

TECHETHOS

FUTURE ○ TECHNOLOGY ○ ETHICS

Anticipation of societal embedding of new and emerging technologies:

Using scenarios to explore public awareness and attitudes in climate engineering, digital extended reality and neurotechnologies

D3.4 | PU



D3.1 Evolution of advanced TechEthos scenarios

Work Package	WP3		
Lead Partner	AIT		
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Due date	30/03/2023		
Submitted date	20/11/2023		
Version number	0.1	Status	Submitted

Project Information

Grant Agreement number	101006249
Start date	01/01/2021
Duration	36 months
Call identifier	H2020-SwafS-2020-1
Topic	SwafS-29-2020 - The ethics of technologies with high socio-economic impact
Instrument	CSA

Dissemination Level

PU: Public	<input checked="" type="checkbox"/>
PP: Restricted to other programme participants (including the European Commission)	<input type="checkbox"/>
RE: Restricted to a group specified by the consortium (including the European Commission)	<input type="checkbox"/>
CO: Confidential, only for members of the consortium (including the European Commission)	<input type="checkbox"/>

Quality Control

Reviewed by:	Review date:
Alexei Grinbaum (CEA)	06.11.2013
Mathijs Vleugl (ALLEA)	05.11.2013

Revision history

Version	Date	Description
0.1	07/02/2023	Initial draft
1.0	03/11/2023	Version submitted for internal quality assurance
2.0	20/11/2023	Final revision submitted to European Commission

Keywords

Scenario development, innovation eco-system mapping, public participation, social and ethical implications

How to cite

Buchinger E, Bernstein MJ, Nishi M, Mehnert W, Csabi A (2023). D3.4 Anticipation of societal embedding of new and emerging technologies: Using scenarios to explore public awareness and attitudes in climate engineering, digital extended reality and neurotechnologies. TechEthos *Project Deliverable to the European Commission*.

The TechEthos Project

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.

TechEthos receives funding from the EU H2020 research and innovation programme under Grant Agreement No 101006249. This deliverable and its contents reflect only the authors' view. The Research Executive Agency and the European Commission are not responsible for any use that may be made of the information contained herein.

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Definitions and abbreviations

Table 1: List of Definitions

Term	Explanation
Acceptance	A person’s excitement and/or concern towards an object, action or event.
Attitude	A person’s mental state, evaluative or affective, referring to an object, action or event.
Awareness	A person’s knowledge of or about object, action or event.
Societal embedding	Acknowledgement that manifold factors are driving innovation, whereby technical and societal developments are conditioning each other.
Scenario	An illustrative description of possible occurrences (actions, events) in the future.
Value	A code or standard for the “desirable” within a society which has some persistence through time and provides orientation for action.

Table 2: List of Abbreviations

Term	Explanation
AR	Augmented Reality
BECCS	Bioenergy Carbon Capture and Storage
CCS	Carbon Capture and Storage
CDR	Carbon Dioxide Removal
CE	Climate Engineering
DAC	Direct Air Capture
LLM	Large Language Model
NLP	Natural Language Processing
NT	Neurotechnologies
R&I	Research & Innovation
SAI	Stratospheric Aerosol Injection
SRM	Solar Radiation Management
VR	Virtual Reality
WP	Work Package
XR	Extended Reality

Executive Summary

The report highlights insights of the societal embedding of climate engineering, digital extend reality and neurotechnologies by using scenarios to explore public awareness and attitudes.

Justifying investments in research and innovation requires the anticipation of the societal embedding of new and emerging technologies. Anticipating future opportunities, risks and challenges of technological innovations means dealing with expectations, speculations, desires, and concerns of various stakeholder groups. This report highlights the most important insights of the societal embedding of the technology families climate engineering (CE), digital extend reality (XR) and neurotechnologies (NT), by using scenarios to explore public awareness and attitudes.

After framing the use of scenario techniques in the introduction, the report proceeds by reviewing results on public awareness across all three technology families. Next public attitudes are described, especially by presenting results on three values prioritized by citizens, going into detail on how the value is expressed in the particular context of each technology family. The values conveyed include equity, reliability, and healthy people and planet.

In the context of these new and emerging technologies, **equity** references questions of just distribution of benefits and burdens associated with innovation, as well as of process used for decision-making. **Reliability** references questions of the extent to which a 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. **Healthy people and planet** references refers to the creation and implementation of technologies with a minimal negative impact on the environment and human health while promoting biodiversity and ensuring healthy society and ecosystems.

Closing thoughts are presented regarding the question of what it means to govern development of new and emerging technologies when excitement is “conditioned” by prioritized values and concerns. Whether or not society “accepts” a technology is suggested as an unhelpful way to consider technological innovation. Instead, we propose to see awareness, attitudes, and acceptance related to new and emerging technologies as contingent on who is being asked about the technological features or goals. This means on the basis of more than 300 participants engaged in TechEthos that any continued investments in CE, NT, and XR R&I stand to benefit from advancing equity, reliability, and regard for healthy people and planet by design, and by actively alleviating ways in which these values are undermined by the technologies pursued.

1 Introduction: Anticipation of societal embedding of new & emerging technologies

Justifying investments in research and innovation requires the anticipation of the societal embedding of new and emerging technologies (EC 2023, EC 2021, EC 2020, OECD 2023). Societal embedding acknowledges that manifold factors are driving innovation, whereby technical (artifacts & techniques) and societal (economy, politics, law, science, public sphere) developments are conditioning each other¹. Anticipating future opportunities, risks and challenges of these conditionings means dealing with expectations, speculations, desires, and concerns of various stakeholder groups.

In TechEthos, stakeholder groups are represented by involving researchers from industry and academia, members of ethics bodies, policy makers, funding bodies and civil society organizations. Their anticipation of future opportunities, risks and challenges were captured via interviews, surveys, workshops, and serious games. The project was organized in five interrelated anticipative exercises as illustrated in Figure 1.

Initially, we have conducted an anticipatory multi-criteria decision analysis (MCDA) as part of a horizon scanning to select the TechEthos technology portfolio (WP1). Five impact dimensions were considered in the MCDA to identify and rank new and emerging technologies that are economically as well as ethically relevant: (i) industrial & economic impact, (ii) ethical impact, (iii) public impact, (iv) policy impact, and (v) legal impact². The resulting TechEthos portfolio consists of the technology families **climate engineering** (CE), **digital extended reality** (XR), and **neurotechnologies** (NT)³.

Succeeding anticipatory analyses on CE, XR and NT addressed ethical values and principles (WP2), legal and policy issues (WP4), and societal awareness and attitudes (WP3). The ethical analysis identified 19 values and principles for CE, XR and NT of which autonomy, responsibility, privacy and justice appeared across each technology family⁴. The legal and policy analysis searched national, European and international legal frameworks related to CE, XR and NT and formulated policy recommendations on enhancing EU legal frameworks⁵. The analysis of the public opinion (object of this report) revealed that participating citizens are not only aware of all three technology families, but also conditionally excited – as long concerns related to values such as equity, reliability and healthy people and planet are prioritized.

¹ See for societal embedding of technologies as co-constructive or co-evolutive process e.g., Geels & Schot (2010), Geels (2005), Jeffrey, Seaton & Stephenson (1997), Westrum (1991), Ellul (1977/1980), Heidegger (1962/1977), Ellul (1954/1964), Mumford (1934/2010) and for the idea "that technology, the social world, and the course of history should all be treated as rather messy contingencies" Bijker & Law (1992: 8).

For approaches exploring predominantly sociological, psychological, and philosophical aspects ("science and technology studies", "social construction of technology", "actor-network theory") see e.g., Stahl (2022), Rohracher (2015), Martin, Nightingale & Yegros-Yegros (2012), Jasanoff (2010), Latour 1996, Jasanoff et al. (eds.) (1995), Bijker & Law (eds.) (1992), Bijker, Hughes & Pinch (eds.) (1987), Winner (1980), Latour & Woolgar (1979/1986).

For approaches dealing predominantly with economic, policy and legal aspects ("evolutionary economics", "systems of innovation", "innovation ecosystems") see e.g., Freeman (2008), Fagerberg, Martin & Andersen (eds.) (2013); OECD (2005), Lundvall & Rikap (2021), Adner (2006), Granstrand & Holgersson (2020), Könnöla et al. (2021), Carlsson, Jacobsson, Holmen & Rickne (2002).

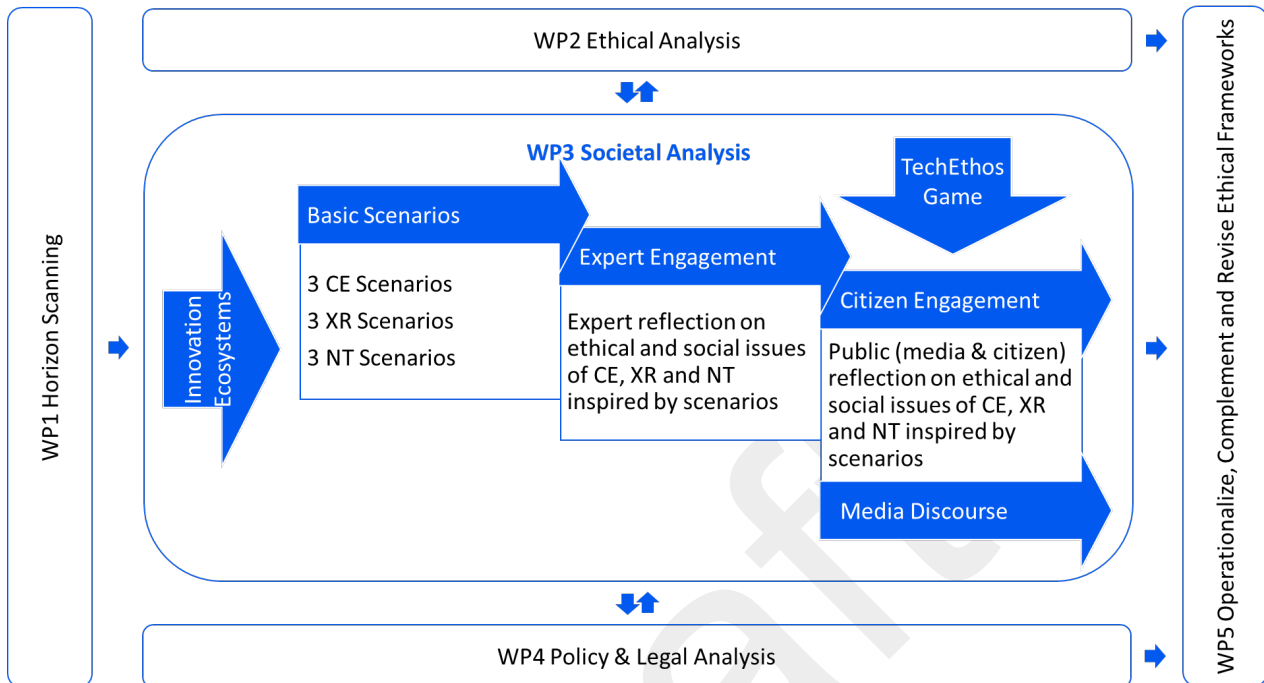
² See for details [D1.1 Description of selected high socio-economic impact technologies](#).

³ See for details [D1.2 TechEthos technology portfolio: Assessment and final selection of economically and ethically high impact technologies](#).

⁴ See for details [D2.2 Identification and specification of potential ethical issues and impacts and analysis of ethical issues](#), and [Policy Brief on XR and general purpose AI: From values and principles to norms and standards](#).

⁵ See for details [D4.1 Analysis of international and EU law and policy](#), [D4.2 Comparative analysis of national and legal case studies](#), and [D6.2 Policy briefs on enhancing EU legal frameworks](#).

The final anticipatory exercise in TechEthos was the application of the learnings of the ethical, societal and legal & policy analysis into the enhancement of specific ethical frameworks for CE, XR and NT as well as into the enhancement of overarching ethical frameworks⁶.



WP Work package
 CE Climate engineering
 XR Digital extended reality
 NT Neurotechnologies

Figure 1: Anticipating the societal embedding of new and emerging technologies in TechEthos

This report highlights the most important insights of the societal embedding of CE, XR and NT by using scenarios to explore public awareness and attitudes. Figure 1 shows how scenario techniques were used in a stepwise process to prepare an adequate framing for expert and citizen engagement. The following sections describe how scenarios were developed and applied in workshops, serious games, and surveys to inspire anticipative reflection on new and emerging technologies and how empirical data were collected.

Basic scenarios to inspire anticipative reflection of new & emerging technologies

Initially, three basic scenarios were prepared by TechEthos experts for each of the TechEthos technology families (table 3), followed by the engagement of external experts to discuss and enrich

⁶ See for details [D5.1 Enhancement of Ethical Frameworks and Outline of Detailed Ethics Framework](#), [D5.2 Enhancing legal frameworks at the national and international level](#), [D5.3 Suggestions for the revision of existing operational guidelines for climate engineering, neurotechnologies and digital XR technologies](#), [D5.4 Criteria for ethical review by RECs in emerging technology research](#).

the basic scenarios⁷. These enriched scenarios together with the “TechEthos game: Ages of Technology Impact”⁸ provided the context for citizens to explore their awareness of and attitudes toward CE, XR and NT. Thereby, the mapping of the innovation ecosystems for CE, XR and NT as well as the learnings from the parallel ongoing ethical, policy & legal and media analysis⁹ informed the process.

Table 3: TechEthos scenarios for climate engineering, digital extended reality and neurotechnologies

Technology family	Scenarios*
Climate engineering (CE)	Scenario 1: Betting on biofuels Scenario 2: Who controls the global thermostat? Scenario 3: Post-consumer societies and natural climate solutions
Digital extended reality (XR)	Scenario 1: Remote work Scenario 2: Training in virtual reality Scenario 3: Speakers for the dead
Neurotechnologies (NT)	Scenario 1: Smith vs Jones Scenario 2: Brain data Scenario 3: Aging society

*Scenarios outlined in chapter 3 of [D3.1 Multi-stakeholder evolution of TechEthos scenarios on ethical issues in climate engineering, digital extended reality and neurotechnologies](#)

Scenario workshops, games and surveys to collect empirical data on anticipative societal awareness and attitudes

In TechEthos we used a combination of scenario workshops, scenario games and accompanying surveys to capture anticipative societal awareness and attitudes towards CE, XR and NT.

- The expert scenario workshops engaged 15 participants in the CE workshop; 8 participants in the XR workshop; and 11 participants in the NT workshop across Europe.
- The citizen engagement involved 331 participants in 20 scenario game workshops combined with surveys, from six European countries (Austria, Czech Republic, Romania, Serbia, Spain, and Sweden) related to CE, XR and NT.¹⁰
- The media discourse was captured by analyzing online news outlets (excluding social media) related to CE, XR and NT in ten EU countries (Austria, Czech Republic, France, Germany, Ireland, Italy, Netherlands, Romania, Spain, and Sweden) and three non-EU countries (Serbia, UK, and USA).

Whereas the expert reflection resulted in the identification of and proposal on solutions to ethical issues related to CE, XR and NT, the citizen engagement produced primary empirical data on

⁷ See for details [D3.1 Multi-stakeholder evolution of TechEthos scenarios on ethical issues in climate engineering, digital extended reality and neurotechnologies](#), and [D3.5 Policy note: Analysis of expert scenarios addressing ethical implications of the selected technologies](#).

⁸ See for details [D3.2 Tools to develop and advance scenarios dealing with the ethics of new technologies](#).

⁹ See for details [D3.3 Results of media analysis](#).

¹⁰ Prior, 449 participants were involved in 15 science cafés to prepare the scenario game workshops (awareness raising events) and recruit participants (especially find participants representing vulnerable groups).

anticipative societal awareness and attitudes. Complementary to the citizen engagement, the online news analysis provided snapshots of societal awareness and attitudes related to CE, XR and NT in the media discourse.

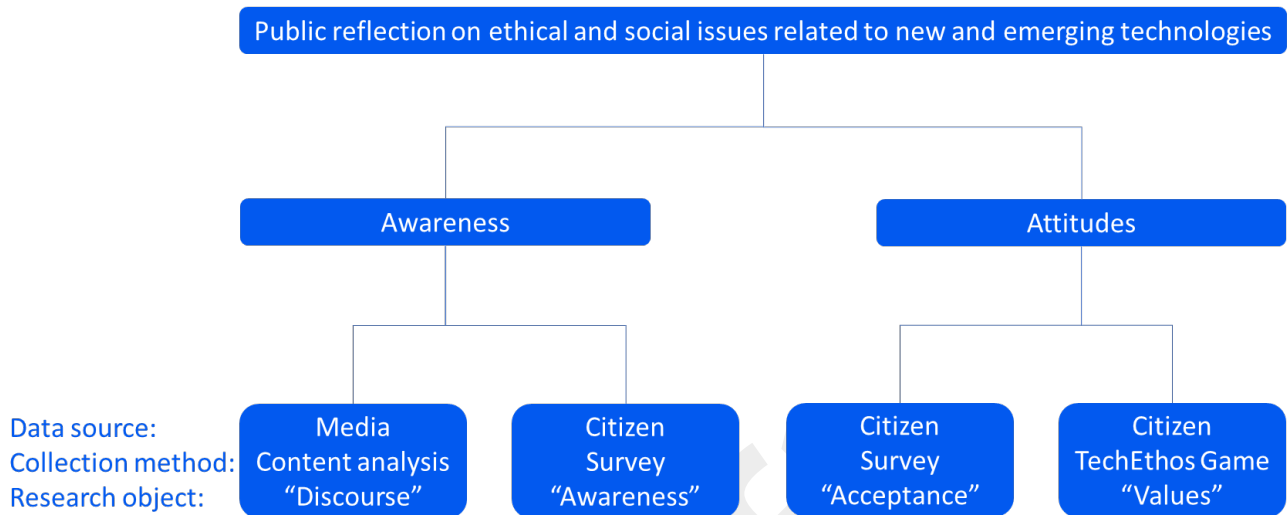


Figure 2: Capturing anticipative public reflection of ethical and social issues related to new and emerging technologies in TechEthos

The conceptualization and measurement of awareness and attitudes in TechEthos has its background in the theory of reasoned action (Pestello 2009, Fishbein & Ajzen 1975, Allport 1935), in grounded theory (Timmermans 2009, Charmaz 2009, Glaser & Strauss 1967) and in value theory (Boenink & Kudina 2020, Schwartz 1994, Inglehart 1977, Kluckhohn 1951, Dewey 1922, Weber 1922). As illustrated in figure 2, awareness and attitudes were captured in TechEthos by different sources and methods.

- Public awareness includes information derived from media discourse via computational tools (keyword search)¹¹, as well as from citizen direct expression via survey (using a Likert scale with response options “very aware,” “somewhat aware,” and “not really aware”)¹².
- Public attitudes are derived from citizens’ direct expressions via survey (question “when you think about these technologies, do you feel excited or do you feel concerned?”) to get information concerning acceptance, and via playing the “TechEthos game: Ages of Technology Impact” (triadic game design approach) to elicit underlying values.¹³

Structure of the report

The report proceeds by reviewing results on societal awareness across all three technology families (section 2). Next (section 3) synthesized results on three prioritized values are presented, going into detail on how the value is expressed in the particular context of each technology family. The values conveyed include, equity, reliability, and healthy people and planet. Closing thoughts (section 4) are

¹¹ See for methodological details [D3.3 Results of media analysis](#).

¹² See for methodological details [D3.1 Multi-stakeholder evolution of TechEthos scenarios on ethical issues in climate engineering, digital extended reality and neurotechnologies](#).

¹³ See for methodological details D3.1.

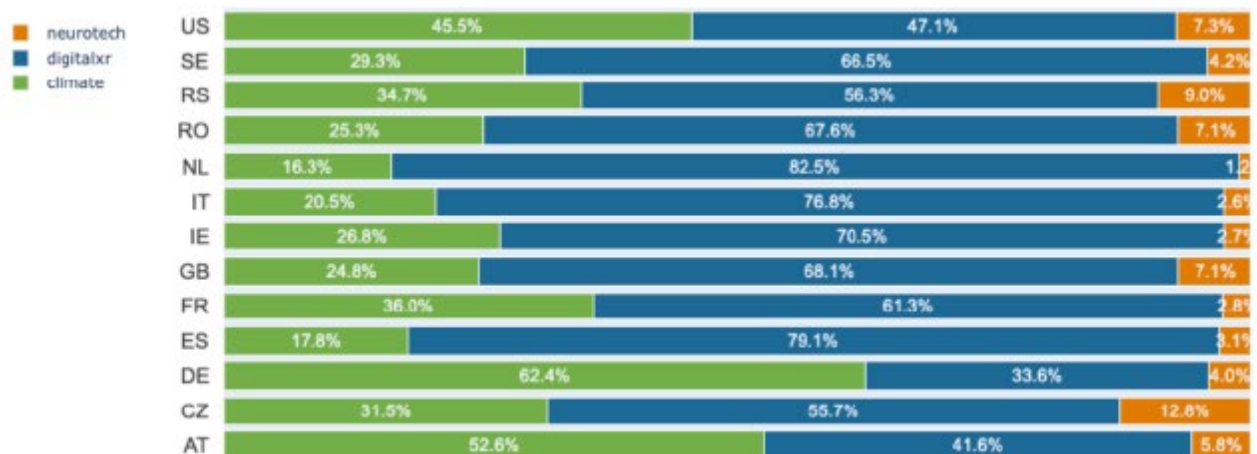
presented regarding the question of what it means to govern development of new and emerging technologies when excitement is “conditioned” by prioritized values and concerns.

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2 Awareness related to CE, XR and NT: Media vs citizens

Media discourses and citizen expressions are quite different sources for the investigation of public awareness of new and emerging technologies. The advantage of using media as a source is that a massive amount of data can be collected by searching online media outlets with keywords. The advantage of using citizens as a source is given by the immediacy and directness of their expressions.

As conveyed in the media analysis, media coverage across countries surveyed shows that the majority of coverage connected to the XR technology family, followed by CE and, minimally, NT (figure 3).



Percentage over the total news stories collected for that country | Source: [D3.3 Results of media analysis](#) (p. 36)
Figure 3: Percentage of news stories collected for each country by technology

When asked directly, citizens indicated similar levels of overall awareness within the survey conducted at the end of the scenario game workshops (very aware + somewhat aware) across all technology families covered in TechEthos. Of 331 participants asked, approximately two-thirds were at least somewhat aware of each technology family (figure 4).

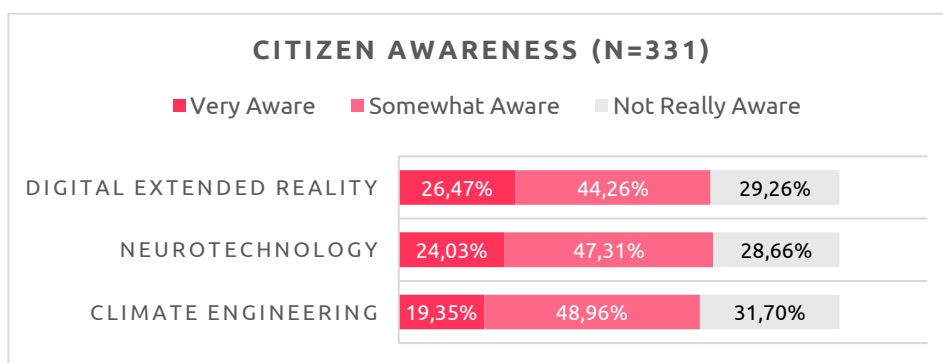


Figure 4: Citizen awareness of XR, NT and CE

The comparison of these two approaches reveals an interesting difference in the awareness of neurotechnologies (although these two investigations are not representative). We know from our

investigations that citizens referred often to science fiction films as a frame of reference, which might explain this difference.

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3 Attitudes related to CE, XR and NT: Excitement and prioritised human values

3.1 Conditionally excited

Eliciting the excitements and concerns of participants allowed us to consider the nature of “acceptance” of the technologies. Participating citizens were asked before and after the scenario game workshops (pre-survey, post-survey) to share excitement, concern, or both. Thereby acknowledging the conditionality of excitement, i.e. that citizens’ positive perception of a technology depends on their impression that concerns are taken seriously.

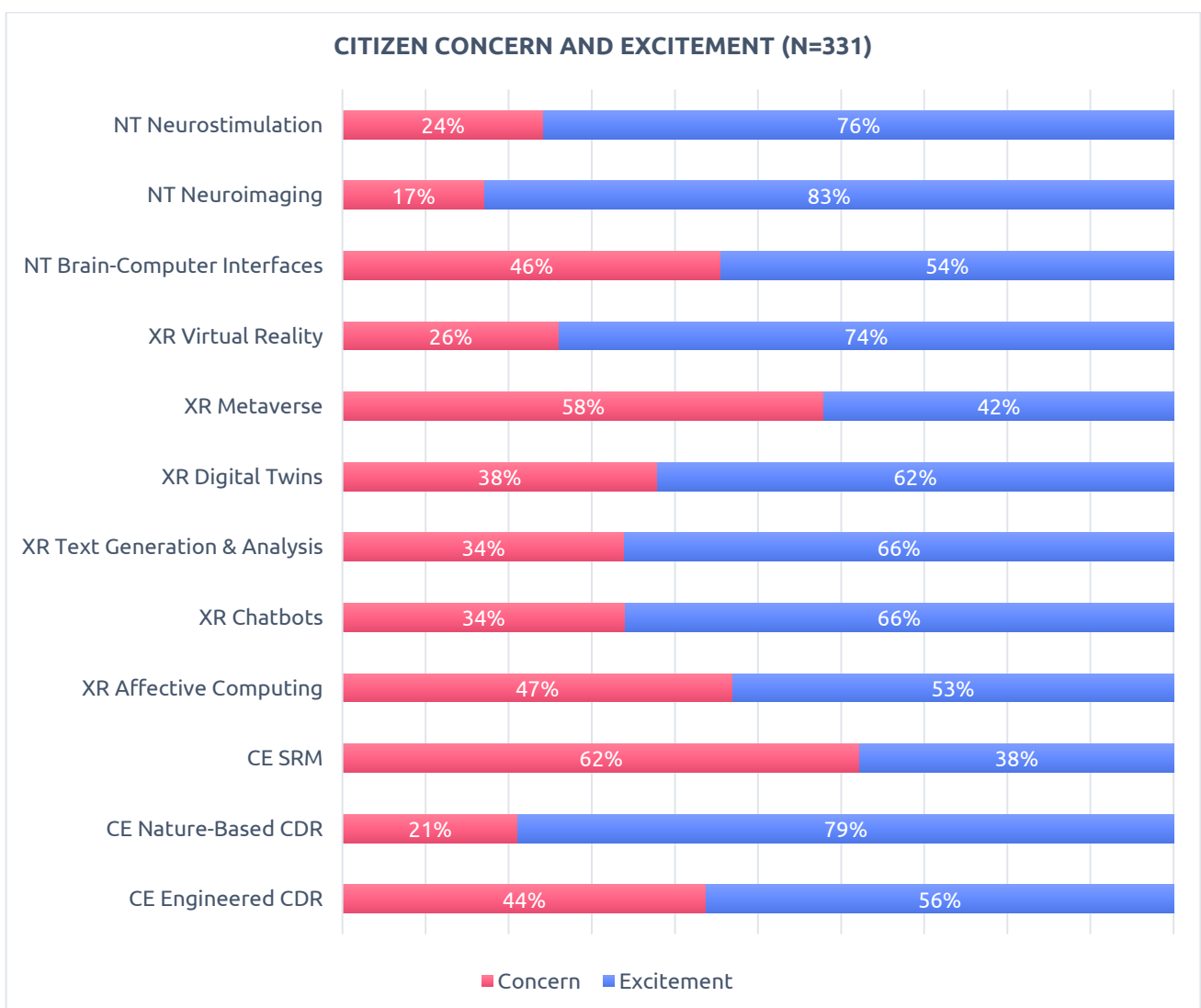


Figure 5: Citizen concern and excitement related to sub-technologies of XR, NT and CE.

The pre-survey indicated that more votes were cast for excitement than concern related to various sub-technologies of XR, NT and CE – except for SRM (solar radiation management) in the CE family and the Metaverse in the XR family (figure 5). One interpretation of the majority of most votes going to excitement could be that participants “accept” the technologies presented. However, such conclusion

discounts the not insignificant proportion of concerns voted for many of the technologies (e.g., more than 40% for engineered CDR, brain-computer interfaces, and affective computing). An attitude towards an emerging technology is not an either-or process. As the results illustrate, participants hold excitements and concerns in coexistence.

This is also reflected in the post-survey¹⁴, which was handed out to the participants after the game exercises and the group deliberation of the technologies. Although the majority (+70%) of the participants was excited or very excited across the technology families, participant ambivalence persisted.

The persistence of excitement and concern thus suggests the utility of delving more deeply into the values expressed by participants in the course of deliberation. In the subsequent sections, we look at three overarching values in particular – equity, reliability, and healthy people and planet – to discuss the nature of such conditionality and ambivalence tempering excitement with concern. The sections below presents a broad synthesis of results reported in detail in TechEthos Deliverable 3.1 (p. 109 – 110).

3.2 Prioritised value “equity”

As a social concern and priority, **equity** features prominently across all three TechEthos technology families. In the context of these new and emerging technologies, equity references questions of just distribution of benefits and burdens associated with innovation, as well as of process used for decision-making. Detailed concerns regarding equity feature differently in each of the technology families. For climate engineering (CE) technologies, equity covers concerns with the power imbalances in play in decision making about interventions with complex and uncontrollable regional and global consequences. 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; the region plagued with drought or flooding as a result of solar radiation management elsewhere) and benefits. For extended reality (XR) technology, equity concerns relate more closely to the dynamics of labour markets and democratic states, where companies and governments may use and design technologies for various forms of monitoring, behaviour modification or control. Questions of the design and accessibility XR, acknowledgment of issues with licenses and authorship, strong social safeguards and consequences, as well as a fair distribution of benefits are essential when pursuing XR equitably. Finally, in the context of neurotechnologies (NT), equity concerns touch on ways in which individuals may or may not have access to life-saving technologies, simply as a function of economic means. Beyond the medical domain, any permeation of NT in society will raise equity challenges, as well, regarding the affordances of people augmented, or not.

In the sections below, we briefly summarize in greater detail the various ways in which equity concerns were observed in the TechEthos technology families.

Climate Engineering

Various TechEthos Scenarios of climate engineering feature concerns regarding equity. CE Scenario 1 features situations in which Inequality worsens as larger firms capitalize on political and financial resources global carbon market regimes (D3.1 p.37); climate mitigation exacerbates globally inequities making for a grossly ineffective regime; and the ravages of food shortages and political disruption

¹⁴ Note: since the questions in the pre- and the post-survey are not completely the same, the two surveys cannot be compared directly.

negatively impacts critically affected people and communities. CE Scenario 2, featuring stratospheric aerosol injection, observes beneficial impact of CE in zones of deployment, but rainfall, ecological, and agricultural yields adversely impacted in uneven ways. In CE Scenario 3 inequities emerge in the ways geopolitical carbon mitigation blocs act, leading to free riding by some at the expense of others.

In discussing these scenarios with diverse experts, three overarching ethical issues were observed related to global development, decision-making, and technological fixes. On development, distributional dynamics related to existing economic paradigms were a concern, as technological “solutions” to climate change “further destabilize environmental and social conditions (D3.1 p.57). On decision making, questions were raised regarding the procedural justice of having incumbent powers (and processes) control decision making about CE, and how vulnerable communities might be included (and/or further disadvantaged). Finally, and related to issues of development, the pursuit of CE as a technological fix raised concerns about ignoring serious environmental harms and human exploitation not directly associated with levels of carbon pollution—for example various forms of water, air, and land pollution or ocean acidification (D3.1 p.58). In conclusion, experts noted that procedural and distributional justice were vital to addressing equity concerns of CE.

Through TechEthos game play, various citizen attitudes and values toward CE were surfaced to complement basic scenario and expert perspectives. Citizens were particularly concerned with misuse or the unintended side effects of the technology. For example, some noted that technology might contribute to addressing climate change but also, “create new [problems] at the same time” (Comment 199, 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), observing the deeper structural problems un-addressed by technological fixes to social and environmental challenges. Citizen values echoed major concerns with justice, 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)” (p.101)

Participants emphasized the importance of making CE technologies available globally and making sure all benefit from them regardless of socioeconomic status or geography.

Extended Digital Reality

Various TechEthos Scenarios of extended digital reality feature concerns regarding equity. In XR Scenario 1, changes in urban and rural residential and commercial place various economic and environmental pressures as virtualization of professional and social worlds progress and inequalities between virtual and material production exacerbate. In XR Scenario 2, advances in digitalization are seen to exacerbate socioeconomic stratification, with particularly strong manifestation in education and employment settings, as well as a rise in prevalence of mental health and social challenges pertaining with virtualization. In XR Scenario 3, equity concerns are expressed through corporate action to further exploit human data for profit comes at the expense of human wellbeing.

In discussing these scenarios with diverse of experts, three overarching ethical issues were observed related to data ownership, digitalization of work and social interactions, and technological solutionism. Experts raised ethical questions over who owns a product or service based on data drawn

from individuals or groups of people, and how new rights, licencing and payment regimes might be necessary to create more equitable XR futures. On digitalization of work and social interactions experts observed how, on the one hand, virtualization of jobs may generate divisions between physical and remote workers, and noted a need to grapple with the distortions in rent, goods, and services for people working, paid, and living in areas with lower costs (currently observed, for example, in Lisbon or Mexico City). Experts also noted the risks to society that comes with dependence on digital infrastructures and associated systems (e.g., energy) without physical social redundancies—potentially affecting vulnerable members of society most acutely. Finally, experts were skeptical of the underlying promise of XR and digital solutions, citing common logics of profit and exploitation under the guise of good-will. Experts noted the questionable ethics of private actors turning individual habits into collectible data or exploiting publicly available services for private benefits instead of creating solutions that benefit the public. In conclusion, experts noted that procedural and distributional justice were vital also to addressing equity concerns of XR, with regard for justice and abuse of power closely related to concerns over data access and privacy.

Through TechEthos game play, various citizen attitudes and values toward XR were surfaced to complement basic scenario and expert perspectives. Citizens, related to equity, were strongly concerned with the issue of unemployment: "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). Such concern is, interestingly, complemented also by excitement, with people noting that systematic approaches to learning and machine inference have "the potential to make a lot of people's jobs easier" (Comment 292, NLP) by, as another stated, "... relieving people of mundane repetitive jobs" (Comment 422, NLP). Citizen values echoed concerns of equity, diversity and inclusion, specifically with regard to access to technological benefit and inclusion of diverse groups in technological design. Noted one participant: "The centre of discussion was the lack of access because of the high cost of this technology. The main concern was inequity by money" (Comment 652, XR). Participants often complemented these discussions with a focus on valuing equal access to XR for all social groups. Concerned about having current social biases (e.g., gender bias) become inscribed into the technology, and, hence, called for responsible development and clear accountability to ensure equitable XR.

Neurotechnology

Various TechEthos Scenarios of neurotechnology (NT) feature concerns regarding equity. NT Scenario 1 referenced conditions in which private companies lead NT developments in productivity-enhancing and recreational applications for consumer and business markets, and raises questions about liability of developers, companies, and users. NT Scenario 2 observes a "wild west" development paradigm of neurotechnologies, where data access is bought at a premium and consumers targeted with technologies to further support data markets for private benefit at expense of individual and public benefit. NT Scenario 3 focused on how neurotechnologies might benefit individuals by preserving memories and countering cognitive declines and reducing costs of elder care, but also raising questions of responsibility for continuity of service and care as usage grows.

In discussing these scenarios with diverse groups of experts, three overarching ethical issues were observed related to neuro-discrimination, neuro-dependency, and neurosurveillance. With the assumption of increased commodification of neurotechnology, experts raised questions on ethical development, for example, related to animal testing and human subject testing. Further, concerns were raised about people only with the means to afford a lifesaving or enhancing technology contributing to socioeconomic divisions and even discrimination against people lacking the means (or desire) to access such technologies. who do not have the means access to such technologies. Related to neuro-discrimination, experts encouraged reflection on ways NT might lead to a new definition of

what it means to be 'healthy' if neurotechnological devices intervene in the body's own functions and regulate emotional states such as anxiety, sadness, or stress; raising equity concerns in cases of discrimination of neuro-divergent individuals and groups. Finally, experts raised ethical concerns regarding scenarios of constant monitoring and tracking vis-à-vis data privacy and ownership, as well as profiling concerns.

Through TechEthos game play, various citizen attitudes and values toward NT were surfaced to complement basic scenario and expert perspectives. Citizen comments revolved around, on the one hand, excitement at the prospect of promised disease prevention or early diagnosis and improved treatment. However, concerns also closely follow on the topic of accessibility and equality, noting one participant, "Rich people will be able to become 'superhumans' and have more and more power over others" (Comment 45, NT). Citizen values related to NT connected to inclusivity regarding different social groups, however cautioned, as one noted that, any efforts at, "reducing neurodiversity can be a big problem because all human beings are unique, it is their singularity" (Comment 508, NT), and another that, "It can promote inequality in accessing, discrimination and it can be a way to manipulate people." (Comment 497, NT). Cross-cutting citizen values of equal access to NT as well as appreciation and respect for neurodiversity and the uniqueness of human individuals stood out related to equity.

3.3 Prioritised value "reliability"

As a social concern and priority, **reliability** also features prominently across all three TechEthos technology families. In the context of these new and emerging technologies, reliability references questions of the extent to which a 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. Through questions of liability, responsibility, and accountability, it also connects to the questions of how governance should be conducted, by whom, and in what contexts. For climate engineering (CE) technologies, reliability connects to concerns regarding unknown effects and potential dangers (both to physical safety and health impacts, as well as the dangers regarding the ecosystem) of the technology and questions as to whether applications have been tested well enough to utilize them safely. From a societal perspective, reliability with CE covers concern with the lack of clear legal and regulatory regimes as regards the deployment and consequences of CE tech. For extended digital reality (XR) technologies, reliability pertains primarily to questions of responsible use of data, data rights, privacy and security. Reliability also covers a priority for human centred development, valuing benefit for individual users (e.g., by reducing harm or addiction) over private sector gain. Issues of reliability for neurotechnology (NT), like XR, connect to questions of data use, privacy, and security. Given the extent of false hopes and unrealizable promises often used to hype certain NT, reliability pertains to responsible stewardship of promises and visions.

In summary, reliability encompasses the trustworthiness and dependability of a technology in terms of expected outcomes and effects – that the technologies work as advertised; that what is advertised is not misleading or dishonest; and that consequences follow destructive behaviour. In the sections below, we briefly summarize in greater detail the various ways in which equity concerns were observed in the TechEthos technology families.

Climate Engineering

Various TechEthos Scenarios of CE feature concerns regarding reliability. CE Scenario 1 reliability concerns cover questions related to costs, effectiveness, and feasibility at scale of CDR (e.g., BECCS). From a societal perspective, questions of reliability also emerge as challenges with BECCS encourage investments into direct air capture (DAC), with national governments partnering with large

corporations including fossil fuel companies who spend large sums rebranding themselves as carbon removal businesses. In CE Scenario 2, reliability concerns turn to the costs, effectiveness, and feasibility at scale of stratospheric aerosol injection (SAI); from a societal perspective, reliability connects to issues of moral hazard, as SAI ushers in continued exploitative economic growth protected from climate impacts by SAI, without any intention of decarbonising or decoupling the economy from environmental impacts. In CE Scenario 3, questions turn to the favorability of more 'natural' approaches like afforestation and reforestation, soil carbon sequestration and agroforestry. Co-benefits of improved agricultural output, soil quality and biodiversity restoration showcase desired reliability outcomes.

In discussing these scenarios with diverse groups of experts, three overarching ethical issues were observed related to development, decision making, and technological fixes. Regarding development, reliability concerns surfaced particularly in challenging the assumption that all countries desire development in a singular mode of extractive, material consumption and environmental degradation as a rationale for CE to abet business as usual. On the optic of decision making, experts discussed reliability as the difficulty of deciding whether to research or deploy CE technologies; reliability being problematic when climate impacts may be uncertain and shape not only climatological but also geopolitical outcomes in drastic ways. Finally, CE and technological fixes, there was emphasis by the experts on the problem of seeking to address climate change through technological fixes alone. Such an assumption, experts warned, ignores systemic, sociopolitical responses to climate change (whether through transit, farming, energy, built-environment, lifestyle or any number of others) which might more reliably address current challenges.

Through TechEthos game play, various citizen attitudes and values toward CE were surfaced to complement basic scenario and expert perspectives on reliability. Citizen attitudes were concerned with the misuse or the unintended side effects of CE to irreversibly alter the climate and ecosystems, and destabilize geopolitics. As one participant pointed out, "Technological solution alone can make climate cooler but does not change society in a beneficial way" (Comment 380, CE). Citizens values reflected a strong desire for addressing **the unknown effects of CE technologies, whether they are posing danger onto people or whether they will fulfil their promises and not cause extra harm.** One participant observed, "Forestry is the only one that has been tested, everything else is at the experimental level" (Comment, 193, CE). Another commented that the uncontrollability of CE technologies seemed dangerous and raised, "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). Citizen participants found trustworthiness of the applications crucial and were concerned about how little transparency and knowledge seemed available about CE, given also their safety and reliability concerns.

Extended Digital Reality

Various TechEthos Scenarios of XR feature concerns regarding reliability. In XR Scenario 1: a society with a robust XR infrastructure infuses virtuality in all social interactions and where technologies remain relevant and can be upgraded to meet new demands. As certain technological conditions improve, social conditions, like labor regulation and worker protections also encounter changes. In XR Scenario 2 as virtual worlds proliferate, increases in digital divide exacerbate socioeconomic stratification, and prevalence of mental health and social challenges increase, questioning the reliability and safety of the technologies. XR Scenario 3 involves questionable profit seeking behavior at the expense of customer privacy, personal data and wellbeing, with little in the way of accountability or recourse.

In discussing these scenarios with diverse groups of experts, three overarching ethical issues were observed related to data ownership, digitalization of work and social interactions, and technosolutionism. Regarding data ownership, reliability issues pervaded expert conversations on intellectual property/ownership especially as machine inference and algorithmic learning combine to generate media draw from many different sources, and often without permission, raising ethical issues about privacy and consent. From the perspective of digitalization of work and social interactions, reliability connected to observations of fragile digital infrastructures and associated systems (e.g., energy) when no physical social redundancies. Another reliability issue connected to authenticity in social interactions as real and fake contacts blur and mis and disinformation, propagate. Finally, from the perspective of tech-solutionism, several reliability issues flowed from championing XR solutions wherein digital infrastructures platform various education, employment and political conditions, glossing over 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.

Through TechEthos game play, various citizen attitudes and values toward CE were surfaced to complement basic scenario and expert perspectives on reliability. Citizen attitudes concerned **data privacy**, for example in the context of affective computing. Noted one participant, "it has potential, but it is very risky. Our personal data may be misused and given or sold" (Comment 102, NLP). Closely related was the topic of misuse, with participants concerned about manipulation of users and, "centralization of power among those who will make this technology" (Comment 101, NLP). Noted another, "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). Related to chatbots and text generation, participant attitudes were concerned about plagiarism and copyright, scientific results being written with programs like ChatGPT and, of unemployment. As one participant stated, "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). Citizen valued responsible use and accountability for XR technology creation and impacts. Usefulness of XR was also a value, related to the diverse potential ways the technology might adapted and applicable in different contexts. Here, participants also appreciated the potential, for example, of digital twins, one stated: "It allows for risk-free practice in professions such as medicine, security and even everyday tasks such as driving" (Comment 635, XR). Citizen participants also valued efficiency and effectiveness, usually XR might improve certain redundant tasks through automation.

Neurotechnology

Various TechEthos Scenarios of neurotechnology (NT) feature concerns regarding reliability. NT Scenario 1 explores the consequences of a light-touch to regulation in favor of unfettered NT industrial and consumer development, and much debate ensues over questions of responsibility if and when false claims are made, or harms result from neurotechnology use. NT Scenario 2 explores widespread adoption and the coincidence of fidelity and consistency becoming problematic as data processing access increases, even as proliferation of data for neurotechnological development highlights gaps in protections for brain data use. In NT Scenario 3, consumer markets outcompete laboratory and medical facilities, and life-saving equipment people rely on face obsolescence when companies close, leaving their technology users stranded.

In discussing these scenarios with diverse groups of experts, three overarching ethical issues were observed related to neuro-discrimination, neuro-dependency, and neurosurveillance. Together, these subsume beneath the larger question of device and service reliability under "neurocapitalism"—specifically touching on questions of data privacy, business regulation, and transparency. Compared to other consumable technologies (e.g., smartphones), technology that becomes part of a human body

may not be so easily modified, repaired, or replaced, and thus carries additional risks from failures in reliability. Experts also noted issues with constant monitoring of human minds raises questions about data privacy and ownership. Additional issues were noted when people become subject to monitoring to assess their productivity or as a form of efficiency control. The experts pointed out how 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.

Through TechEthos game play, various citizen attitudes and values toward NT were surfaced to complement basic scenario and expert perspectives. Citizens' attitudes toward NT clustered in part about concern over the **misuse of or the manipulation of people through Brain-Computer Interfaces**. One participant expressed, "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). For all concerns with data privacy and security, many expressed positive attitudes of medical uses of NT. In the case of NT reliability issues, citizens value safety from negative side-effects as well as responsible use and accountability should things go awry.

3.4 Prioritised value "healthy people and planet"

As a social concern and priority, "healthy people and planet" covers the creation and implementation of technologies with a minimal negative impact on the environment and human health while promoting biodiversity and ensuring healthy society and ecosystems. It notes the need to design, develop, and deploy technologies with an eye toward avoiding potential harm for human health such as physical or mental exploitation, addiction, or disease; or for improving or enhancing human health. Healthy people and planet also emphasizes the need to address environmental challenges, such as climate change, resource depletion, pollution, and habitat destruction, by integrating sustainability principles into the development, deployment, and use of emerging technologies. Human health and planet health are often discussed separately, but particularly citizen's enrichment shows that these two values are interrelated in terms of maintaining or/and improving overall societal well-being.

In the case of CE, this concern is expressed strongly in the context of biodiversity and pollution. Biodiversity becomes relevant when discussing nature-based solutions for CDR, as a range of forestry or agricultural solutions often pursue harmful monocultures for economic reasons. Pollution touches upon the issue of toxic waste created through CDR or atmospheric SRM (the aerosols involved in stratospheric aerosol injection are classified under current legislation as pollutants). For CE human health is a topic through potential unintended consequences of concern, for example effects crop-yields, severe weather, accidents, etc.

For XR, environmental concerns become an issue due to the water and energy nexus through carbon emissions necessary for a globally accessible infrastructure for training LLMs (large language model) and storing data. Additionally, the production and disposal of the necessary hardware becomes a future issue (i.e., toxic computer wastes; increasing often destructive rare earth mining). Health concerns connected to issues of social isolation and mental health.

With NT, healthy people and planet concern covers rising energy consumption for data storage, maintenance and obsolescence issues, as well as the sustainability of the devices. The citizens particularly referred to the medical use of the technologies rather than recreational use, which shows that citizens' priority lay on human health (rather than enhancement) capabilities.

In short, facing climate change and 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. TechEthos findings implicate the need for a wider perspective on human health and well-being to be taken into account for designing and developing CE technologies. As the findings show, fostering a more sustainable future for both people and planet through the development of emerging technologies, mitigating environmental harm and creating solutions is a cross-cutting concern of importance.

Climate Engineering

Various TechEthos Scenarios of CE feature concerns regarding healthy people and planet. CE Scenario 1 explores the potential impacts of wide-spread implementation of BECCS in the Global South, undermining biodiversity, food and water security although the influence of climate change at the global scale. CE Scenario 2 explores the different measurements to mitigate climate change and different regional consequences e.g., heatwaves and ocean acidification. In CE Scenario 3, post-consumer societies prioritize the environmental protection and take a nature-based way to protect/revive the natural environment.

In discussing these scenarios with diverse experts, three overarching ethical issues were observed related to development, decision making, and technological fixes. Regarding healthy people and planet, there were remarks on side/indirect effects of CE to the environment and people on the site and on wider value system in the course of development and deployment of CE. Implementation of CE is often associated with massive land-use, monoculture, and change of local environment, causing potentially significant disruptive effects on land use, agriculture, terrestrial, and marine and freshwater systems, and human settlements. Although the implementation of CE for climate change mitigation may be beneficial at the planetary level, rapid decarbonization may cause biodiversity loss, microclimate change, health issues at the regional or local level. In addition, the experts pointed out that the societal priority of healthy people and planet cannot be taken for granted as shared across all countries. Rather, countries might act according to (geo)political and economic interests. The experts also pointed out that the assumption of technological fixes as the only way to approach climate change would ignore other serious environmental harms and human exploitation and harms connected not only to carbon pollution but underlying systemic drivers.

Through TechEthos game play, various citizen attitudes and values toward CE were surfaced to complement basic scenario and expert perspectives. Citizens were particularly concerned with healthy people and planet. Ecosystem health is the most addressed value category that captures the different values like biodiversity, sustainability, or the protection of the environment from pollution and harms. One participant addressed potential side effects of CE technologies at a territorial level; “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). In addition to the previous scenario enrichments, citizens emphasized the value of naturality – in other words, valuing approaches that are rather nature-based – as well as letting the environment naturally restore itself, and returning to earlier practices, when the climate situation was not as bad as today. Noted a participant, “Change of approach in sowing practices, returning nutrients to the soil, natural fertilization, these are the principles we should take back” (Comment 288, CE). Here, the societal priority, healthy people and planet, is often discussed in terms of balance and harmony of human and the environment, that can be seen in the result of citizens’ acceptance that the most excited among the three technologies was nature-based CDR, as it appears to be the least harmful technology and potentially in balance with nature.

Extended Digital Reality

Various TechEthos Scenarios of XR feature concerns regarding healthy people and planet. XR Scenario 1 features wide use of XR technology for remote work, which on the one hand, improves the living environment (e.g., air quality in cities, or harmonized life in countryside), on the other hand, increases carbon footprint from the energy-intensive technology as well as decreases real human interactions. XR Scenario 2 points to a lack of authentic human connections from widespread deployment of XR for training in everyday life. XR Scenario 3 emphasizes the transformation and confusion of the relationship between human and technology due to infiltration of XR technology in the everyday.

In discussing these scenarios with diverse experts, three overarching values were related in data ownership, digitalization of work and social interactions, and technosolutionism for social problems. Authentic human connection may be disrupted through software's intermediation of machine-generated text. Remote working may impact on the mental and physical well-being of remote worker and resilience to external stressors in life. Finally, the experts pointed out that environmental impacts of XR technologies, in terms of rare metals and energy consumption for server construction and maintenance should not be underestimated.

Through TechEthos game play, various citizen attitudes and values toward XR were surfaced to complement basic scenario and expert perspectives. Citizens were particularly concerned with the ability for human interactions and experiences which is associated with the importance of human-human interaction and the value of this, considering that, for example, a chatbot would change the nature of interactions. Moreover, citizens valued realness, referring to finding something valuable because it does not only exist in the online sphere, including personal presence, physical reality, and human sensations. A participant noted, "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). Additionally, citizens regard potential harm and health issues to children. 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). Finally, citizens addressed the importance of human experience regarding cultural experience of historical sites and entertainment. The priority of access to cultural experiences with use of XR was an additional emphasis in the citizens' enrichment.

Neurotechnology

Various TechEthos Scenarios of NT feature concerns regarding healthy people and planet. NT Scenario 1 features a controversy derived from a wide use of BCI, posing a hypothetical about whether neural enhancement would improve the user's concentration and thus safety in everyday activity. The scenario also address a question of competing resource distribution between medical and commercial purposes. NT Scenario 2, featuring neuromodulation device use and the private company's partnership with national security agency, explores sensitivity of neuro data that people initially use to improve their well-being. In NT Scenario 3, substantial use of neurotechnology for medicine or "well-being" shakes the concept of cognitive health and confronts conventional medical practice, with implication for reducing chemical and drug waste.

In discussing these scenarios with diverse experts, three overarching ethical issues were observed related to neuro-discrimination, neuro-dependency, and neurosurveillance. While in medicine, devices might be used to help people with disabilities communicate, move, or otherwise interact with their environment, use of technologies outside of medical use also raises questions regarding human subjectivities, concepts of healthiness, human and animal exploitation for experiments. According to the experts, normalization of neurotechnologies with ability to intervene in the body's own function

and regulate emotional status might lead to re-define the feeling of anxiety, sadness, or stress. 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. This also poses a question about a “right way” of ageing, namely, expectations on ageing and the role of the technology. Further, the experts noted concerns with the environmental impact from energy usage for data storage, issues of maintenance and obsolescence, and sustainability of devices.

Through TechEthos game play, various citizen attitudes and values toward NT were surfaced to complement basic scenario and expert perspectives. Citizens were particularly excited (almost two out of three) about neurotechnologies because of the potentialities for medical use to prevent and treat disease. One participant shared their experience of use, noting “the doctors used [Neurostimulation] to treat my back pain - it helped, it's a good method to help patients with pain.” (Comment 338, NT). Also, the citizens were both excited and concerned with the intervention of neurological status: “Someone who has trauma from the war would like to have those memories erased” (Comment 145, 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). Additionally, the citizens valued human health regarding the authenticity of humans, meaning autonomy and agency. In conclusion, the citizens’ emphasis on healthy people implies human-centered design of neurotechnology devices, particularly, for use of health and well-beings.

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4 Conclusion

European research and innovation investments increasingly call for the “societal acceptance” of technologies being developed. The term “societal acceptance” implies that people can take or leave a technology being developed, but have little effect in shaping its development. Yet as illustrated in the results presented above on participant values, excitement and concern, people do indeed have a voice and preferences that could, if considered directly condition the direction of research and innovation. It is rather perhaps, that such voices are heard too little or too late, or given less weight in the context of research and innovation investments and technology development. As European R&I frameworks continues to strive toward reflecting European values, a recognition of the conditional nature of “acceptance” could improve technological development by directly orienting research and innovation toward prioritized valued and addressing concerns associated with said values.

The “ethics by design” approach championed by TechEthos sought to identify guidelines to support inclusion of social and ethical concerns in the earliest possible stages of technology development (see for example Legal recommendations and Deliverable 5.3). The primary responsibility of work package three, as conveyed in summary form, above, was to gather the perspective of expert stakeholders and citizens to ascertain their attitudes, concerns, and values associated with developments in CE, XR, and NT. As noted in Deliverables 3.1 and 3.2, this was completed with a combination of horizon scanning, scenario construction, expert engagement, and serious-game-based workshops.

In presenting the prioritized values of equity, reliability, and healthy people and planet, TechEthos presents a clear opportunity for policy, business, and researchers interested in pursuing CE, XR, and NT – and having a better chance of addressing core values and concerns of people directly and indirectly affected by these technologies. Indeed, the above societal values illustrate how there are range of potential benefits and potential burdens associated with the development of these technologies – often sharing two sides of the same coin. For example, the ultimate aims of CE are absolutely vital: addressing climate change is more urgent now than ever before. However, the medicine must not be worse than the cure – and this is where the societal priorities of equity, reliability, and healthy people and planet come into play. Whether or not “society” “accepts” a technology is an unhelpful way to consider technology development. It inherently diminishes the legitimate values and concerns of millions of people and, further, does not distinguish that different groups of people may have different values and concerns (rather than being one homogenous “society”).

Acceptance, in this sense, is contingent. This has been the main argument in our presentation and discussion of results from engaging more than 300 participants across six countries in the TechEthos project. “Acceptance” is contingent on who is being asked about the technological features or goals. “Acceptance” is contingent on whether researchers, policy makers and business interests genuinely – “by design” – work to address societal priorities in the process of technology development. As one table facilitator reported of a discussion during one of the workshops:

“They concluded that they had arrived at the desired world because everyone had had a say in decisions. The group was heterogeneous in terms of gender and age and this made it possible to approach problems from different perspectives. The young people from vulnerable groups at the table highlighted the fact that they had felt important during the game because it was the first time someone had listened to them” (XR, 43).

TechEthos, through its extensive work, has illuminated three societal priorities where ethics-by-design efforts can be directed to improve the social and environmental outcomes of technology development. The use of the anticipatory and participatory methods used illustrate the potential of approaches to engaging societal concerns in more meaningful ways to support “ethics by design”.

Going forward, this means any continued investments in CE, NT, and XR R&I stand to benefit from advancing equity, reliability, and regard for healthy people and planet by design, and by actively alleviating ways in which these values are undermined by the technologies pursued.

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