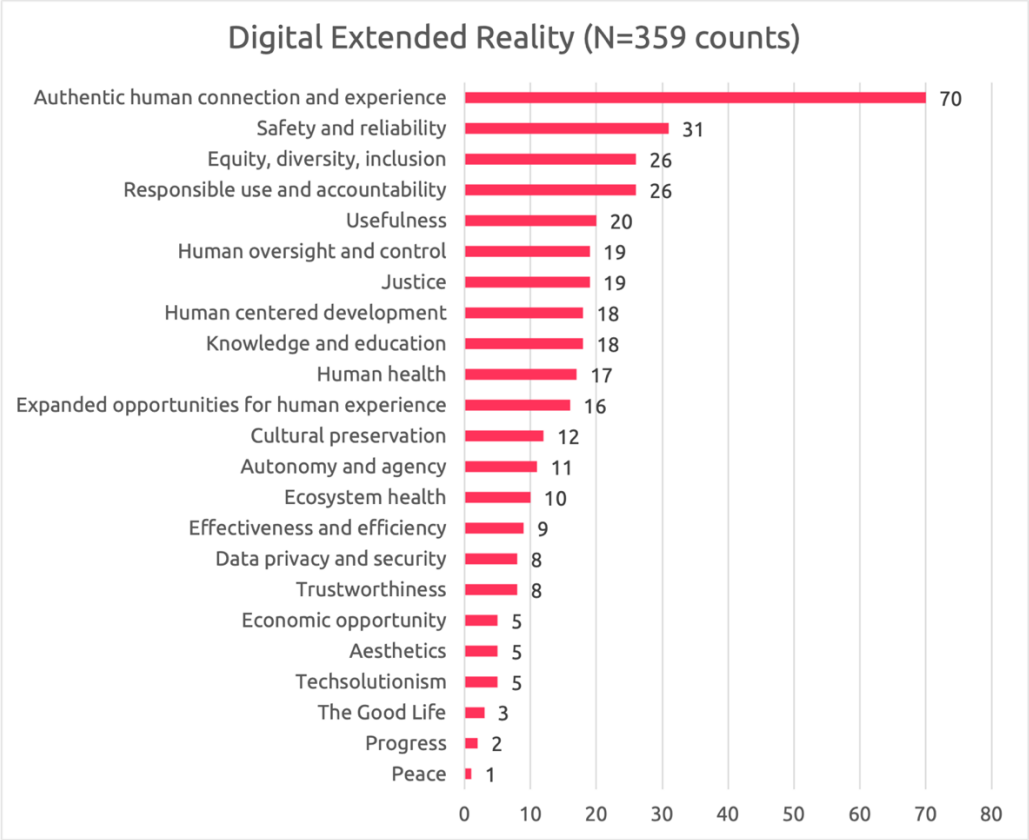

Figure 36: Value categories and number of instances coded for XR

Responsible use and accountability for NLP and XR refers to the question of who will take responsibility and who will be accountable for the results of what the technology creates. As there are multiple actors involved in the development and deployment process, this question becomes important.

"An important question to be determined: Who is responsible? - The first dilemma is whether the chatbot manufacturer or the user is responsible, and I have a whole chain of command actors between them." (Comment 137, NLP)

"If people start creating AI apps to make money at the expense of others, it's going to be a ruthless fight and a lot of people are going to get angry that AI cheated them. The anger will be all the greater because they won't be able to point the finger of blame. There will be protests from the people." (Comment 307, NLP)

"The technology is not to blame, but it opens up many new opportunities for misuse. The problem is not with technologies, but the misuse of technologies. Nobel did not think that dynamite would lead to what it would lead to." (Comment 89, XR)

Authentic human connection and experience captures the importance of human-human interaction and the value of this, considering that, for example, a chatbot would change the nature of our interactions. Moreover, it captures also values like realness, referring to finding something valuable because it does not only exist in the online sphere, including personal presence, physical reality, and human sensations.

"The chatbot will change our personality through interaction, we will start to behave differently, and it is very possible that it will dehumanize us." (Comment 131, NLP)

"I am concerned, but not because I think it is some great evil. - It's a shame that we won't see the Mona Lisa live, that we won't sit and talk like this at the table anymore. I fear that we will stop communicating verbally and start living like in science fiction movies." (Comment 91, XR)

Usefulness for NLP and XR refers to the variability of utilization of the technologies, as well as their adaptability and applicability in different contexts and use cases.

"With a good regulation it can be very useful. For example, in the case of the actor Val Kilmer, with throat cancer, the simulation of his voice has been created." (Comment 626, XR)

"AI could be taking over administrative work - …and relieving people of mundane repetitive jobs." (Comment 422, NLP)

Safety and reliability referred to valuing the technology contributing to a safer life of humans, but also citizens were cautious about the safe use of the technology.

"It allows for risk-free practice in professions such as medicine, security and even everyday tasks such as driving. - They claimed that this is the best advantage of having digital twins because it would avoid many risks in different areas." (Comment 635, XR)

"He's worried that people will be fooled - like gaming, young people can't get away from it." (Comment 312, XR)

Equity, diversity and inclusion appeared only in digital extended reality as one of the most frequent value categories. Usually, people were talking about equality in having access to the technology or the technology being inclusive to diverse social groups.

"The centre of discussion was the lack of access because the high cost of this technology. The main concern was inequity by money." (Comment 652, XR)

Effectiveness and efficiency got a high importance regarding natural language processing, as the most frequent value category. Citizens usually refer to how it would take some burden off of people with automatizing certain tasks, as well as contribute to the overall working efficiency.

"It's possible you'll get yourself imitated and you won't have to write any more emails. So, the AI will have us all loaded." (Comment 299, NLP)

- **Social:** To avoid a social divide because of technology gap, lack of accessibility or understanding, values like **equity, diversity and inclusion** are prevalent in the discussion.
- **Technological:** The **safety and reliability** of the technology needs to be assured. Not only due to potential harm, health issues or addiction but also with regards to the trustworthiness of digital models.
- **Ecological:** -
- **Economic**: The **effectiveness and efficiency** refers to the use of XR to improve education and work, while at same time assure job security. This goes together with the value **usefulness,** meaning that the technology should be applicable in different contexts and use cases.
- **Political:** In this dimension the **Responsible use and accountability** for NLP and XR refers to the question of who will take responsibility and who will be accountable for the results of what the technology creates.
- **Values:** Here **Authentic human connection and experience** becomes an important value, as the citizens are concerned that XR technology will change the way we behave towards each other or lose grip with reality.

Neurotechnology

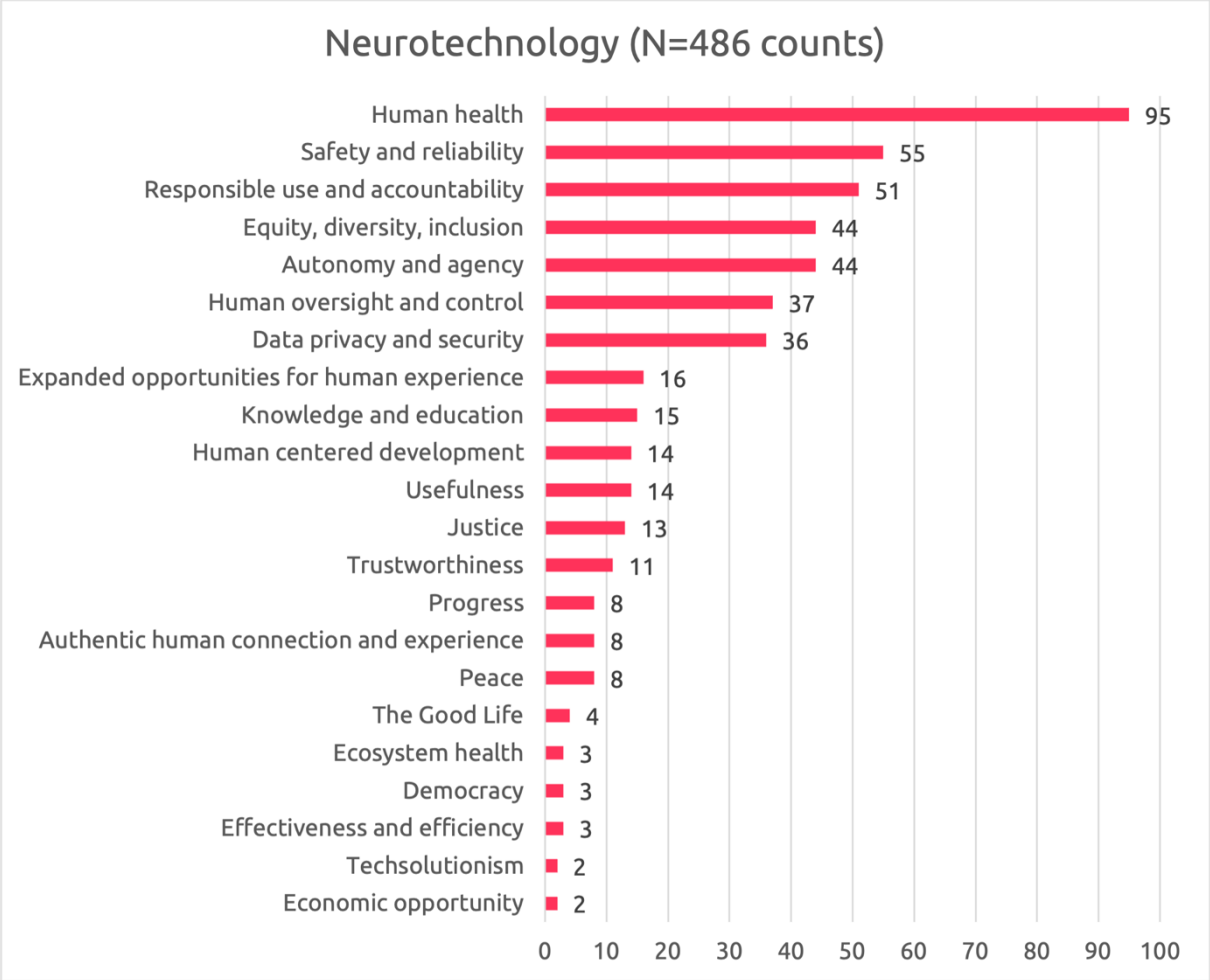

Figure 37: Value categories and number of instances coded for NT

In neurotechnology **human health** appears most often with an occurrence in every fifth code. **Safety and reliability** and **responsible use and accountability** follows with fairly the same distribution of appearing in around every 10th code. Finally, **equity, diversity and inclusion**, as well as **autonomy and agency** is mentioned approximately in every 11th code.

The value category **human health** captures that people value the use for treating diseases and illnesses, including mental illnesses.

"From a medical point of few this technology is very helpful for diagnostics - Can be essential for survival for many people." (Comment 448, NT)

"The technology feels important, above all for healthcare. New technology can help us cure diseases such as Parkinson's and other brain diseases. In addition, the knowledge and ability to treat psychological conditions such as depression or physical conditions such as back pain increases." (Comment 774, NT)

Safety and reliability in the context of neurotechnology refers to the trust in the technology that its use is not causing harm but will bring the desired effects without side-effects. There was a divide between non-invasive and invasive technologies, the former bringing less concern while the latter more.

“It is not very risky and could significantly improve medicine - It doesn't seem to be very invasive, which makes it relatively safe.” (Comment 181, NT)

"Technology can be good or harmful. Invasive Interfaces can damage the brain" (Comment 464, NT)

Responsible use and accountability includes valuing a wise use of the technology, meaning that the choice of utilisation was thoughtful and well-planned and that the use cases for such a technology are focussing on important contexts rather than, for example entertainment. Furthermore, citizens refer to taking responsibility over the use of the technology and that there should be a party accountable for its consequences.

“Every technology could lead to extremes and should be carefully monitored.” (Comment 46, NT)

"There are a lot of offline forms of entertainment, we should focus on the tech that could make a difference." (Comment 66, NT)

Equity, diversity and inclusion refers to being inclusive regarding different social groups. This often means that equal accessibility is ensured. Neurodiversity and its value is also debated under this category regarding neurotechnology.

“If everyone has access to this, it will clearly help with the inequity.” (Comment 52, NT)

"They said that reducing neurodiversity can be a big problem because all human beings are unique, it is their singularity.” (Comment 508, NT)

“It can promote inequality in accessing, discrimination and it can be a way to manipulate people.” (Comment 497, NT)

Autonomy and agency for neurotechnology includes concerns regarding cognitive sovereignty, having control over one’s life and decisions when it comes to the use of the technology.

“We don’t need more personalized adverts, especially on things I imagine but cannot have anyway! Google is enough!” (Comment 479, NT)

“If we lose our autonomy, there is no point in discussing anything else. - We would only create an even bigger gap if we threatened people's autonomy.” (Comment 166, NT)

- **Social:** The most important issue mentioned by the citizens was **human health**, referring to the health benefits as well as the control of potential risks. Furthermore, with regards to neurodiversity or the promises of neuroenhancement, the assurance of **Equity, diversity and inclusion** becomes important to avoid a separation of society.
- **Technological:** Regarding this dimension, citizens valued the **responsible use and accountability**, meaning that the choice of utilization is thoughtful and well-planned. Furthermore, **Safety and reliability** is a dominant topic, meaning that the technology will bring the desired effects without side-effects (especially regarding invasive technologies).
- **Ecological:** -
- **Economic**: Although not high ranked, the topic of **Data privacy and security** and the economically responsible use of the collected data was mentioned by the participants several times.
- **Political:** Citizens refer to the importance of attributing responsibility for potential harm of the technology and that there will be a party accountable for consequences.
- **Values:** The category **Autonomy and agency** addresses concerns of losing cognitive sovereignty or free will.

Discussion

Looking at the value distributions for the three technology families, it is evident that each technology family has unique values that are more prominent.

For **NT** the focus is on **human health**, **safety and reliability**, and **responsible use and accountability**. Neurotechnology deals with the human brain and nervous system, which are crucial for human health and wellbeing. Our analysis results made it clear that these values are indeed high on the citizens' agenda.

In contrast, **NLP & XR** have a stronger focus on **authentic human connection and experience**, as well as **responsible use and accountability**. This is also understandable as both these technologies aim to simulate human experiences and interactions; however, it also confirms that from the citizens' point of view there is a need to ensure that these simulations are safe, reliable, ethical and responsibility is taken for their use.

Finally, **CE** had **ecosystem health** as its most often mentioned value category. After which **safety and reliability**, **effectiveness and efficiency**, **justice**, and **naturality** follow. Climate engineering aims to manipulate and control the earth's natural systems, and from our results we can draw the conclusion that form the citizens' perspective it is valuable if this is done in a safe, effective and just way.

Overall, it is clear that each technology family has its own unique set of values that are most prominent. However, **safety and reliability** appear to be important across all three technology families. Additionally, **responsible use and accountability** are important values in both neurotechnology and natural language processing/extended reality. **Ecosystem health** is a major concern in climate engineering, but also appears in all the other technology families.

5.4 Concluding thoughts & cross cutting values

This chapter concluded the exploration of the public awareness, their attitudes and citizen values towards the three technology families. Through this exercise, we elicited citizens' excitements and concerns and created a set of values to consider when developing the ethical guidelines in WP5.

With the help of our Linked Third parties (science centres across Europe) we conducted several citizen engagement activities from science-cafes to scenario game workshops. With a strong focus on vulnerable groups, we reached a broad and diverse audience to discuss and elicit their values and concerns regarding the technology families and included unheard parts of society that often remain underrepresented when relying on expert knowledge only. Looking at gender distribution for example, what emerges is that 58.25% of workshops audience identifies as female. Usually, expert processes are disproportionately dominated by male voices. Integrating female and non-binary persons' voices better represents the values of all people potentially implicated by the technologies.

For this purpose, we developed the "**TechEthos game: Ages of Technology Impact**", a low threshold, engaging and interactive exercise to elicit participant's awareness, attitudes, and values. The game-based method aimed at reducing the complexity of the topic and enabled a more open and creative discussion about the excitements and concerns regarding the technology families.

The aim of this exercise was to enrich the developed scenarios further and include perspectives and ethical issues that have not been considered in the beginning of this activity. We chose the STEEPV heuristic to better compare and analyse the stated concerns and values. The heuristic, as shown above, aims at the reflection of each technology family individually. In the following, we will look at finding across the technology families.

5.4.1 Cross cutting values

Across all three technology families, we observed several value categories which the participants were excited or concerned about.

One relates to **safety and reliability**, which occurs in all three areas but manifests differently in each:

- **In CE**, participants were worried about the unknown effects and potential dangers (both to physical safety and health impacts, as well as the dangers regarding the ecosystem) of the technology and questioned whether the applications have been tested well enough to utilize them safely.
- **In XR** participants valued its contribution to a safer life, especially in the context of dangerous jobs, but also expressed some worry about the addictiveness of the technology and its safe use, especially among younger generations.
- **In NT**, safety mostly referred to the health impacts of the technology and a differentiation was made between invasive and non-invasive applications, with the latter causing more concern about the potential harms.

A second value category common across the three technology families is **Equity, diversity and inclusion**.

- **In CE**, this value category is focused on the individuals, but more prominently on the countries on a global scale and it is closely related to the value **justice**. A major concern is global distributive justice and intergenerational justice, as well as fairness in decision making regarding the use of the technologies. Coming from these considerations participants also emphasized the importance of making these technologies available globally and making sure that all can benefit from them regardless of socioeconomic status or location.

- **In XR** the discussion was often focused on ensuring equal access to the technology for all social groups. Participants raised concerns about the high costs of the technology and therefore the potential for exacerbating the existing inequalities between social classes.
- **In NT** the value category **equity, diversity and inclusion** was also linked to the equal access of the technology. Furthermore, neurodiversity and respecting the uniqueness of humans was also a major topic.

A third mentioned value category relates to issues of **responsible use and accountability**.

- **In CE**, **responsible use and accountability** is referring to having an accountable party for the potential disasters and making sure that the applications of the technology are used in a wise, thoughtful and well-planned way.
- **With XR** the concerns around this value category emerge around the question of who is responsible and accountable for the results of the technology and its consequences as there are many different actors involved from the creation of the technology until its utilization. Furthermore, citizens are worried about the misuse of the technology.
- **In NT** the discussion is more focused on the question of what sectors should use the technology. Citizens mention that well-planned use of the technology is crucial and that we should prioritize its application in more important areas like health care, and not in entertainment. Furthermore, having a clear accountably with regards to the collected data and for unintended consequences of the technology is a mentioned issue.

5.4.2 Limitations of the approach

We would like to pause here to observe a few points regarding the collection and analysis of the results presented above. These points, we believe, accompany much qualitative social science research, however bear repeating in the interest of transparency. First as readers will observe, the created categories reflect the subjective choice of the reviewers in terms of titling and description. Every attempt was made to impart clarity, as well as to ensure the demarcations between categories were as discrete as possible. Nevertheless, it is plausible that another group might have abstracted a slightly different set of 25 values from the list of 84 axial codes. We believe – despite all coders working together on the same team with a similar academic background (STS), coming from a range of ages, backgrounds, expertise, genders, nationalities, and cultures, lends a degree of robustness to the agreed upon codes sufficient for reporting with confidence. As the TechEthos effort is a coordination and support action and not a research action, additional steps to validate the 25 value categories is beyond the scope of the present deliverable. However, additional review by an outside research group would offer a step for further validation of the categories constructed.

Second, as clear in the language above, all of these values are constructed – in accordance with the grounded-theory approach – based on the interpretation, experiences, and mental models of the research team. In some cases, value categories directly reflect words in participant comments. In other cases, the content (either with reference to process described or outcomes expressed) of participant statements is what the researchers deemed associated with a value category. The consensus method helped assure an internal consistency of the coding effort, however another group of coders may well have identified a different initial set of open codes. Given the team's social science expertise, however, we remain confident in the findings presented above.

Finally, the participant statements coded for values were translated into English by our linked third-party colleagues responsible for delivering and facilitating the workshops. As such, some information—context, cultural or national nuance—may have been lost in translation. However, given that the LTP colleagues who conducted the workshops were sensitized to the kind of material of

interest to the TechEthos team, and were themselves the translators, we have a high degree of confidence in the accuracy and validity of the recorded and coded statements.

6 Scenario evolution overview

In the face of the uncertainty that comes with the development of new and emerging technologies, it is necessary to have knowledge in order to orient oneself and make decisions. This knowledge can come from different sources and offer different perspectives. In foresight, for example, one way to create knowledge is through the construction of scenarios to explore and anticipate what the future might look like or to depict possible pathways into an unknown future. Other knowledge can come from stakeholders that reflect on current issues and values and hold perspectives on the challenges of dealing with these emerging technologies.

In TechEthos, we have used both forms of knowledge for a comprehensive analysis of the possible ethical and social implications of the respective technology families. We conducted a multi-stage & multi-stakeholder scenario approach involving diverse stakeholder groups with different levels of understanding and perspectives. The approach consisted of three stages, starting with the creation of basic scenarios to structure trends and drivers and contextualize the emerging technologies, followed by a scenario reflection with various experts to enrich and discuss the findings and ethical issues, and completed by a citizens engagement activity to sketch out conditions for preferable futures and consider citizen values that might be at stake when these technologies are in use.

1- Basic scenarios

- based on the elaboration of innovation ecosystems for each technology of the TechEthos portfolio, three basic scenarios have been developed. That is, “plausible” and “contrasting” scenarios have been created by using STEEPV (social, technological, economical, ecological, values) factors for structuring the basic scenario creation as well as scenario narratives.

2- Expert engagement

- Scenarios have been used to explore the awareness, attitudes, and values of various stakeholders towards ethical implications of new and emerging technologies. In the second stage we elicited expert stakeholders’ attitudes to ethical implications of the TechEthos technology families (i.e., expert enrichment).

3- Citizen engagement

- The aim of the third stage in the evolution of TechEthos scenarios was to capture citizens' awareness, attitudes, and values (i.e., citizen enrichment) in 20 workshops across six different countries with an overall number of 331 participants.

The following chapter will conclude on the synergies of all three stages and bring together the learnings from this multi-stage and multi-stakeholder scenario enrichment process.

6.1 Results of the enrichment process

To compare and enrich the results with each step we used the STEEPV heuristic. In this way a common ground from all three stages (basic scenarios, expert engagement with the TechEthos scenarios and citizen engagement with the TechEthos game) was created, which allowed to map out different dimensions of ethical implications.

The STEEPV categories were defined earlier as follows:

- **Social** developments may include factors such as demographics (aging, urbanization, migration), inclusion/exclusion, lifestyle (health, leisure), education and community (family, peers, neighbourhood).

- **Technological** developments may include factors such as research and development (academia/industry), innovation & diffusion, private & public strategies (roadmaps, action plans), and standards.

- **Economic** developments may include factors such as industrial structures, markets (B2C, B2B) & competition, investment (risk capital, subsidies), trade, jobs, entrepreneurship, and circular economy.

- **Ecological** developments may involve factors such as global warming (fossil vs renewable vs nuclear energies), pollution (air, water, soil), resource depletion and biodiversity.

- **Political** & legal developments may include factors such as political (in)stability, regulation (law, standards, tax policies, consumer protection), jurisdiction, trade unions and lobbying (multinational companies, NGOs).

- **Value** developments may include factors such as: culture & subcultures, religion & ideology, attitudes of various (professional) stakeholder groups.

As shown in chapter 5.3, 25 value categories were constructed by coding the material elicited from the citizen engagement. In order to get an understanding of how these values confirm, enrich and add to the basic scenarios and the reflection of the experts on these scenarios the 25 value categories were sorted according to the STEEPV categories. It is acknowledged that the value categories pertain to overarching values that were derived from citizen discourse, while the STEEPV dimensions are covering distinct societal domains. Consequently, some value categories may be applicable to multiple STEEPV areas. For example, human-centred development can be attributed to the technological dimension, e.g.: designing technologies with a human-centred approach, but it can also be regarded as a broader ideology of technology development falling within the realm of the value domain. It should further be noted that the value domain may encompass most of the value categories of specific areas. This is due to the nature of the analysis of the citizen input, which was aiming at extracting the awareness, attitudes, and values of citizens. Nevertheless, certain value categories can be directly associated with a particular STEEPV area, such as effectiveness and efficiency within the technical domain, even though they are also capturing a value of citizen's wishes for example. In these cases, they were not listed as part of the value domain.

The following is an analysis of the themes and aspects that emerged in the three different stages.

6.1.1 Scenario enrichment for CE

The different stages of the research brought a rich variety of issues to light. Some of them were discussed in all three stages, while some new and unique insights emerged only in two or one of the stages.

Social dimension of CE

- **Inequality and equity** has been a topic in all three stages of the research.
- Experts focused more on issues of **global consequences** of the technology, like geopolitical and environmental instability, while citizens were also concerned about the impacts on **human health** specifically.
- Important to highlight and consider the prominent presence of the value category **safety and reliability** in the citizen enrichment. This seems to be somewhat less emphasized in the basic scenarios and the expert enrichment, but for the citizens this was very high on the agenda.

Technological dimension of CE

- A rather overarching topic was **effectiveness and efficiency.**
- The notion of **techsolutionism** (also mentioned under the value dimension) was highlighted both by the citizens and the experts. With the experts, this led to a critical discussion about alternative solutions like a change in behavioural patterns or systemic changes instead of pseudo technological fixes while continuing harmful habits.
- The citizens found **trustworthiness** of the applications crucial and were concerned how little **transparency and knowledge** is spread about climate engineering despite its crucial impacts.

Ecological dimension of CE

- **Ecosystem health**, including biodiversity and environmental quality in general was of high importance in all three stages.
- An interesting addition from the citizen engagement is that they put a high emphasis on **valuing more the natural ways** of climate engineering, over other more artificial applications.

Economic dimension of CE

- Economic developments, the **potential for growth** was an overarching topic, but citizens were more focused on the individual perspective (how jobs and businesses locally will be impacted), while the experts critically highlighted the power dynamics of big companies and corresponding concerns in the market.

Political dimension of CE

- **Distributive justice** is an overarching value category that is emphasized both by the experts and the citizens.
- The lack of liability of the technologies mentioned by the experts is also discussed by the citizens under **responsible use of the technology**.

Value dimension of CE

- The idea of **lifestyle changes** (and the idea of the good life) and moving away from the consumerist society is a topic that was discussed overarchingly as an alternative to the proposed technologies and the risks that come along with it.
- **Techsolutionism** as a general mindset was highlighted by both experts and citizens, but it varied in the ways it was discussed. Experts were more emphasizing that we should think outside of the technological domain when it comes to solving climate change, while in the citizen enrichment people were often thinking within the paradigm of techsolutionism and believing in the “tech will save us” idea, if the technology is efficient, reliable and holds its promises.

6.1.2 Scenario enrichment for XR

Social dimension of XR

- Across all three stages the risk of a **social divide** was mentioned. This concern goes along with social isolation and the **lack of authentic human connection and experience** due to the

virtualization of life. Experts and citizens alike were worried that it may increase mental health and thus social challenges.

- Furthermore, the affordability, accessibility and applicability of the technology might cause a **technology gap** between remote workers fully remote workers and in-person workers (physical separation, uneven distribution of opportunity to engage in homebased work). To avoid a social divide because of the technology gap, lack of accessibility or understanding, **values like equity, diversity and inclusion** are prevalent in the discussion.

Technological dimension of XR

- Following the assumption that a version of an online, virtual "metaverse" has strong presence in peoples' daily lives, from corporate and government presence to social interactions, the **safety and reliability** of the technology needs to be assured.
- Citizens were worried about impact on young people, for example causing **addictions** but also due to potential harm and health issues.
- With regards to the trustworthiness of digital models and data security citizens and experts both mentioned that training on **digital devices do not represent the reality** (e.g., as it lacks haptics or authentic social interaction).

Ecological dimension of XR

- Additional environmental impact of servers and energy costs will **cause additional CO2 emissions** and increase the carbon footprint.
- The need for resources of ubiquitous technology (e.g., constructing and maintaining the infrastructure) causes increased **rare earth mining.**
- **Urban forms change** in response to the prominence of virtualization, affecting residential and commercial areas, traffic, other forms of transit.
- Significant **rural repatriation progresses** as virtual workers may be able to work from anywhere.

Economic dimension of XR

- The use of **chatbots** and LLMs will has to potential to improve but also **disrupt education and labour market**, which caused excitement and concerns among the citizens. On the one hand it can simplify certain areas of work, on the other hand it can make certain jobs obsolete.
- As experts pointed out, XR and remote technology will cause a **change in attitude towards work** – some jobs become less attractive because online work offers a better work-life balance. There is a risk of acceleration trends toward work-from home in 'white-collar' settings, but not evenly distributed either within or across national boundaries.
- The citizens were most concerned about affective computing due to possible **misuse and data protection** issues.

Political dimension of XR

- On a more systemic level, the experts pointed out that **data protection issues** can cause issues for democracy but also organizing labour unions or protests due to a lack of physical interaction and an external oversight of communication.

- Furthermore, **the rights and use of individual data** (e.g., of dead people) is an unsolved problem. The experts also pointed towards authentication issues with deep fakes and a legitimization issue of what is fake and what is not.
- The main concern for citizens is the lack of regulation of digital companies (e.g., Meta). In accordance with the experts, the citizens called for a **responsible use and accountability**, referring to the question of who will take responsibility and who will be accountable for the side-effects and potential misuse of the technology.

Value dimension of XR

- The experts pointed out that XR will change our relation to death, asking for **dignity of posthumous data**, a different understanding of privacy and taking care of **digital legacy** before we pass away.
- Similar to the impacts on the social dimension, the experts mentioned issues like **depersonalization**, **depression** and **decreasing of social skills**. XR would enhance social isolation.
- Current social biases (e.g., gender bias) will be inscribed into the technology. Citizens here called for a responsible development and a clear accountability to ensure **equity, diversity and inclusion.**
- From the citizen engagement we learned that **authentic human connection and experience** is an important value that might get lost, as the citizens are concerned that XR technology will change the way we behave towards each other or lose grip with reality.

6.1.3 Scenario enrichment for NT

Social dimension of NT

- The prevailing issue that was mentioned across all three iterations was the factor **human health**, meaning that NT should predominantly be used in this context. However, there is a tendency that this technological fix of healthcare might lead to **altering definitions of people with disabilities or enhancements**, with discriminatory consequences.
- Issues that arise from other fields of applications, for example in the labour market or as a tool for individual enhancement, are a **technology gap** between users and non-users. If the technology will be made available for other market segments, both citizens and experts noted that **equality in accessibility** should be ensured.
- Another important aspect was **autonomy and agency** referring to cognitive sovereignty and non-manipulation. Here the experts and citizens both focused to two aspects: On the one hand the device should **not influence aspects of own agency** (e.g., stimulating the brain for marketing purposes or forced stress reduction for more effective work); on the other hand, the collected data may not be used for **psychometric profiling of behaviour**.

Technological dimension of NT

- Regarding this dimension, the most prevailing issue across all three research stages is **responsible use and accountability**, meaning that the choice of utilization is thoughtful and well-planned. The use cases for such a technology should focus on health-related contexts rather than, for example entertainment.

- **Safety and reliability** is a dominant topic in general, meaning that it should be ensured that the technology will bring the desired effects without side-effects (especially regarding invasive technologies).
- **Data privacy and security** is an issue highlighted by experts as well as citizens. The crucial questions of who and how will own the data should be addresses. Experts also put an emphasis on making sure that data transferability is ensured across different developers and devices in case a company cannot provide the service anymore.

Ecological dimension of NT

- **Ecosystem health** was an overarching topic with different aspects emphasized. The experts particularly highlighted energy consumption for data storage, maintenance and obsolescence issues, and the sustainability of the devices.

Economic dimension of NT

- Economic dimensions mostly appeared in the expert enrichment, where the power of private companies was discussed with the concern of them being **responsible and transparent** with the use of private data. Experts mentioned that infringement of **autonomy** can be a cause for concern is humans become the product of the technology (i.e.: users are not paying).

Political dimension of NT

- The topic of **responsible use and accountability** was highlighted in all three stages of the research. Experts even considered the question of where we draw the line between “tech is responsible” and “the user is responsible”. The **issues of misuse** of the technology were worrying both the experts and citizens. Citizens emphasized the issue of accountability for potential harmful consequences.
- The issue of **neurodiscrimination and the governance of big data management** was in the focus of the experts.
- Both citizens and experts brought up concerns regarding the **infringement of autonomy and agency**, including cognitive sovereignty.

Value dimension of NT

- Experts emphasized how the role of the **technology** can **change** certain **concepts**, like the way we see “the right way of ageing”.
- For citizens, **a human-centred way of developing** the technology was important (considering for example neurodiversity).

Stage 1
basic scenario insights

Stage II
enrichment from expert engagements

Stage III
enrichment from citizen engagement

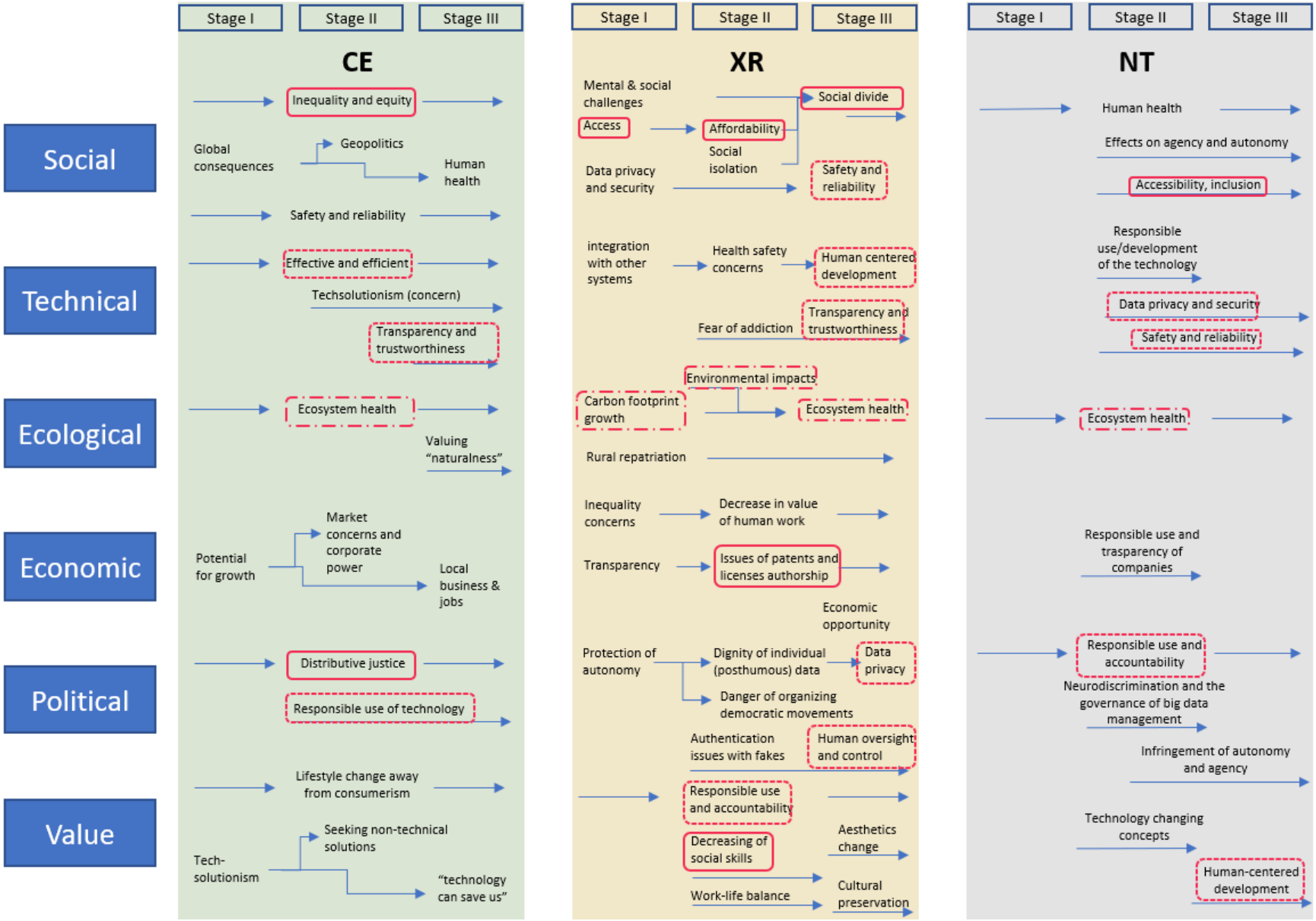

Figure 38: Enrichment process stage by stage

6.2 Highlights & discussion

The goal of the presented multi-stage & multi-stakeholder approach was to explore ethical issues through eliciting attitudes and values of various stakeholders regarding the identified new and emerging technology families. To present a comprehensive analysis of possible implications, we enriched the early findings (basic scenarios) with different perspectives – giving voice to experts and citizens – using appropriate methods to engage the diverse range of stakeholders.

When dealing with ethical and social implications of emerging technologies, it's necessary to involve different societal perspectives. Adopting a mixed-method approach is vital to surface such diverse perspectives. On its own, each approach leaves blank spaces due to the biases, limited perspectives, and necessary foci. Thus, each stage enriches the set of results by offering new perspectives on the social-ethical dimensions of the technology families (see figure 38):

- The authors of the basic scenarios build on an ecosystem perspective and anticipate potential and contextualized issues of the technology in a narrative form;
- the experts shared a broader and systemic perspective, with a specific emphasize on looking beyond a techsolutionist scope;
- the citizen's focus was on their lived experience, how the technology might impact the reality of their everyday life and allowed to elicit what individual participants valued.

All three activities combined allowed for a comprehensive understanding of ethical issues to be considered in the development of emerging technologies – not only with the three technology families but also with emerging technologies in general, as will be explained in this section. The section highlights & discussion will conclude the main results and lessons learned from conducting the multi-stage & multi-stakeholder evolution of TechEthos scenarios.

Main takeaways

Following the multi-stage & multi-stakeholder approach and combining different kinds of knowledge allowed us to enrich the perspective on potential ethical issues of emerging technologies. While there were overarching topics within each stage (see below), the different stages also offered new information. Certainly, for example, the creation of the basic scenarios and the engagement with experts generated a range of ethical issues, yet they do not offer insight into the prevalence of such values as was achieved through the analysis of the citizen engagement results. Furthermore, each activity allows different perspectives, together leading to a rich understanding of ethical challenges. On the one hand, by offering issues that were on the fringes of the current discourse (which are covered through the citizen engagement). On the other hand, by opening up perspectives beyond the scope of the researchers and showing systemic gaps in perception such as acknowledging the functionality of the emerging technology. This was critically marked by the experts by not only challenging the feasibility and promises of the technology but also by pointing out other solutions beyond technological applications.

One of many challenges of this multi-stage & multi-stakeholder approach is the rich amount of material created which necessarily needs to be abstracted to stay comprehensible. However, each abstraction also reduces the richness of information and comes with the compromise of losing context or nuance. Therefore, the presentation of complexity is a "necessary evil", while at the same time it has to ensure the balance between an information overload and a comprehensible report. In the following we highlight the three overarching themes "equity", "reliability", and "environmental safety"

for the sake of presenting to the interested reader particularly remarkable results (not necessarily for WP5, where the nuances of the technology families should be considered).

Equity

The introduction of new and emerging technologies into a social system can stir the established dynamics within this system, as the technology creates benefits for some groups and disadvantages for others. The concept of equity in this context refers to the fair and just distribution of benefits and risks associated with these technologies. It recognizes the importance of ensuring that positive consequences derived are accessible to all participants of the community, regardless of their socioeconomic background, their geographical location, or other specific characteristics.

In the context of CE for example, equity refers to the power imbalances that is created between those countries with access to the technology and those without. As climate change is a global phenomenon, there is the concern that the technology may enhance or stabilize already unjust power dynamics. To assure equity in this context, the development of CE also needs to consider a global accessibility to the benefits or CCS or SRM. Equity concerns in CE also manifests at local levels, in terms of the distribution of burdens (e.g., the local community poisoned in the event of a CO2 gas transit pipeline explosion) and benefits.

For XR, equity is concerning the affordability of the technology as well as the fair distribution of benefits. Especially with regards to shifting dynamics within labour markets. Here the concern is that, if XR and NLP will become relevant in future working conditions (whether through the use of LLMs or AI-image-generators in certain areas or the through the advanced use of telework), the disruption of markets might shift power dynamics in favour of AI developing companies. Thus, accessibility to the technology, acknowledgment of licenses and authorship, as well as a fair distribution of benefits among society is needed to prevent a potential social divide.

In the context of NT, equity is referring to the accessibility to the technology especially in medical treatments. Based on the findings, the concern is that people in need of treatment (e.g., people suffering from neurological disorder) are not able to afford it. This concern grows assuming that NT might be used outside of medical contexts. If NT finds its way into other areas (e.g., the labour market, education or as a tool for individual enhancement – which is currently more science-fiction than science-fact), equity in accessibility should be ensured to prevent a potential technology gap between users and non-users.

In general, equity includes considerations of affordability, accessibility, fair distribution of benefits, as well as the mitigation of unintended negative consequences. Therefore, emphasizing equity in the development of emerging technologies is necessary for a responsible innovation process.

Reliability

A prominently emphasized and overarching concern within all technology families is the reliability (feasibility as well as liability) of technologies and their applications. Specifically, this pertains to the extent to which technology functions as intended, causing minimal undesirable unintended side-effects, ensuring safety, and delivering the promised outcomes and results without significant issues or adverse effects.

In the context of CE, reliability covers two concerns: The first is with regards to the promised outcome; the technologies discussed need to work effective and efficient that is ensuring the technological feasibility of capturing more CO2 than which is emitted during the production of those devices. The

other aspect covers the issue of liability; the concern is the lack of clear and legal accountability with regards to the created waste and potential side effects.

In the context of XR, this concern covers areas of privacy and security. As with many digital technologies, the question of data rights and the responsible use of the collected data becomes important. The findings show that next to the transparent use of data, the trust in companies and holding companies accountable if necessary is an important ethical concern. Furthermore, reliability also covers a focus on human-centred development, valuing the benefit for individual users (e.g., by reducing harm or addiction) over company revenues generated from the technology.

In NT, like XR, reliability is connected to the question of data privacy and security, as it's unclear what the data might be used for in different contexts. Furthermore, the proprietary of the technologies causes problems when in need of another technology provider. Thus, data transferability needs to be ensured across different developers and devices. Lastly, it is important to mention that the vision of human enhancement and the use of NT in contexts outside of medicine is creating false hopes and unrealizable promises. In the case of NT, reliability thus also covers the responsible use of promises and visions.

In short, reliability encompasses the trustworthiness and dependability of a technology in terms of expected outcomes and effects. It is particularly important as emerging technologies play an increasingly important role in various sectors such as healthcare, labour market and communications. To deal with this concern, the liability of technology developers and companies should be clearly addressed.

Environmental sustainability

The third cross cutting concern we want to highlight is environmental sustainability. It covers the creation and implementation of technologies with a minimal negative impact on the environment while promoting biodiversity and ensuring healthy ecosystems. It emphasizes the need to address environmental challenges, such as climate change, resource depletion, pollution, and habitat destruction, by integrating sustainable principles into the development, deployment, and use of emerging technologies.

In the case of CE, this concern is expressed strongly in the context of biodiversity and pollution. Biodiversity becomes relevant when discussing natural based solutions for CDR, as these solutions are often focussing on monocultures due to economic reasons. Pollution touches upon the issue of toxic waste created through CDR or atmospheric SRM.

For XR, environmental sustainability becomes an issue due to the rise of CO2 emissions providing a globally accessible infrastructure for training LLMs and storing data. Additionally, the production and disposal of the necessary hardware becomes a future issue (i.e., increasing rare earth mining).

With NT, like XR, this concern covers rising energy consumption for data storage, maintenance and obsolescence issues, as well as the sustainability of the devices.

In short, facing climate change, understanding environmental sustainability of emerging technologies as an ethical concern involves considering the entire life cycle of a technology, including its design, manufacturing, operation, and disposal, with a focus on minimizing carbon emissions, reducing waste generation, conserving resources, and preserving biodiversity. As the findings show, fostering a greener and more sustainable future through the development of emerging technologies, mitigating environmental harm and creating solutions that support ecological well-being and resilience is a cross cutting concern that is perceived as highly important with regards to the protection of our planet and future generations.

Conclusion

The report covered the multi-stakeholder & multi-stage approach to reflect on ethical issues of emerging technologies. By presenting the results of the multi-stakeholder & multi-stage approach, the richness of ethical issues, the plurality of values and the complexity which need to be taken into account when responsibly developing emerging technologies as has been shown by the examples of climate engineering, digital extended reality and neurotechnologies. The chosen path for this endeavour went through different stages. By writing scenarios, reflecting on potential implications with experts, and immersing into future with citizens within the TechEthos game workshop, we elicited attitudes and values and highlighted ethical issues through these foresight practices. The report, as well as the chosen mixed-method approach, becomes a proof of concept for an applied integration of foresight & ethics. It showcases how to work with foresight methods to engage expert and citizen stakeholders in the reflection on ethical issues of new and emerging technologies. Beyond the TechEthos project, this report also holds a relevant contribution to communities dealing with ethical and social impacts of emerging technologies.

The aim of this report has been to start further discussion on the elicited values and ethical issues within the TechEthos project. The different research activities concluded and the according results presented in this report will be taken up on multiple occasions: For one, this report is accompanied by D3.2 and D3.5 in the same WP. The highlights and the presented results of this report will be discussed in WP5 and inform the operationalization of the guidelines.

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8 Annexes

8.1 Exemplary expert feedback on the scenarios

8.1.1 Climate engineering

Feedback for all three Climate Engineering scenarios

In general, participants observed an absence of timeframes in all three scenarios and suggested this made orienting within the scenarios more difficult.

Feedback about Climate Engineering Scenario 1

In addition to comments on the issue of scenario timeframe, participants raised specific questions or comments related to:

- **Clarity of presentation; concreteness; resolution of ambiguity:**
    - Example: why has Biofuel become more profitable than food?
- Missing **actors in the carbon** market:
    - Example: who are the key players buying and selling carbon in the carbon market?
- Issues **related to CDR or CCS**
    - Example: Does not deal with the dangers of carbon capture and storage which is already creating some chaos here in the US.
- **Food versus biofuel**
    - Example: why would biofuel become more profitable than food - especially given rising food prices due to CC impacts?
- Elaborate unintended consequences in the biodiversity and interconnected environment.
- Other comments
    - The scenario is still following the paradigm of economic growth.

- Positive feedback
    - Competition of different targets, i.e., CO2 removal versus agriculture and inequality in impacts
    - Biomass focus remains policy relevant given recent IPCC assessment
    - Vivid description
    - Raises some of the possible north-south dynamics
    - Considered the issue of food shortages related to the use of biofuels
    - Scenario notes that mitigation would have uneven impacts on global equity

Feedback about Climate Engineering Scenario 2

- On scenario framing and clarifications
    - Example: a “towering inferno” may be problematic. If there needs to be debate on whether SAI should be used, it may be problematic to reflect only a ‘towering inferno’ situation. A **balancing scenario may be helpful to balance the ethical reflection**.
- **Geopolitical dimensions**
    - What drives down global collaboration?
    - Geopolitics of China & EU cooperation might need additional elaboration, and consideration of potential responses from the US.
- **Missing the impacts of climate change**. With the level of change baked-in to the scenario, there are a lot of impacts unaddressed. For example, there already is and would continue to be a lot of impact on agriculture, which is not reflected. In the scenarios, people freak out about climate impact - but what are the impacts? Is not stated.
- On deployment of SAI
    - Sudden SAI that immediately cools seems like a very poor/unlikely choice as it results in inverse **termination shock**.
- **Elaborating range of reactions:** Why use climate denialism, and not closed borders as a right-wing reaction to climate impacts?

- Positive feedback
    - Describing a realistic political scenario (e.g., far-right populists); Very realistic reaction / neglection from the far right
    - Illustrating that there is reaction when nothing happens
    - This scenario mostly avoids the '(climatic) upsides of measures taken are not elaborated upon' problem because it includes the wet bulb event
    - China partnering with India, EU and UN losing its power
    - Capturing concern over SAI
    - Good idea that the impacts of warming causes climate denialism will be outlawed

Feedback about Climate Engineering Scenario 3

- **General clarifications**
    - Example: How to address locked-in emissions from today? If emissions keep rising for another decade, there will be a lot of warming baked into the climate system.
- **Clarifications regarding CDR in contexts**
    - Example: Better address rapid decarbonization: CDR isn't going to reduce emissions, it's got to happen through decarbonization, so that rapid transformation could be addressed in a bit more detail -- more than all the CDR description. How does decarbonization happen?
- **On BECCS, afforestation, and land-use**

    - Example: Inconsistency related to land use for BECCS and afforestation: e.g., going in on non-commercial land use for BECCS but then also doing significant afforestation each seem to have land implications, so the differences might need to be better spelled out or acknowledged

- **On geopolitical dimensions**
    - Example: How to adopt a pluralistic, non-imperial approach to talking about development in currently poorer countries.
- **On values** implicit / explicit in the scenario
    - Example: **Bottom Up Lifestyle Changes** should also be reflected in the political landscape – painting a richer picture of decarbonizing world: Are there enough simple solutions explored, e.g., public transport, free bicycles - or is this part of the post-consumer society?

- Positive feedback
    - Showing that different generations react differently to climate change questions
    - Interesting to include carbon tariffs
    - The idea that EU & China could cooperate very closely
    - The legal recognition of the rights of nature
    - Useful for reflecting on reasonably optimistic takes on CC response but even still with moderate CDR

8.1.2 Digital extended reality

Feedback about Digital Extended Reality Scenario 1

General Feedback

- The parent's perspective on the "new normal" wasn't very clear.
    - Example: Protagonist parents: They accepted it, but are they approving it or do they judge it? If this becomes clearer, the intergenerational comparison could be built out in a consistent way.
- More technical details were needed. The detailed design of the technologies is not discussed.
- Why did the school system work this way? The history and the reasoning behind it could be more elaborated.
- The problem solving could be better reflected within the scenario. It lacks a reason of why this technology was created for. Why do we need this tech? What's the problem it's going to solve?
- The generational differences are well explained but could be emphasized more in detail.

What went well:

- The scenario demonstrated the tension between the opportunity of augmented reality and the potentially innate discomfort people have (represented by the child's perspective) about a disconnected experience in human interaction.
- The concept of the training was interesting. Using only technology does not complete it. Instead, there is always a physical / real part behind it (swimming, fixing cars).
- The description of the different forms of isolation caused by the technology:
    - Between humans, as there were social groups separated by the technology ("old news")
    - Between humans and the environment.
- The techdeterministic description of the technology was a good moment for discussion:

Feedback about Digital Extended Reality Scenario 2

General Feedback

- The scenario is missing to explain what might happen to people unable to transition to virtual work.
    - Example: Is there potential social discrimination? What about illegal workers? What about workers that can't work online (e.g., nurses, plumbers)?
- Missing discussions about equity…
    - Example: regarding the costs of home offices. It requires more space, which means larger homes, which means more means.
- Misses the pros and cons of remote working.
- Missing discussions about different cultural factors.
    - Example: Reactions to in-person schooling, remote work, the desire to stay in cities, families function differently (care taking) are different with national norms and cultural backgrounds.
- The scenario does not reflect the speed of social norms but only the speed of technology.
    - It could make more explicit, that in different sectors change happens at different speeds. In some dimensions it will be slowly / rejected. In other dimensions it's faster and accepted. Comparing University courses and care taking, for example. The social acceptance of robots in medicine is different than students learning online.

What went well:

- The setting of a lacking public transport (just taxis) is very dystopian, unfortunately very realistic.
- The scenario deals well with new approaches to urbanization. Reinvention of the urban spaces is a big strength.

Feedback about Digital Extended Reality Scenario 3

General Feedback

- The scenario could explore more possible application spaces.

- What kind of defence mechanism against it do exist in this scenario?
- What was the average reaction to those spams?

What went well

- Shows different possible applications of the technology.
- Presents different human reactions like sorrow or trickery.
- Focuses on language as a human trait that can become overwhelmed by automated generation of content.
- Addresses the issue of "digital leftovers" and the use of personal data.
- Highlighted of the absence of legal consequences and the limitations of the legal system

8.1.3 Neurotechnology

Feedback about Neurotechnology Scenario 1

General Feedback

- Regarding the **trial**:
    - Accidents in law work differently: Someone presents a charge against a party and this party defends against the charge.
    - From a legal perspective, liability is not based on the mental state but on what was happening objectively.
    - We are already using non-regulated enhancers. Caffeine, nootropics, etc. None of them has had to stand trial or been held liable in place of the consumer. Thus, it's not clear why the neurotechnology would absolve the individual from responsibility?
    - The same arguments would work for both. So, both would be liable. If Smith wins, it's also the problem for Jones and vice versa.
- Regarding the **use case**
    - Technical clarification is missing. Is it an active or a passive device? Is it only monitoring the concentration? Or does it have an active component (like stimulating when concentration drops).
    - The premise was unbelievable: Liability likely to be determined by unmentioned factors unrelated to the BCI. Therefore, it would help to describe the accident itself more in detail. The device is just communicating with the car. So, the actual problem could also be a loss of communication, which would make the dilemma obsolete.

- Regarding the **setting**
    - The devices are widely used. But it's surprising that there are no legal cases (see for example smartphones not allowed while driving.)

What went well:

- Presentation of one of the fundamental ethical issues at stake (responsibility)

- Very imaginative and relatable narrative that showcases the potential of neurotechnology to spur public imagination and become an important technological reality
- Captures the difficulties of having a nuanced understanding of the complexity of the legal ramifications of human-neurotechnology interactions.

Feedback about Neurotechnology Scenario 2

General Feedback

- **Function Creep** – more broadly also called "technology creep".
- Regarding the **Data**
    - Important to clarify in scenario if it's a medically prescribed tech, which would protect the data...or an under-regulated consumer device.
- Regarding the **use case**
    - Why are the users locatable? Doesn't sound like GPS is needed for neuromodulation.
    - The technology creates the human categories, defines what is "normal".
- **General**
    - Too many topics in one scenario. The second part with the security-related scenario was less realistic compared to the overall issue of commodification. Also having markets for brain data vs. state security are two very different topics. It's not helping to mix them.
    - Without neuromonitoring devices widely available (and socially accepted), neurosurveillance would not be an issue.
    - Neuromonitoring for enhancing productivity / efficiency etc. feed into / fuel economic imperatives of (self-)optimization and growth: "Neurocapitalism".
    - Highlights the importance of vulnerability; here neurodiversity putting a person at risk to being exploited.

What went well:

- The scenario - like the first one - illustrates fundamental issues with a new/increased clarity: what constitutes ''good' / desirable states of consciousness? Does 'normal' equal 'good'? What is normal? What are the dangers/pitfalls of defining some states of consciousness as more normal than others?
- The commodification process of brain data seemed quite realistic.
- The scenario shows slow creep of ethical issues nicely.
- The scenario establishes that neurotech in a consumer setting will come with a network and not exist in isolation.

Feedback about Neurotechnology Scenario 3

General Feedback

- Regarding **the setting**

    - The final paragraph seems to undermine the relevance of the long preceding scenario description - implying that we shouldn't really care about Otto's case since he's using the device recreationally rather than 'seriously'. The stakes in the narrative are not high enough.
    - Scenario touches on the environmental impact of drugs used for cognitive decline but not that of neurotechnology as a tech embedded into the big data/clouds infrastructure.
    - What's the specific relevance to neurotechnology? The two lines seem to be relevant for every technology (being addicted to tech and manufacturing being stopped).
- Regarding the **use case**
    - From the engineering side, a larger problem seems to be related to venture capital.
    - From the scenario it's not clear if this is a medical use case or not. If yes, it would be highly regulated.
    - Underregulating neurotechnology based on marketing / framing ("well-being", "cognitive training" etc.) leads to obfuscation of ethical issues.

What went well:

- The scenario highlights the issue becoming dependent on consumer technology for health-related issues well.
- Making explicit that private companies are ready to "play" with fear/emotions for profits.
- The scenario, that a company on which you are dependent on goes bankrupt, is all too real (see. secondsight).
- I like the ambiguity that it's not clear whether or not the device actually improves his memory or if it's just for his own consciousness (placebo effect).

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8.2 Data Collection protocols

8.2.1 Pre & post survey

Delivery: Each participant will receive a packet containing a Unique, randomized ID in the bottom corner of the participant information sheet, informed consent sheet, pre- and post-survey.

Pre-participation survey

5-10 minutes, written or completed with assistance

Learning a bit more about you

This information is being collected for research purposes only and will not be shared or used in a way that is identifiable to you.

First name

Family name

Please share the nationality by which you identify:

Please share the gender by which you identify:

- Female
- Male
- Non-conforming
- Neither
- Both
- Prefer not to say
- Other…

Please share your educational background, as relevant: The last course of education I have completed is…

- Primary education
- Secondary education
- High school education
- Vocational training
- University degree
- Advanced vocational training
- Other….

How did you hear about this event?

- Direct invitation
- Word of mouth
- Science Café
- Local newspaper
- Advertising for the event (poster in the museum, social media)
- Other

Did you attend a Science Café organised by the science museum for this technology?

- Yes
- No

If you attended the Science Café, had you heard of this technology before the Science Café?

- Yes
- No

What motivated you to participate today (choose all that apply):

- I have a passion for technology
- I am curious about technology
- I want to be involved in how technology develops
- I want to express my thoughts or feelings
- I like the activities of the host organisation
- I want to meet people
- I am attending for the compensation/gift/etc.
- Other

Is there anything you're particularly excited or curious about regarding this technology?

…….

Is there anything you're concerned about regarding this technology?

……..

Is there anything you want to learn more about regarding this technology?

.....

Post-participation survey

5-10 minutes, written or completed with assistance

Your feelings about Technology Family X

After participating today, how excited are you about possible future developments of this technology? (attitudes)

- Very excited
- Excited
- A little excited
- Not excited

- Not sure how I feel about the possible future developments of this technology

After participating today, how concerned are you about possible future developments of this technology:

- Very concerned
- Concerned
- A little concerned
- Not concerned at all

- Not sure how I feel about the possible future developments of this technology

After participating today, what potential applications of the technology would you be most interested in?

- List a few….

After participating today, what issues raised by thinking and talking about this technology are most important to you?

- List a few….

What concerns you the most about possible future developments and this technology?

- List a few….

Keeping in touch

Do you wish for us to remain in contact with the results of this workshop by being subscribed to the TechEthos newsletter?

- Yes, my email address is ….
- No

Do you wish for the organisers to remain in contact with you about opportunities to participate in future TechEthos events in country X:

- Yes, my email address/phone number is ….
- No

8.2.2 Game workshop script

Key concepts

Throughout the workshop, there are three key concepts to pay attention to: Awareness, Attitudes & Concerns, and Values. The questions featured in the game workshop script are meant to elicit responses in line with these key concepts. As you facilitate discussions, you can also prompt these reflections with questions such as:

a. **Awareness:** "Have you heard of …?"

b. **Attitudes & Concerns**: "What's your general attitude toward this card? Do you think the technology is beneficial or harmful? If so, in which way?"

c. **Values**: This is a tricky concept, as it is an indirect concept. Values describes what the participants value and what they want to protect or enhance through the use of the technology and what they feel is endangered by the technology. For example, if someone says "I'm not a fan of the metaverse. Then we'll all be hanging in those virtual realities and not talk to each other anymore." The value, that is expressed here is social connection or a direct interaction between humans. We can read the values out of the quotes afterwards; however, we'll need you as facilitators to watch out for statements that touch this concept.

In practice

We recommend assigning one note taker per game table, and that they record data in their native tongue. Responses can be translated and typed up later in the "Data collection (English)" document.

Several textboxes and tables allow you to collect data collection throughout this document.

Pre-event welcome (30 minutes)

- Be available to welcome people in the room 30 minutes prior to the start of the session.
- As they arrive, ask them to sign an attendance sheet and present them with their workshop pack.
- Point out the Informed Consent Form in the pack and ask them to take the time to read it.

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Check list

Everybody has signed the attendance sheet	☐

Introduction (30 minutes)

Objective: Participants will learn about research ethics and data collection, the context and the planning (timeline, schedule, etc.) of the workshop.

- Goal of the day
- Getting to know each other (ice breaker)
- Informed consent & pre-participation survey (see Annex)
- Programme & house rules
- Intro to TechEthos & the technology family being discussed

Check list

Everybody has signed the Informed Consent Form	☐
Everybody has completed the pre-event survey	☐

Warm-up (35 minutes)

Objective: Triggering a reflective mindset on the question 'What's important for me?'

Part I: Sticky dots (awareness; attitudes) (10)

Data collection: At the end of the session, take pictures of the posters and note down the number of sticky dots on each technology poster. Add this information in the data reporting template.

Each workshop is dedicated to one technology family. Posters should be set up around the room for each exemplary technology or use case. The moderator can then say something like:

- "As you heard in the presentation, there are a number of technologies associated with Technology Family X. We've put up a few posters around the room."
- "Please stand up, shake a bit, and then go on a tour and use the sticky dots in your pack."
    - Place blue dots on technologies you had heard about before; you can choose to indicate how familiar you are with them: very, somewhat, not at all
    - When you think about these technologies, do you feel excited, do you feel concerned?
        - Place green dots if you remember feeling excited about the technology when hearing about it, before or during the earlier presentation

- Place red dots if you remember feeling a little concerned about the technology when hearing about it, before or during the earlier presentation.

Part II: Talk to your neighbour (attitudes) (25)

Discussion in pairs

Participants pair up to discuss their excitements and concerns regarding the technology family.

"Great, thanks everyone. Looks like (short recap of visual perception of dot distribution).

Now let's have everyone find a partner and share a bit about our choices. You have 10 minutes to discuss together. We will give you a warning (say what form this will take), when you have about 1 minute left; then the other person should begin to share their impressions. Here are the questions:

- What were the technologies you'd heard about? Where did you hear about them?
- Is there something really exciting to you about the technology that you'd like to share?
- Is there something about the technology that concerns you that you want to share?

Plenary

Moderators gather the thoughts of participants and take the pulse of the room.

Data collection: One person in your team should take notes of the answers and the number of hands that is raised for each answer. You can use the table below to record this information.

- "Would somebody like to volunteer to share what was discussed in your pair? Could you share with us what your interview partner was excited about?" Moderator to probe whether it is about a specific tech.
- "Thank you for the answer. Everybody else, could you raise your hand if in you were excited about the same thing?"

- Then ask the actual person who was excited about it: "Why were you excited about it?"
- Ask for a new answer from a different group: "Did another group have a different reason to be excited? Could you share with us?" Repeat the show of hands and asking the reason behind the excitement, until about 5-6 answers are shared.
- Repeat the same steps for concerns.
- Depending on how long the exchanges take, you could consider reducing the number of answers to 2-3 for excitement and 2-3 for concerns.

Reason for excitement (E) or concern (C)	Answer	About which technology?	Why?	Hands raised

Game play (45 minutes)

Data collection: use the tables below to record game actions (e.g., which cards are eliminated), which cards are discussed and the reasons brought up by participants.

During the game play, a moderator should be available at the table:

- Help with the rules;
- Facilitate the game itself; in particular, moderators should be aiming at eliciting the "why" behind the choices made by participants;
- Answer questions about the card content (e.g., the technological contents of the Tech Cards); and,
- Carry out data collection.

Introducing the game

You can refer to the game manual for more information.

- Teams of players are made by inviting everybody to take a seat at a random table. The game can be played by 3 to 7 players per table.
- Next, the narrative of the game and the position of players as members of the Citizen World Council are explained. You can read the “Getting started” text in the Game Manual, page 1.
- The technology family and corresponding deck for the game play is introduced. The game board is set up according to the instructions in the Game Manual, page 5. The World Card should have difficulty **Normal**.

Player Round Tech Age-1

Unveiling the technology family

The ***Technology Family Card*** is flipped and read out loud. Ask participants about their first impressions of the card.

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Technology Family	Discussion

Tech Age Evolution

Pick the ***Tech Cards*** corresponding to the current age and place them all faced up around the ***Technology Family Card*** in the middle. They will unveil the evolutions taking place in the World.

Ask participants to take turns to pick up, read out loud and place cards back on the table.

Open debate

As members of the Citizen World Council, the players must decide which ***Tech Cards*** they value the most to bring forward into a future world. Invite players to take turns to express their points of view and pros and cons for the specific technologies.

Guiding questions for the open debate & vote

In **Age-1**, you must decide which technology should be developed in your ideal future. You might decide to explain to your fellow players, for example, why the Metaverse would be beneficial in the future and why digital twins would be better not to be developed further. **Vote for the technology which should be developed further.**

> “Do you think the tech has the potential to benefit you or people you know/care about? How?
>
> Do you think the tech has the potential to harm you or people you know/care about? How?

Citizen World Council Vote

After the debate, it's time for the players to vote in secret for the ***Tech Cards*** they want to keep in the game. The ***Tech Card*** that has scored the least will be discarded.

In each age, one ***Tech Card*** should be removed and no more.

Invite participants to place one or both of their ***Vote Cards (+1 Vote Card*** and/or ***+2 Vote Card)*** face down next to any ***Tech Cards*** of the current ***Age***. If they wish, they can use both of their ***Vote Cards*** for the same ***Tech Card***, to increase its chances of being kept in the game.

When all players have voted, flip over all ***Vote Cards*** and count the number of votes for each ***Tech Card***. In case of a tie, give back the ***Vote Cards***, ask participants to discuss and vote again on the cards in the tie.

Tech Age-1 Card	Discussion	Votes

In case of a tie

Card name	Discussion	Votes

World Round Tech Age-1

Impacts

After the players decided which cards will stay, flip over the ***Impact Card*** corresponding to Age-1. On this card, players can find the impact scores of all ***Tech Cards*** remaining on the table.

Ask one player to read the scores on the ***Social Factor*** modifiers written next to each ***Tech Card*** remaining on the board in the current ***Age***. Another player can move the ***Impact Tokens*** on the ***World Card*** according to the scores, as illustrated in the textbox below.

Counting Impact

In Age 2, you decide that the card **Health** will stay. This has a +1 impact on **Social Disconnection** and a +1 impact on **Data Control** you move the relevant tokens one step to the right on the **World Card**.

World status

Check the status of the ***World Card***. If any ***Impact Token*** has reached the end of the scale, the world is in peril. Players can now take a decision regulating the technology, area of people's lives where it is making a change or ethical issue that has caused the world to break.

It is not possible to break the world in Age-1, but this can begin to happen from Age-2 onwards.

Moving on to the next Tech Age

Pick up the deck corresponding to the next Tech Age, Age-2. Look at the back of all new cards. Remove any ***Tech Cards*** in that deck that have ***Dependence Icon*** of the cards you eliminated in the Age before.

Discarding cards based on the dependencies

In **Tech Age-1** you removed **Metaverse**. Before you enter **Tech Age-2** you have to discard **Gaming**, **Social Networking** and **Second World** from the **Tech Age-2** deck, as they have the **Dependence Icon Metaverse** on the back of the cards.

Proceed to play the Player Round with the remaining Tech Age-2 cards.

Player Round Tech Age-2

Tech Age Evolution

Place the remaining ***Tech Age-2 Cards*** all faced up around the ***Technology Family Card*** in the middle. They will unveil the evolutions taking place in the World.

Ask players to take turns to pick up, read out loud and place cards back on the table.

Open debate

As members of the Citizen World Council, the players must decide which ***Tech Cards*** they value the most to bring forward into a future world. Invite players to take turns to express their points of view and pros and cons for the specific technologies.

Guiding questions for the open debate & vote

In **Age-2**, you must decide in which areas of life you would like the technologies selected in Age 1 to be applied. **Vote for the application areas you would like to see become a reality.**

> What's your general attitude toward this card?
> Do you think this application is beneficial or harmful? If so, in which way?"

Citizen World Council Vote

After the debate, it's time for the players to vote in secret for the ***Tech Cards*** they want to keep in the game. The ***Tech Card*** that has scored the least will be discarded.

In each age, one ***Tech Card*** should be removed and no more.

Invite participants to place one or both of their ***Vote Cards (+1 Vote Card*** and/or ***+2 Vote Card)*** face down next to any ***Tech Cards*** of the current ***Age***. If they wish, they can use both of their ***Vote Cards*** for the same ***Tech Card***, to increase its chances of being kept in the game.

When all players have voted, flip over all ***Vote Cards*** and count the number of votes for each ***Tech Card***. In case of a tie, give back the ***Vote Cards***, ask participants to discuss and vote again on the cards in the tie.

Tech Age-2 Cards	Discussion	Votes

In case of a tie vote

Card name	Discussion	Votes

World Round Tech Age-2

Impacts

After the players decided which cards will stay, flip over the ***Impact Card*** corresponding to Age-1. On this card, players can find the impact scores of all ***Tech Cards*** remaining on the table.

Ask one player to read the scores on the ***Social Factor*** modifiers written next to each ***Tech Card*** remaining on the board in the current ***Age***. Another player can move the ***Impact Tokens*** on the ***World Card*** according to the scores, as illustrated in the textbox below.

World status

Check the status of the ***World Card***. If any ***Impact Token*** has reached the end of the scale, the world is in peril. Players can now take a decision regulating the technology, area of people's lives where it is making a change or ethical issue that has caused the world to break.

Citizen World Council Response

To do this, ask players to select a ***Tech Card*** whose effects they would like to cancel. Players should think about who might be impacted negatively by the situation described on the ***Tech Card*** and how they, as a Citizen World Council, would solve the problem.

After each player has thought about their solution individually, the results are discussed as a group to find a common response to the problem at hand. If the solution seems plausible for everyone at the table, and if at least half of the players agree, write down the solution on a ***Council Response Card.***

Filling out a Council Response Card

Put the ***Council Response Card*** next to the ***Tech Card*** it addresses. As players have solved the problem, undo all the impacts of the ***Social Modifiers*** connected to this card, by moving the ***Impact Tokens*** backwards. Proceed to address another card if needed.

Congratulate the players! They have found a solution and the world survives for another age. If no satisfying solution has been found between players, the game is over.

Card addressed	Discussion	Final phrasing on the card

Moving on to the next Tech Age

Pick up the deck corresponding to Tech Age-3. Look at the back of all new cards. Remove any ***Tech Cards*** in that deck that have ***Dependence Icon*** of the cards you eliminated in the Ages 1 & 2.

Player Round Tech Age-3

Tech Age Evolution

Place the remaining ***Tech Age-3 Cards*** all faced up around the ***Technology Family Card*** in the middle. They will unveil the evolutions taking place in the World in this Age.

Ask players to take turns to pick up, read out loud and place cards back on the table.

Open debate

As members of the Citizen World Council, the players must decide which ***Tech Cards*** they value the most to bring forward into a future world. Invite players to take turns to express their points of view and pros and cons for the specific technologies.

Guiding questions for the open debate & vote

In **Age-3**, you are called to reflect on the principles and values that may be impacted by your previous choices. You must decide which ethical issues are the most important for your group to tackle, in relation to the technologies you have selected and the areas of life in which they have been applied. **Vote for the most crucial societal and ethical issues that need to be addressed so to preserve the values you believe in most.**

"What's your general attitude toward this card? Do you think the technology is beneficial or harmful? If so, in which way?"

Citizen World Council Vote

After the debate, it's time for the players to vote in secret for the ***Tech Cards*** they want to keep in the game. The ***Tech Card*** that has scored the least will be discarded.

In each age, one ***Tech Card*** should be removed and no more.

Invite participants to place one or both of their ***Vote Cards (+1 Vote Card*** and/or ***+2 Vote Card)*** face down next to any ***Tech Cards*** of the current ***Age***. If they wish, they can use both of their ***Vote Cards*** for the same ***Tech Card***, to increase its chances of being kept in the game.

When all players have voted, flip over all ***Vote Cards*** and count the number of votes for each ***Tech Card***. In case of a tie, give back the ***Vote Cards***, ask participants to discuss and vote again on the cards in the tie.

Tech Age-3 Cards	Discussion	Votes

In case of a tie vote

Card name	Discussion	Votes

World Round Tech Age-3

Impacts

After the players decided which cards will stay, flip over the ***Impact Card*** corresponding to Age-1. On this card, players can find the impact scores of all ***Tech Cards*** remaining on the table.

Ask one player to read the scores on the ***Social Factor*** modifiers written next to each ***Tech Card*** remaining on the board in the current ***Age***. Another player can move the ***Impact Tokens*** on the ***World Card*** according to the scores, as illustrated in the textbox below.

World status

Check the status of the ***World Card***. If any ***Impact Token*** has reached the end of the scale, the world is in peril. Players can now take a decision regulating the technology, area of people's lives where it is making a change or ethical issue that has caused the world to break.

Citizen World Council Response

To do this, ask players to select a ***Tech Card*** whose effects they would like to cancel. Players should think about who might be impacted negatively by the situation described on the ***Tech Card*** and how they, as a Citizen World Council, would solve the problem.

After each player has thought about their solution individually, the results are discussed as a group to find a common response to the problem at hand. If the solution seems plausible for everyone at the table, and if at least half of the players agree, write down the solution on a ***Council Response Card.***

Put the ***Council Response Card*** next to the ***Tech Card*** it addresses. As players have solved the problem, undo all the impacts of the ***Social Modifiers*** connected to this card, by moving the ***Impact Tokens*** backwards. Proceed to address another card if needed.

Congratulate the players! They have found a solution and they have won the game. If no satisfying solution has been found between players, the game is over.

Unfortunately, this may not be a World they'd like to live in. But take heart: the discussion afterwards will offer them an opportunity to reflect on alternative pathways!

In case a Council Response Card was completed in this round

Card addressed	Discussion	Final phrasing on the card

Reflection (45 minutes)

Objective: Reflections will be getting at concerns, values, and things that could be done differently, to inform scenario revision.

Part I: Reflection on the game (15 minutes)

Data collection: the moderator will be using the pre-prepared template to write down the issues players raise and the cards which are further discussed in this reflection.

- "We played a game by REMOVING undesirable things and trying to keep the world in equilibrium…did we arrive at a world that you like? Why or why not?"

Why?	Why not?

- Are there other issues left on the board that you would have liked to address? Which ones should be a priority?
- Share a bit about why these are priority issues.

- Do you have thoughts on what might be done about these kinds of issues?

Issue	Priority	Why?	What might be done?
	☐		
	☐		
	☐		
	☐		
	☐		
	☐		

	☐		

Part II: Building a story from the future? (30 minutes)

Data collection: the moderator will be using the pre-prepared data collection template to write down the issues players raise and the cards which are further discussed. The story-building sheet is also photographed at the end of the session.

- ‘Let’s imagine that we are in the shoes of a character from this future world we built in the game. Let’s tell a story about how a day-in-the-life of this person might look.’

- ‘Who is the character? What does their day look like? We have this large sheet where we can describe them. We will take turns to come up with ideas, using the simple rule of ‘Yes, and…’, meaning that we have to listen and build on the idea of the person that spoke beforehand.’

Story of the character living in this future world

Conclusion (15 minutes)

Resource sharing & next steps. As an end of the session, resources should be pointed out and provided for all players, for example covering TechEthos and the Technology Families they played/discussed. It could be leaflets, books, research articles, videos, and websites. Each LTP can generate their own based on the material available in the local language.

A **post-participation survey** is shared and completed before participants leave.

Thanks. Thanking everyone for participating, for their energy, and for sharing their perspective. The project takes their input seriously and will be working to include it in the results and tools that will be built to guide the actions of researchers and innovators in these technology areas, as well as those of people assessing the ethical aspect of their work and of policy makers.

Checklist

Everybody has completed a post participation survey	☐

After the workshop

Checklist

Take pictures of: • the posters and sticky dots • the Council Response Cards filled out at your table • the sheets representing a journey in somebody's life	☐

Add the information collected from the pictures e.g., sicky dot counts, Council Response Cards, etc.) in the data reporting template	☐
Add your notes to the data reporting template (typed up and in English)	☐

8.3 Definitions of the citizen value categories

Aesthetics

Aesthetics includes values that refer to beauty and taste in the context of art, nature, and design. It involves evaluating and appreciating the qualities that make objects appealing (visually as well as emotionally) but also having the capability of artistic expression & creativity.

"(…) technology is quite technically and materially demanding. It takes up a lot of space, it's visually ugly." (Comment 274, CE)

"It could also destroy creativity and limit the vocabulary, but I still think that is useful if utilised correctly." (Comment 76, NLP)

"If we replicate and artwork, the original will lose it value. (…) I might be lazy to go to some museum in Brussels because I've already seen that at in a digital form (…)." (Comment 119, XR)

Authentic human connection and experience

Authentic human connection and experience on the one hand involves building relationships with other human beings through direct connections that acknowledge the necessity of immediate communication to build empathy and understanding. One the other hand, it also entails a sensual or emotional experience of reality and values being present.

"Could be used in healthcare e.g., in connection with mental health to determine how a person feels if they don't want to talk about it." (Comment 735, NLP)

"The chatbot will change our personality through interaction, we will start to behave differently, and it is very possible that it will dehumanize us." (Comment 131, NLP)

"The group was concerned that virtual interaction would hinder the natural development of social skills, especially in the case of the younger ones." (Comment 609, XR)

Autonomy and agency

Autonomy and agency refer to the capacity and right of individuals to make decisions and take actions that are self-determined, self-directed, and aligned with their values and goals. It involves having control over one's life, cognitive capabilities, and decisions. It includes regard for concerns like anti-manipulation, cognitive autonomy, political and individual freedom, and sovereignty.

"Sounds interesting. - It's good because each of us can make a contribution." (Comment 212, CE)

"Children could be manipulated just like they are doing in religious schools now." (Comment 77, NLP)

"Can give more autonomy for disabled people. Could be used for 'mind reading' what appears very dangerous." (Comment 464, NT)

Cultural preservation

Cultural preservation involves protecting and maintaining the artifacts or practices of a particular culture or community and respecting the diversity of different cultures. It entails using technology to maintain expressions of culture and make them accessible over time (e.g., for future generations) and space (e.g., to people living on the other side of the globe).

"It's good, because if historical objects and buildings are destroyed for some reason, they are still preserved." (Comment 723, XR)

"What about dialects and values?" (Comment 742, NLP)

"With earthquakes and wars (…), this will be extremely helpful for future generations, to see the world as it was, to see the art and walk to the historic places." (Comment 35, XR)

Data privacy and security

Data privacy and security refer to the protection of individuals' personal information and the prevention of unauthorized access, use, or disclosure of sensitive data. It involves confidentiality, and integrity of data, and ensuring compliance with ethical and legal standards.

"It has potential, but it is very risky. – Our personal data may be misused and given or sold." (Comment 102, NLP)

"The group was concerned about data collection, how people, companies and institutions will process that data and how ethical it is. They think that good intentions are not in the hands of large companies that have other interests." (Comment 490, NT)

"We don't need more personalized adverts, especially on things I imagine but cannot have anyway! Google is enough!" (Comment 479, NT)

Democracy

Democracy holds principles like popular sovereignty, majority rule, and protection of individual rights. It entails ensuring equal access to political participation, promoting transparency and accountability, and fostering civic engagement and dialogue.

"It is perceived as undemocratic as the card says that the technology is expensive and only the rich countries and industry can benefit from this." (Comment 719, CE)

"Is a lot to think about here, because if a State makes something illegal, like criticising the government, and the chatbot revels a conversation where people are doing just that, it means that chatbots can be used as informants." (Comment 83, NLP)

"'Minority Report' comes to mind and not in a good way. (…) We lived under a dictatorship; this seems like it will lead in a far worse direction." (Comment 50, NT)

Economic opportunity

Economic opportunity involves providing individuals and communities with access to resources, education, and infrastructure that enable them to improve existing or develop new business models. It contains statements that refer to job qualities and job creations or worries about fairness in the production of wealth and economic value.

"It promotes inequalities, mainly in countries in which people depends economically on agriculture. This measure increases the gap between rich and poor countries." (Comment 581, CE)

"Threats to authors and others who make a living from writing. But could be a good complement when writing even for an author too." (Comment 736, NLP)

"It is not science fiction that people will be upgraded and become superhumans. this will bring problems and differences that will be controlled by the power of money." (Comment 344, NT)

Ecosystem health

Ecosystem health refers to the balance and resilience of natural systems that support life on Earth. It involves protecting and restoring the biodiversity, habitats, and ecological processes that sustain ecosystems, and ensuring their sustainable use and management.

"There is concern about the large amount of water needed and what it could mean for our ecosystem. Are we using fresh water or salt water? Is the groundwater affected?" (Comment 715, CE)

"I am worried about overpopulation, with people living too long and dreaming about immortality." (Comment 65, NT)

"It saves the environment; people don't have to fly all over the world to see the sights." (Comment 323, XR)

Effectiveness and efficiency

Effectiveness and efficiency refer to the (potential) ability to achieve a better future by implementing technologies with high sensitivity to their performance relative to resource requirements. Effectiveness means the applicability and scale of implementation while efficiency is concerned with the ability to accomplish an intended use, with minimal time, effort, other resources, or waste.

"Engineered CDR technologies can be used in a variety of contexts, including power plants, industrial processes, and transportation, allowing for flexibility in implementation." (Comment 255, CE)

"Seems to be a very slow process. Is it worth investing in it? But isn't it good to do that, as long as it helps in some way? Or is it better to choose more effective methods? It can be harmful to spend time and resources on the wrong things." (Comment 706, CE)

"This is great, it really works well. – Translators find other ways to use language skills, the benefit of technology to society is immensely higher" (Comment 302, NLP)

Equity, diversity, inclusion

Equity, diversity, and inclusion refer to creating a fair, welcoming, and respectful societies – and the technologies they employ – embracing differences in race, gender identity, sexual orientation, ability, age, and other characteristics.

"Rich people will be able to become 'superhumans' and have more and more power over others." (Comment 45, NT)

"By creating a society that works for everyone, not just that you are like 'everyone should be'. The municipality's daily operations are important!" (Comment 765, NT)

"The extended reality can be a good educational tool, mainly in moments in which unexpected events occur like a pandemic. – It can solve educational needs, in unexpected situations and when people have no access to the physical space because of different reasons." (Comment 638, XR)

Expanded opportunities for human experience

Expanded opportunities for human experience refers to the potential benefits that emerging technologies can offer in terms of enhancing or augmenting different aspects of human life. Citizens often refer to their experiences to use existing technologies such as VR headsets or in medical trials of neuroprosthetics to elaborate their opinions.

"I think it sounds better than it really is. These technologies give us the ability to get out of our limited environment. What are the extended possibilities that this offers? Implementation is important, not technology as such." (Comment 129, NLP)

"I have an extremely positive opinion about this implementation of neurotechnologies. I vote for this, I participated in the development of a neuroprosthetics with the help of a neuromuscular joint that enables the patient to lift the foot, to move." (Comment 161, NT)

"The initial impression was positive. - They claimed that it provides a personal chance for getting goals that it would be impossible to achieve in the real world. The negative side of this is that people could be confused about what is real or fake." (Comment 644, XR)

Human-centred development

Human-centred development focuses on designing and implementing emerging technologies with consideration of the needs, perspectives, and experiences of individuals who will be directly and indirectly affected by these technologies. This category covers values from the protection of human rights to the aspirations for a flourishing, humanistic society, as well as orientations beyond profit.

"The solution could be to focus on wetlands and places that will have less negative impact on the local population." (Comment 21, CE)

"From an ethical point of view, I fear that we will lose our humanity. – Emotion is the most important to me, and the computer doesn't have that. That's why I'm worried." (Comment 90, XR)

Human health

Human health covers the physical and mental health of humans. Many of the participants shared their concerns and excitement about emerging technologies that might harm or improve human health. Many of them talked about specific diseases like Parkinson's disease, epilepsy, or hearing impairment, to relate themselves to the technologies.

"From a medical point of few this technology is very helpful for diagnostics - Can be essential for survival for many people." (Comment 235, NT)

"(It) could be good to develop technical aids for people with disabilities (like us) can maybe help my friend who has dyslexia, so that everything he wants to write comes out correctly if he thinks the words." (Comment 769, NT)

"Some relaxation programs maybe – I think more people get the disorder by using VR than get cured of it. It's one of the possibilities, before they used to give people drugs to have a better experience and relax, now this may help." (Comment 333, XR)

Human oversight and control

Human oversight and control include regulation, monitoring, and assessment of the uses of technologies. It entails the individual's and official's ability to manage and control technology to a higher level of control and regulation.

"There is no legislation regulating this. It is not fast, and the current situation needs immediate solutions. – Because technology is evolving before the law and ethics code." (Comment 564, CE)

"It should be possible to switch off the tech, whenever the patients want to. (…) Relatives / close friends or a supporting caretaker could be involved in the process to also monitor developments" (Comment 480, NT)

"When it's all subject to artificial intelligence, at some point we're going to lose control - you have no way of knowing if it's a person or a program talking to you" (Comment 314, XR)

Justice

Justice references fair processes related to use, access, and distribution of emerging technologies. Values on justice concern who should or should not invest, develop, or manage the technology; how future generations are regarded; how burdens and benefits are distributed globally or locally, etc.

"Even if the facilities end up in rich countries, the whole world benefits. The climate is global. Maybe even improves air quality in some countries?" (Comment 707, CE)

"These conditions can be regulated, but can they be controlled? … If we need to regulate them, there is a space for regulation of discrimination and environment impact. … Working with online tool is a priority, so what happens with us who don't have such education?" (Comment 127, XR)

"Murderer Diagnosis: Person diagnosed with being likely to murder someone due to Brain form indicators. Person should be seen as a threat for people (...). On the other hand, it is unfair to punish someone for something this person has not done (yet) and should be treated as a normal person." (Comment 470, NT)

Knowledge and education

Knowledge and education refer to people's understanding of technologies and the educational use of technologies. Raising awareness and knowledge of technologies are often considered important for the research, development, and implementation of technology. Additionally, this category includes knowledge transfer.

"Technological solution alone can make climate cooler but does not change society in a beneficial way – It does not lead to a change in behaviour, you can't sit back and rely on technology. A change of society would be good and necessary. Reduction of Emissions is necessary." (Comment 380, CE)

"'Everyone should vote for this', said one participant. ... The education that exists today is the same for everyone, but everyone has different situations and different ways of learning, and this is where this technology would be positive. ... Education is the basis of everything." (Comment 737, NLP)

"I automatically see the benefit for all professions. Pilots already have those simulations. It is especially useful in education. (…)" (Comment 110, XR)

Naturality

Naturality as a category involves participants' evaluations of whether solutions and approaches are primarily: sympathetic to, antithetical to, composed of, embodied, or exemplify a reverence, appreciation, and a degree of harmony with natural systems.

"SRM Measures on Earth Surface are probably reversible. SRM in Atmosphere is maybe uncontrollable. Could be dangerous since this is not natural. It is maybe similar to Volcanic eruption and hence also natural in some way." (Comment 406, CE)

"That's the gentle way - reforestation, can provide additional co-benefits such as habitat restoration, improved water quality, and increased biodiversity." (Comment 256, CE)

"They are more confident because they see less human intervention and less incorporation and use of artificial substances. – Pros: It generates less impact and gives the possibility to redirect again. Against: Alteration of the ecosystems." (Comment 549, CE)

Peace

Peace refers to a state free from conflict, violence, or disturbance between individuals, groups, or nations. Regarding CE citizens were particularly concerned about global conflicts. As for NT and XR the utilization in military contexts concerned participants. This category also captures demilitarization and overall valuing of a peaceful world.

"I'm a pacifist and I'm always against war, I don't like the world I live in, and I'd prefer that some things didn't develop, no matter how much they make our life easier." (Comment 183, NT)

"I imagine there will be a lot of migration and fight for resources, with global conflicts" (Comment 23, CE)

Progress

Progress represents a regard for development in a society, often characterized and enabled by improvements or advancements in technology and science.

"Great for researching and disease prevention. I see the positive aspects. It could help heal people, not only from physical disease, but also mental ones. And also, (it) could help in many areas of study and research." (Comment 62, NT)

"On one hand, it helps to the advance of medicine, and it can be good for prevention, but on the other hand across XR they collect data without the consent of individuals." (Comment 649, XR)

Responsible use and accountability

Responsible use and accountability refer to the ethical and mindful application of resources, technology, or power, with a focus on ensuring the well-being and fairness of all stakeholders involved. People often consider responsibility and accountability regarding priority of issues, well-planned, wise use, misuse, impacts on society and environment.

"This raises questions about who would be responsible for regulating the technology and ensuring that it is used in a safe and effective manner." (Comment 267, CE)

"The main issue of primary concern to the group is the person or persons who will be using the technology and not so much the person receiving the treatment or the technology itself." (Comment 526, NT)

"If this technology falls into the wrong hands, people can be manipulated and duped – there are many ethical aspects to consider." (Comment 724, XR)

Safety and reliability

Safety and reliability pertain to the characteristic of being secure and dependable. In relation to particular technologies, discussions were centred on their adequacy in terms of testing, reliability level, and ability to produce expected outcomes without unforeseen adverse effects. Additionally, this category also encompassed topics such as avoiding hazards and ensuring physical safety, particularly of children.

"Some neurotechnologies, such as implants, can have side effects and risks associated with disruption of normal nervous system function. This leads to concerns about the safety and reliability of these technologies." (Comment 369, NT)

"That unpredictability is really worrying. - I don't know if it's worth it, and the consequences are unpredictable." (Comment 205, CE)

"He's worried that people will be fooled - like gaming, young people can't get away from it." (Comment 312, XR)

Techsolutionism

Techsolutionism is a category that covers comments with the implicit or explicit belief that technology can solve all problems or provide the only solutions to all social or environmental issues. Techsolutionism tends to prioritize technological solutions over other type of approaches, like coordinated social action, changes in behaviour, or top-down regulation.

"They believe that this type of technology is part of the natural evolution of society and, therefore, they are confident that it will be put to good use and applied correctly. They also point out that humans have been linked to technology since the beginning of our existence and that it has always brought more benefits than harm to society." (Comment 616, XR)

"Maybe we will have technologies in the future to solve this kind of problems." (Comment 392, CE)

The Good Life

The good life refers to the ancient philosophical notion of a quality of life and lifestyle characterized by meaning, balance, material and non-material values, quality, and experiences of happiness, health, having access to nature and enjoying leisure time.

"Progress in this field can have a major impact on improving the quality of life of people with disabilities, as well as on the development of new technologies and industrial applications." (Comment 368, NT)

"I would like to live in the nature outside the city, but I also like to work in an office and to be in contact with people." (Comment 111, XR)

Trustworthiness

Trustworthiness covers the qualities and values of being truthful, honest, transparent, and having a sense of ethics. Regarding technologies it means that users can have trust in the technology that it will provide true information, it will not be abused, its development and deployment will be transparent and ethical.

"How can we control big financial players? Will the really use the technology the way they say they would?" (Comment 233, CE)

"If transparency doesn't exist it is very complicated to know what is real and what is fake." (Comment 653, XR)

Usefulness

Usefulness references the adaptability and applicability of technologies and methods to various, dynamic contexts of deployment. This category also encompasses how technologies are regarded for their contribution to assisting in life, for example through labour, providing solutions to various problems, or otherwise contributing to a human application / pursuit.

"AI could be taking over administrative work (...) and relieving people of mundane repetitive jobs." (Comment 422, NLP)

"It can be a particularly useful method for the region where we live: Andalusia, with a view to reducing high temperatures." (Comment 553, CE)

"I like this technology because it can be used for medical purposes. – It is one of the most precise methods, it can relieve us of tension and make our life easier. It seems to have great potential for wide application in medicine." (Comment 153, NT)

8.4 Citizen value categories and STEEPV dimensions merged

Based on the STEEPV descriptions and the citizen value category definitions in 5.3.3, the 25 values have been classified in the following STEEPV dimensions:

Table 25: Citizen value categories and STEEPV dimensions merged

Citizen value categories	STEEPV
Aesthetics	Value
Authentic human connection and experience	Value
Autonomy and agency	Social
Cultural preservation	Value
Data privacy and security	Political
Democracy	Political
Economic opportunity	Economic
Ecosystem health	Ecological
Effectiveness and efficiency	Technological
Equity, diversity, inclusion	Social
Expanded opportunities for human experience	Social
Human-centred development	Technological / Value
Human health	Social
Human oversight and control	Political

Justice	Political
Knowledge and education	Social
Naturality	Ecological
Peace	Political
Progress	Technological
Responsible use and accountability	Political
Safety and reliability	Technological
Techsolutionism	Technological / Value
The Good Life	Social
Trustworthiness	Technological / Political
Usefulness	Technological

8.5 Enrichment of the scenarios

This table was used to compile the results from the three stages sorted by the STEEPV categories to make them comparable.

8.5.1 CE

Table 26: Scenario enrichment for CE

STEEPV	Basic scenarios	Expert enrichment	Citizen enrichment
Social	Inequality Environmental stewardship Trustworthiness (about information)	Environmental and geopolitical instability (safety and peace) Storage siting issues Intergenerational tensions Different desires for development in the Global North and Global South Lifestyle changes (the good life)	**Autonomy and agency** Equity, diversity, inclusion **Human health** **Knowledge and education** The Good Life **Safety and reliability**
Technological	Cost efficiency and effectivity Feasibility Naturality Biodiversity	Prevalent technooptimism about DAC and marine CDR Using catastrophic forced-choice situations to make policies that push quick-acting, short-term technological fixes	Effectiveness and efficiency Human-centred development **Safety and reliability** Techsolutionism **Trustworthiness** **Usefulness**
Ecological	Food security Biodiversity Land use	Environmental justice Intrinsic values of non-humans Ecosystem health (biodiversity loss, monocultures)	Ecosystem health **Naturality**
Economic	Economic growth Sustainability Species extinction (ecosystem health)	Unfairness - abuse of economic power by companies who gained profit from the emission now benefit from storage Governance mechanism — carbon credit trading remains cheaper than emissions reduction	Economic opportunity (creation of jobs, new ways of doing business, effects on local economies etc.)

Political	Multilateral cooperation	Distributive justice (energy use and burden sharing) Power of markets and private governance (land-grabbing) Lack of exploration around potential abuse of SRM Legal recognition of the rights of nature expenses	**Democracy** **Human oversight and control (planned actions are needed and accountability is a key issues)** Justice **Responsible use and accountability** Peace Trustworthiness
Value	Materialism/post-materialism Anthropocentrism (anti)consumerism	Manipulation of nature Lifestyle changes Techsolutionism	Techsolutionism **Aesthetics** Human-centred development

8.5.2 XR

Table 27: Scenario enrichment for XR

STEEPV	Basic scenarios	Expert enrichment	Citizen enrichment
Social	Overconsumption Potential for increased access to diverse and novel experiences made available through realistic virtual worlds (expanded opportunities) Equality Mental health and social challenges Data privacy and security	Affordability of the technology Social isolation Education Equality of opportunity in home-based work/in-person work Voice of non-living entities	Authentic human connection and experience Autonomy and agency Equity, diversity, inclusion Expanded opportunities for human experience Human health Knowledge and education The Good Life Safety and reliability

Technological	Progress in technology development	Safety concerns Human health (fear of addiction) Change in human-human interaction	Effectiveness and efficiency Human c/entered development Progress Safety and reliability Techsolutionism Trustworthiness Usefulness
Ecological	Carbon footprint growth Rural repatriation	Maintenance of infrastructures Environmental impacts (rare earth mining, additional environmental impact of servers and energy usage)	Ecosystem health
Economical	Inequality concerns Transparency of companies (personal data exploitation)	Value of the human work vs algorithm work Inequality in receiving a certain type of education Issues of patents and licenses authorship	Economic opportunity
Political	Legislation for automatic attention control (protection of autonomy)	Rights regarding the use of dead people's data (dignity of posthumous data) Legal status of birth and death Authentication issues with fakes (trustworthiness) Issues with organizing democratic movements (labour unions, protests etc.)	Data privacy and security Democracy **Human oversight and control** Justice (usage and how it can be accessible or not to certain groups) Peace **Responsible use and accountability** Trustworthiness
Values	Value changes Low-tech interests	Fairness Gender bias Depersonalization, depression and decreasing of social skills and social isolation Work-life balance (good life) Loss of individuality	**Aesthetics** Cultural preservation Human-centred development Techsolutionism

8.5.3 NT

Table 28: Scenario enrichment for NT

STEEPV	Basic scenarios	Expert enrichment	Citizen enrichment
Social	Human health	Issues of addiction (human health) Inclusion (accessibility - exclusion from labour market) Effects on identity, self, agency, or autonomy Psychometric profiling (autonomy and agency)	Human health Equity, diversity, inclusion **Authentic human connection and experience** Autonomy and agency Expanded opportunities for human experience Knowledge and education The Good Life
Technological	-	Responsibility of engineers, researchers, developer companies Digital ecosystem interactions (data transferability and ownership) Data privacy and security Issues with updates and afterlife of devices	Effectiveness and efficiency Techsolutionism Trustworthiness Usefulness Progress Safety and reliability
Ecological	Potentials for improving the ecosystem health by replacing more environmentally destructive alternatives	Energy consumption of data storage – sustainability Issues of maintenance and obsolescence	Ecosystem health

Economic	-	Power of private companies accessing the data (data privacy and security) Humans being the product of the technology is not paying (autonomy) Equality and equal opportunity	Economic opportunity
Political	Responsibility Public safety Scientific progress	Governance of big data management (data privacy and security) Line between “technology is responsible” vs “user is responsible” (responsibility) Issues of misuse and liability Neurodiscrimination Fundamental freedoms and rights might be impacted if brain activity is measured (autonomy and agency)	Data privacy and security Democracy Human oversight and control Justice (referring to neurodeterminism) Peace (that it's not used in military contexts) Responsible use and accountability
Values	Public safety Technological progress	Right way of ageing – expectations on ageing and the role of the technology	Aesthetics Human-centred development Trustworthiness

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