TECHETHOS

FUTURE ○ TECHNOLOGY ○ ETHICS

TechEthos technology portfolio: Assessment and final selection of economically and ethically high impact technologies

Deliverable 1.2

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D1.2: Assessment and final selection of economically and ethically high impact technologies			
Work Package	1		
Lead Partner	Associazione Italiana per la Ricerca Industriale (AIRI)		
Author(s)	Eva Buchinger, Manuela Kinegger, Georg Zahradnik, Michael Bernstein (AIT), Andrea Porcari, Gustavo Gonzalez, Daniela Pimponi, Giuliano Buceti (AIRI)		
Contributor(s)	Alexei Grinbaum (CEA), Laurence Brooks, Kathleen Richardson (DMU) Nicole Santiago (TRI), Pieter Vermaas (TUD)		
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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.

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Definitions and abbreviations

Table 1: List of Definitions

Term	Explanation
New and emerging technologies	Any type of technology that performs a new function or improves some function significantly better than other commonly used technology, which is expected to be developed and deployed in the next 5 to 10 years.[1]
Technology family	Set of technologies that are characterized by one or more of the following aspects: aim to perform similar functions; address similar goals/concerns/trends; raise similar ethical issues; are based on similar (scientific) working principles.[2]
Impact assessment criteria	For TechEthos impact assessment dimensions with corresponding criteria have been defined. For example, the ethical dimension has the two assessment criteria (i) the potential of the technology family to significantly affect or engage ethical principles and values is high/medium/low and (ii) the need for additional guidance in dealing with ethical aspects of a technology family (e.g., not covered by existing guides, standards, regulations) is high/medium/low.

Table 2: List of Abbreviations

Term	Explanation
ADIM Board	Advisory and Impact Board
AI	Artificial intelligence
R&D	Research and development
R&I	Research and innovation
XR	Extended reality (i.e., digital extended reality)
WP	Work Package
MCDA	Multi-Criteria Decision Analysis

[1] Definition adapted for TechEthos from OECD (2017) and EC (2018). See for details TechEthos D1.1.
[2] See TechEthos D1.1.

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Executive Summary

This deliverable presents the results of the assessment and final selection of technologies as part of the TechEthos horizon scan. Within this process the 16 technologies resulting from the horizon scan's first part and described in detail in D1.1 "Description of selected high socio-economic impact technologies" were evaluated and the final TechEthos technology portfolio was decided.

A horizon scan refers to the act of seeking out diverse sources of information about short, medium, or long-term research, innovation, social, political, and economic developments. Our TechEthos horizon scan set out with the clear goal of developing a portfolio of three technology families. Specifically, we sought to identify potentially high socio-economic and ethically impactful technologies according to the following five TechEthos impact dimensions: industrial and economic, ethical, public, policy, and legal impacts.

The horizon scanning process involved three selection procedures to successively identify, refine, and winnow-out TechEthos relevant technology families.

First, identification of new and emerging technologies which are economically and ethically relevant. This selection procedure consisted of a desk-based document analysis identifying about 150 promising technology families which – through a series of iterative internal deliberations with our team of technical and social experts and accompanied by an assessment criteria development process – created a short-list of 16 technologies.

Second, assessment of the shortlisted technologies. This selection procedure of the horizon scan comprised a quantitative and a qualitative approach. The quantitative assessment was based on patents (EPO PATSTAT database) and on EU framework research projects (AIT EUPRO database) and confirmed the relevance of all of 16 shortlisted technologies. Thereupon the qualitative assessment was conducted via a survey including 77 external technical and social experts from 21 countries and additional expert interviews. These approaches resulted in an impact assessment matrix with technologies and the selection criteria as its axes.

Third, final decision of TechEthos' technology portfolio. This selection procedure consists of the validation of the impact assessment matrix by TechEthos internal and external experts and the succeeding final refinement of the technology families. As a result, the TechEthos technology portfolio includes "Climate Engineering", "Digital Extended Reality" and "Neurotechnologies".

Whereby the first procedure is object of deliverable 1.1 "Description of selected high socio-economic impact technologies", the second and the third procedure are objects of this deliverable (D 1.2).

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1 Introduction

TechEthos' first major milestone has been the identification of three technologies with high socio-economic impacts to become the basis for the succeeding analyses aiming at the production of operational ethics guidelines for stakeholders such as researchers and innovators, ethics committees, civil society organisations and policy makers. Its initial work package (WP1) consists accordingly of a comprising horizon scan to identify and select new and emerging technologies which are economically as well as ethically relevant.

TechEthos WP1 consists of three tasks. It started with the identification and refining of methodology, criteria, and resources for the development of a specific TechEthos horizon scan methodology (task 1.1). On this basis a wide range of technologies has been identified via a desk research meta-study and iteratively be refined and reduced from about 150 to 35 to 16 technology families (task 1.2). The iterative refinement and reduction used assessment criteria which have been simultaneously developed. The process and the results are already documented in Deliverable 1.1 "Description of selected high socio-economic impact technologies".

Task 1.3 – which is the focus of this deliverable – deals with the assessment and final selection of the previously short-listed 16 technology families. This has been done by developing a multi criteria decision analysis (MCDA) matrix to support the evaluation of the short-listed technologies impact bases on selected criteria as its axes (see Table 3 for the conception of the impact assessment matrix). The MCDA impact assessment matrix benefits from desk research results as well as from quantitative and qualitative assessments and serves as a basis for the final selection and final refinement of the TechEthos technology portfolio.

Table 3: Example of the Multi-Criteria Decision Analysis impact assessment matrix with TechEthos impact dimensions*

	Industrial & economic impact	Ethical impact	Public impact	Policy impact	Legal impact
Technology family 1	High	Very high	Low	Medium	Very low
Technology family 2	Low	Very low	Medium	Very high	High
Technology family n	Very high	Medium	High	Very low	Very high

*TechEthos impact dimensions agreed upon during task 1.1 and task 1.2

This report (D 1.2 "TechEthos technology portfolio: Assessment and final selection of economically and ethically high impact technologies") has the following structure: After explaining the methodology (section 2) and briefly characterizing the work and results of task 1.1 and task 1.2 (section 3), the quantitative and the qualitative assessment applied to the impact matrix will be described in detail, whereby the quantitative assessment is based on patents (EPO PATSTAT database) and on EU framework research projects (AIT EUPRO database) and the qualitative assessment on an online survey including 77 external technical and social experts from 21 countries as well as on a few additional expert interviews (section 4). In the next step, the results synthesized in the MCDA impact assessment matrix have been validated by the TechEthos internal and external experts in workshops considering additional criteria such as EC commission interest and political priorities, potential TechEthos value-add, and project participant scientific and intellectual interest (section 5). Finally, the WP1 team synthesized findings and decided the TechEthos technology portfolio which broadly explores the interaction of technologies with the planet, the digital world, and the human body, i.e. "Climate Engineering", "Digital Extended Reality", and "Neurotechnology" (section 6).

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2 Methodology

The TechEthos horizon scan approach is a combination of the analysis of available resources and experts' judgements. Given the qualitative and dispersed nature of the information collected, a multi-criteria decision analysis (MCDA)[3] approach is being used to compare, assess, and support the selection of technologies. Assessment criteria have been iteratively identified, refined, and validated within in the entire horizon scan process. The TechEthos consortium agreed on 5 impact dimensions to which assessment criteria are related: industrial and economic, ethical, public, policy, and legal impacts.

The horizon scan process evolved in a series of steps, which can be attributed to three different procedures (see Figure 1) to successively identify, refine, and winnow-out TechEthos relevant technology families. First, identification, analyzation and shortlisting of new and emerging technologies which are economically and ethically relevant. Second, assessment of shortlisted technologies. Third, final decision on TechEthos' technology portfolio. The first procedure is explained in Deliverable 1.1 "Description of selected high socio-economic impact technologies" and the path from 16 to 3 technology families is treated in this deliverable (D1.2). Reflection and method generalization will be outlined in D1.3.

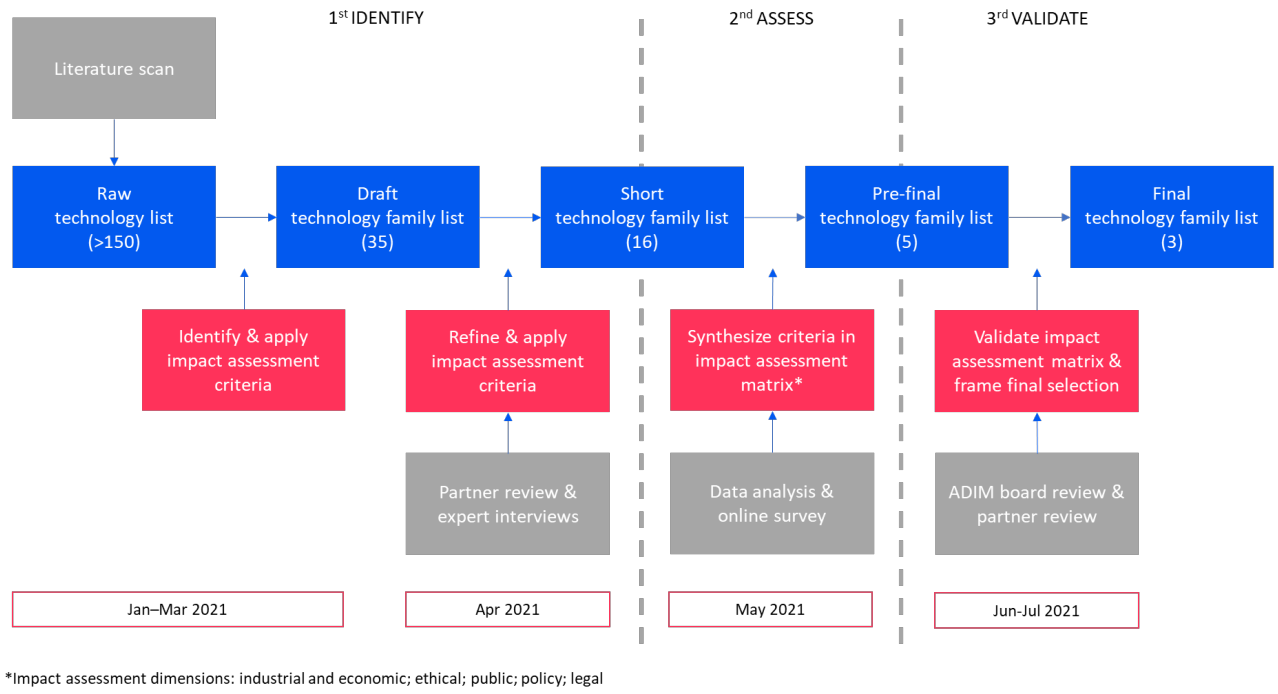

Figure 1: TechEthos Horizon Scan Approach

The assessment of the 16 shortlisted technology families combines a quantitative and a qualitative approach. It started with the quantitative assessment derived from a data analysis including patents (EPO PATSTAT database) as well as EU framework research projects (AIT EUPRO database). The

[3] See Linkov et al. (2006), Linkov & Moberg (2017), Linkov et al. (2020), Porcari et al. (2021a), Zhang et al. (2021).

quantitative assessment confirmed the relevance of all shortlisted technologies and became part of the factsheets of the follow-up qualitative assessment. This was conducted via an online survey including 77 external technical and social experts from 21 countries. Additional expert interviews were conducted to cross-check the appropriateness of the technology selection process as well as the assessment criteria development. These approaches resulted in an impact assessment matrix (i.e., technologies and the selection criteria as its axes). The impact assessment criteria used for the assessment matrix are shown in Table 4.

Table 4: TechEthos impact assessment dimensions, related criteria, and data sources

Impact dimensions & criteria		Data Source
1	**INDUSTRIAL AND ECONOMIC IMPACT**	
1.1	**New and emerging:** the level of novelty of the technology family is … *Low: Mostly incremental innovations technologies driven by minor improvements compared to existing technologies* *High: Mostly radical or disruptive technological development, transforming products, services, or processes*	Desk research Interview
1.2	**Enabling:** the degree of cross-sectorial and systemic relevance of the technology family across economic sectors is … *Low: Enables innovation in few industrial and economic sectors* *High: Enables innovation in most industrial and economic sectors*	Desk research Interview
1.3	The level of **interest by industry and investors** in the technology family is... *Low: Low interest is indicated by stagnating job growth or job loss, low investments, low profitability expectations, lack of sector-wide effects, etc.* *High: High interest is indicated by significant job growth, high investments, high profitability expectations, potential for sector-wide transformations, etc.* *Note: for industrial R&D strength see quantitative data in the factsheets*	Desk research Interview Quantitative analysis Survey (Q1)*
2	**ETHICAL IMPACT**	
2.1	The potential of the technology family to significantly affect or engage **ethical principles and values** is … *Low: The advance of the technology family has limited or no effects on ethical principles and values.* *High: The advance of the technology family has big effects on ethical principles and values.* *Note: Ethical principles and values include e.g., equality, privacy and data protection, autonomy as well as specific concerns related to health, environment, and human interactions*	Desk research Interview Survey (Q4)* Workshop
2.2	The need for **additional guidance** in dealing with **ethical aspects** of a technology family (e.g., not covered by existing guides, standards, regulations) is … *Low: The ethical implications of the technology family could be managed with existing guidelines, standards, and regulations.* *High: The ethical implications of the technology family will need new guidelines, standards, and regulations.*	Survey (Q5)* Workshop
3	**PUBLIC IMPACT**	
3.1	The potential of the technology family to have a significant impact on **societal challenges** (e.g. Sustainable Development Goals, principles of the European Pillar of Social Rights) is … *Low: The technology family has little or no impact on societal challenges (opportunities, threats).* *High: The technology family has a large impact on societal challenges (opportunities, threats).*	Desk research Survey (Q3)* Workshop
3.2	The potential impact of the technology family on **people's lives** (also considering minority and vulnerable populations) is … *Low: A relatively small impact on people's lives, e.g., how people work, move, transport, interact.* *High: A relatively high impact on people's lives, e.g., how people work, move, transport, interact.*	Desk research Survey (Q2)* Workshop

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4	**POLICY IMPACT**	
4.1	The **policy** level of focus on the technology family within government/policy strategies, action plans, foresight exercises at national, EU and global level (s) is … *Low: no or very limited policy activities such as strategies, action plans, foresight exercises.* *High: many / prioritised policy activities such as strategies, action plans, foresight exercises.* Note: for EU policy priorities see e.g., quantitative data in the factsheets Note: has an overlap with "additional guidance" see above 2.2	Desk research Interview Quantitative analysis Workshop
5	**LEGAL IMPACT**	
5.1	The potential of the technology to significantly affect **existing legal frameworks** is … *Low: no or very limited changes in existing legal framework* *High: significant changes in existing legal framework (e.g., creating new laws; establishing new legal bodies)*	Desk research

*Q Survey question number

Third, final decision of TechEthos' technology portfolio. This selection procedure consists of the validation of the MCDA impact assessment matrix by TechEthos internal and external experts and the succeeding final refinement of the technology families. As a result, the TechEthos technology portfolio includes "Climate Engineering", "Digital Extended Reality" and "Neurotechnologies".

3 Scanning and shortlisting of promising technology families

Deliverable 1.1 describes the process of identification, analysation and shortlisting of 16 new and emerging technologies which are economically and ethically relevant.

The scanning exercise identified a first a comprising raw technology list (>150) which has been reduced to a draft list of 35 technology families, integrating a wide number of specific technologies retrieved from the literature that have been further selected and refined to a list of 16. Criteria used for assessing and selecting technologies include considerations on industrial and economic, ethics, public, policy, and legal impacts. In particular, the level of coverage of a technology family in terms of ethics analysis by other initiatives has been a criterion.

Considering the broad character of the analysis, a mix of different approaches has been used to describe the technology families, including descriptions that are sectoral-oriented (e.g., precision farming), concerns-related (e.g., climate technologies, threat detection and response), application-based (e.g., mobility), and technology-based (e.g., quantum technologies, synthetic biotechnologies).

In D1.1 the 16 families have been grouped in research and innovation (R&I) fields (Bio & Environment, Digital, Health, Materials & Manufacturing), broadly identified based on scientific disciplines and European policy fields to facilitate their overall presentation and description.

The identified set of 16 technology families with high socio-economic impact and ethical relevance comprises:

R&I field: Bio & environment

1. Environment & climate technologies
2. Bioengineering & industrial biotech (excluding healthcare)
3. Synthetic biology

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R&I field: Digital

4. Data processing technologies (excluding quantum techs)
5. Quantum technologies
6. Internet of things (IoT)
7. Cognitive and behavioural technologies
8. Virtual/Augmented reality

R&I field: Health

9. Regenerative medicine
10. Artificial human/neuro-technologies

R&I field: Materials & manufacturing

11. Additive and advanced manufacturing technologies
12. Autonomous systems
13. Threat detection and response technologies
14. Precision farming
15. Mobility technologies
16. Space technologies

A review of resources and selection criteria and the rationale of the methodological approach are explained in section 2 of D1.1. In section 3 of D1.1 the shortlisted 16 technology families are described in factsheets, including a description of the functions and capabilities, industrial sectors, specific technologies and their areas of application, time to market, key ethical issues and expected socio-economic impacts.

4 Assessment of short-listed technology families

The assessment of the 16 shortlisted technology families combines a quantitative and a qualitative approach. It started with the quantitative assessment derived from a data analysis including patents (EPO PATSTAT database) as well as EU framework research projects (AIT EUPRO database). The quantitative assessment confirmed the relevance of all shortlisted technologies and became part of the factsheets of the follow-up qualitative assessment.

4.1 Impact assessment data analysis

The desk analysis process and results described in D1.1. provided the search strategies to use quantitative data for the assessment of the shortlisted 16 technology families. In particular, patents (number, growth, share) and industry participation in EU Framework Programmes (EU-FP) related to a technology family have been used as indicators for the industrial and economic impact. The number and growth of EU-FP projects related to a technology family have been used as indicators for the policy impact. A 3-points Likert scale (low, medium, high) has been used to qualify the indicators.

Industrial and economic impact dimension: Quantitative indicators for industrial R&D strengths

- Number of patents: For 2014-18 period, absolute number of patent applications filed for a specific technology family relative to those filed for the full sample of technological families included in the TechEthos project. Deemed representative of a technological family's industrial R&D strength.

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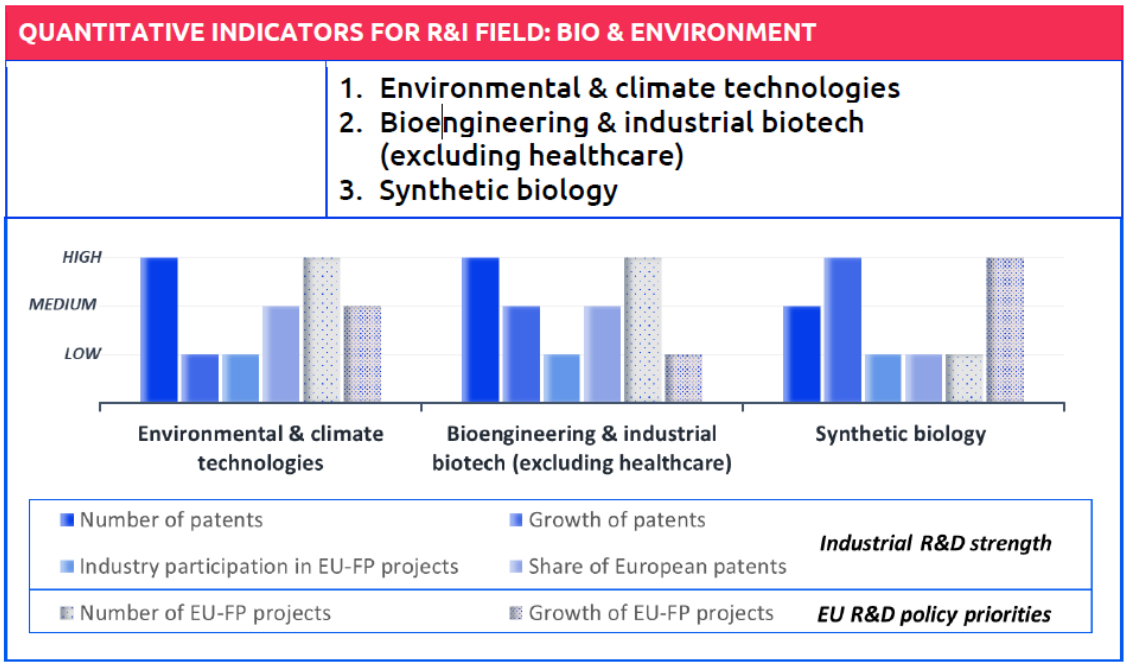
- Growth of patents: For 2007-13 and 2014-18 periods, growth in patent applications filed for a specific technology family relative to growth in filings for all patents. Deemed representative of a technological family's industrial R&D growth.
- Share of Europe in patents: For 2014-18 period, share of patents with inventors located in Europe within the technology family relative to the total share of inventors located in Europe in all patents. Deemed representative of the relevance of Europe in global industrial R&D for the technology family.
- Industry participation in EU-FP projects: For 2014-18 (H2020 projects), share industry participation in the technology family relative to industry participation in all EU-FP projects. Deemed representative of a) degree of industry participation in publicly funded R&D and b) technological readiness level of the technology family (based on the assumption of low industry participation in basic research).

Policy impact dimension: Quantitative indicators for EU R&D policy priorities

- Number of EU-FP projects: For 2014-18 (H2020 projects), absolute number of technology-family-related EU-FP projects relative to the total number of EU-FP projects for all TechEthos technology families. Deemed representative of technology family's prominence among EU policy priorities.
- Growth of EU-FP projects: For 2007-13 (FP7 projects) to 2014-18 (H2020 projects) periods, growth in related EU-FP projects for a technology family, relative to growth in all EU-FP projects. Deemed representative of a technology family's growth in prominence among EU policy priorities.

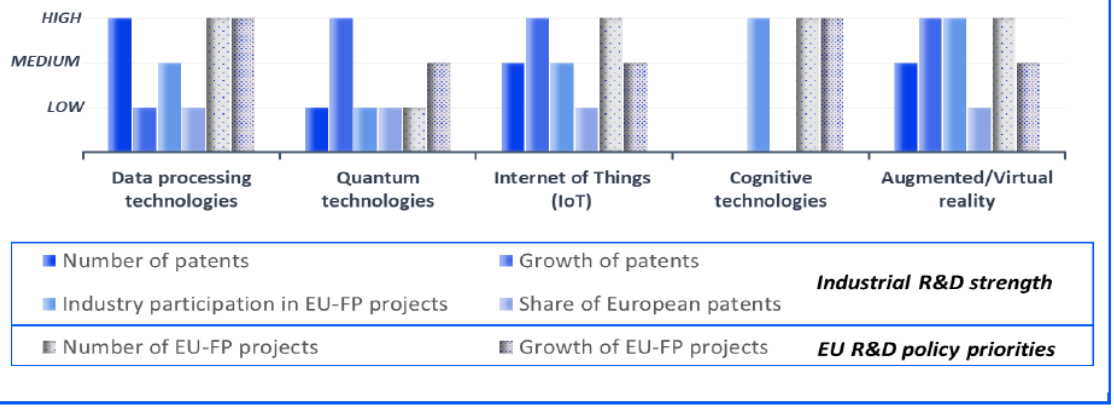
The quantitative data per technology family and research and innovation (R&I) field are shown in Figure 2.



Source: EPO PATSTAT database and AIT EUPRO database, own calculations and Oldham, P., & Hall, S. (2018) for synthetic biology patents.
Note: For patent data, patents filed under the Patent Cooperation Treaty (PCT) were used. The assignment of a patent to a specific technology family was done using the Cooperative Patent Classification (CPC) system. For EU-FP projects, a keyword search strategy was applied to the objectives of all EU-FP projects to identify relevant project s to include in the technology family. A patent or EU-FP project may therefore be relevant for (and included in) multiple technology families.

QUANTITATIVE INDICATORS FOR R&I FIELD: DIGITAL

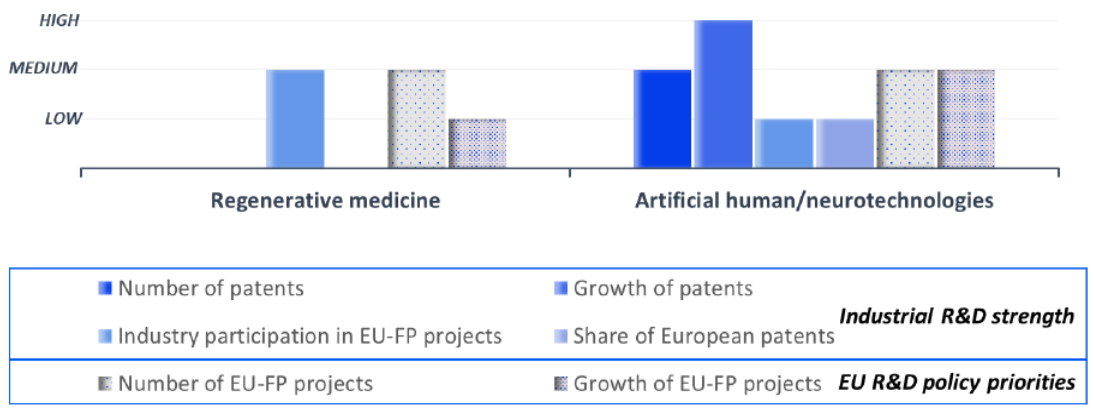
4. Data processing
5. Quantum technologies
6. Internet of things (IoT)
7. Cognitive technologies
8. Virtual reality/ Augmented reality



Source: EPO PATSTAT database and AIT EUPRO database, own calculations and Trappey, A. J., Trappey, C. V., Govindarajan, U. H., Chuang, A. C., & Sun, J. J. (2017) for Internet of Things (IoT) patents and Evangelista, A., Ardito, L., Boccaccio, A., Fiorentino, M., Petruzzelli, A. M., & Uva, A. E. (2020) for Augmented reality/Virtual reality patents.
Note: For patent data, patents filed under the Patent Cooperation Treaty (PCT) were used. Retrieving patent data for cognitive technologies was not possible within this task, as the TechEthos classification differs from the CPC system. The assignment of a patent to a specific technology family was done using the Cooperative Patent Classification (CPC) system. For EU-FP projects, a keyword search strategy was applied to the objectives of all EU-FP projects to identify relevant projects to include in the technology family. A patent or EU-FP project may therefore be relevant for (and included in) multiple technology families.

QUANTITATIVE INDICATORS FOR R&I FIELD: HEALTH

9. Regenerative medicine
10. Artificial human/neuro-technologies



Source: EPO PATSTAT database and AIT EUPRO database, own calculations
Note: For patent data, patents filed under the Patent Cooperation Treaty (PCT) were used.
Retrieving patent data for Regenerative medicine was not possible within this task, as the TechEthos classification differs from the CPC system. The assignment of a patent to a specific technology family was done using the Cooperative Patent Classification (CPC) system. For EU-FP projects, a keyword search strategy was applied to the objectives of all EU-FP projects to identify relevant projects to include in the technology family. A patent or EU-FP project may therefore be relevant for (and included in) multiple technology families.

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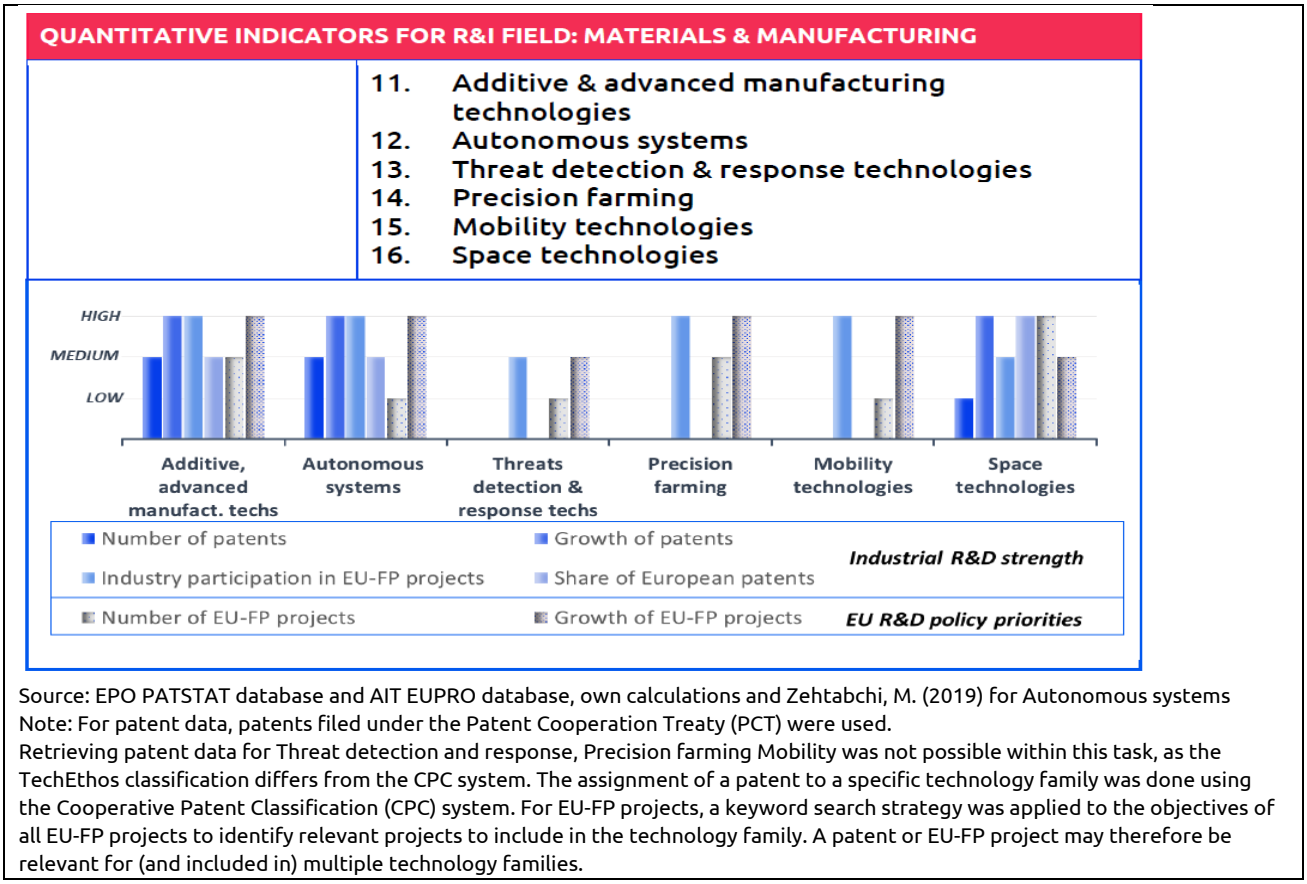

Source: EPO PATSTAT database and AIT EUPRO database, own calculations and Zehtabchi, M. (2019) for Autonomous systems
Note: For patent data, patents filed under the Patent Cooperation Treaty (PCT) were used.
Retrieving patent data for Threat detection and response, Precision farming Mobility was not possible within this task, as the TechEthos classification differs from the CPC system. The assignment of a patent to a specific technology family was done using the Cooperative Patent Classification (CPC) system. For EU-FP projects, a keyword search strategy was applied to the objectives of all EU-FP projects to identify relevant projects to include in the technology family. A patent or EU-FP project may therefore be relevant for (and included in) multiple technology families.

Figure 2: Quantitative indicators for industrial R&D strengths and for EU R&D policy priorities

4.2 Impact assessment expert survey

Based on qualitative assessment criteria, an online survey was designed to gather opinions of external experts in ethics and/or in the 16 pre-selected emerging technology families. The online survey asked experts to assess and validate the expected economic, social and ethical impacts (positive or negative) of these pre-selected emerging technology families in four research and innovation fields ("Bio and environment", Digital", "Health", and "Materials and manufacturing") to support the prioritisation of the technology families and the final selection of a portfolio of three technology families.

Survey design

To collect expert feedback on technology families, the online survey tool ALCHEMER[4] was used for a questionnaire. The full outline of the survey is given in Annex A: Survey.

Before the survey was launched, there was a test run by the consortium members to ensure that there were no content or technical deficiencies in the survey and to ensure a smooth run. In addition, an ethical approval process was successfully conducted prior to the survey under the guidance of consortium partner DMU to ensure that all necessary ethical requirements for stakeholder engagement were met.

[4] https://www.alchemer.com/

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To minimise the exchange of experts' personal data, each TechEthos consortium partner was asked to suggest 15-20 experts working in the field of the 16 selected technology families, ethics for new technologies or related fields and send them invitations to the survey. The selected experts came from the professional network of the TechEthos consortium partners or were derived from web-based research. When selecting the invited experts, care was taken to ensure that the spectrum was as balanced as possible in terms of gender, nationality, stakeholder group, expertise, and professional background. The consortium partner AIT had access to all names and checked the list of experts for overlaps. Invitations were sent either directly by email to each expert individually or via an email distribution platform (e.g., Mailchimp). All TechEthos partners sent out the invitations in a coordinated manner on 17 May 2021 and with a prepared cover letter. In total, about 300 experts were invited to participate in the survey. The survey was open from 17 May to 7 June 2021; a reminder letter was sent to the experts by the TechEthos consortium partners on 31 May 2021.

Respondents could select one or more of four research and innovation fields and the associated new and emerging technology families that they were interested in or felt confident to assess in the survey. Based on the results of the previous horizon scan steps the research and innovation fields and the associated new and emerging technology families comprised:

- Bio and environment including the following technology families: ● Environmental and climate technologies ● Bioengineering & industrial biotech (excluding healthcare) ● Synthetic biology
- Digital including the following technology families: ● Data processing technologies ● Quantum technologies ● Internet of Things (IoT) ● Cognitive technologies ● Augmented reality/Virtual reality
- Health including the following technology families: ● Regenerative medicine ● Artificial human/Neurotechnologies
- Materials and manufacturing including the following technology families: ● Additive/advanced manufacturing technologies ● Autonomous systems ● Threat detection and response technologies ● Precision farming ● Mobility technologies ● Space technologies

There were five questions per research and innovation field as well as technology family on the expected economic, social, and ethical impact; the questions were the same for each of the four fields:

- Question 1: The level of interest by industry and investors in the technology family is...
- Question 2: The potential impact of the technology family on people's lives (also considering minority and vulnerable populations) is …
- Question 3: The potential of the technology family to have a significant impact on societal challenges (e.g., Sustainable Development Goals, principles of the European Pillar of Social Rights) is …
- Question 4: The potential of the technology family to significantly affect or engage ethical principles and values is …
- Question 5: The need for additional guidance in dealing with ethical aspects of a technology family (e.g., not covered by existing guides, standards, regulations) is …

The survey participants could rate the expected impact of the technology families using a 5-part Likert scale (very low, low, medium, high, very high). Factsheets for all technology families were added to the survey to provide survey participants with background information on the specific scope of the selected technology families (see Porcari et al. 2021b).

In addition, the survey participants could share additional comments on the technology families, their expected impact, or potential disruptions. To be able to statistically record the diversity of the survey participants, additional questions were asked about gender, nationality, affiliation to certain stakeholder groups and professional background. The complete list of questions for the survey can be found in Annex A.

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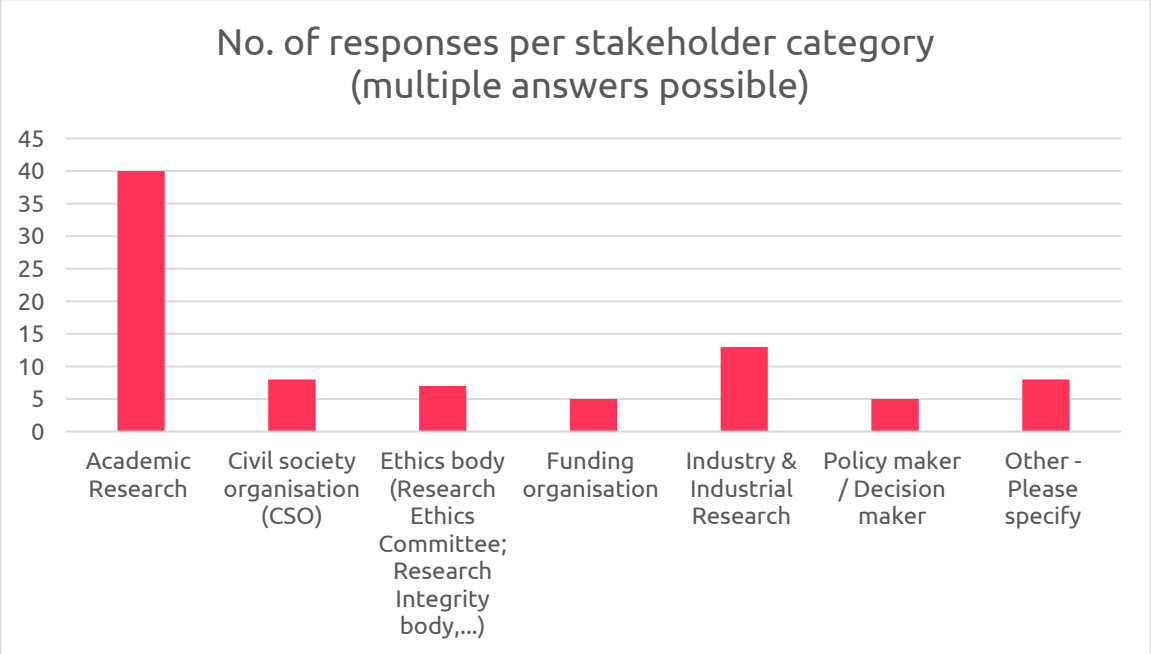
The anonymised data of the survey were processed and analysed using MS Office Excel. The answers of the survey (median per technology family and question) were then combined with the results of other expert reflections in a matrix for better comparability and fed into the further selection process (see Figure 4).

Survey respondents

In total, 77 experts (68% male, 31% female, 1% no answer) from 21 countries completed the survey. Seventy-five percent of respondents came from EU-27, 19.1% from European countries outside EU-27, and 5.9% from non-European countries. The majority of respondents came from Italy (16%), Austria (15%), United Kingdom (9%) and France, Netherlands, and Switzerland (each 4%). The latter also reflects to a large extend the nationalities of the TechEthos consortium partners.

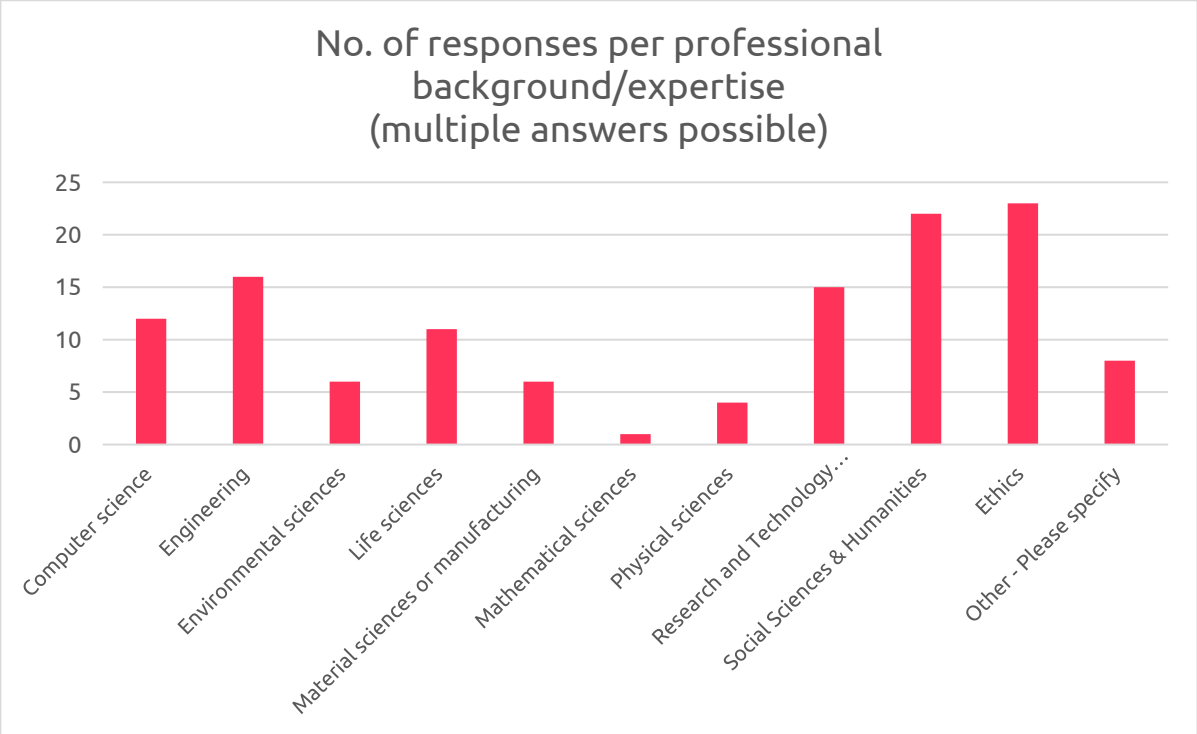
The majority of respondents declared themselves as academic researchers (54.1% of 77 respondents) or as industrial researchers or industry representatives (17.6%), while 9.5% were representatives of ethics bodies (Table 5). The category "Other" included individual representatives of e.g., consultancies, media, international organisations, and research support. That half of the respondents are academics was probably due to the scientific environment and network of the TechEthos consortium partners, from which the invited experts were recruited, but also due to a lower interest of non-academic groups to participate in a survey of a research project. However, the respondents represent a balanced set between academic and non-academic representatives.

Table 5: Stakeholder category of survey respondents (n=77).



The professional background of respondents comprised a wide range of disciplines (Table 6). The majority of respondents indicated a background in ethics (31.5% of 77 respondents), Social Sciences and Humanities (30.1%, or Engineering (21.9%), which reflects the main research areas covered in TechEthos.

Table 6: Professional background of respondents (n=77).



Respondents could select one or more research and innovation fields for assessment. In total, there were 116 responses from 77 respondents (Table 7). Almost two-thirds of respondents considered themselves knowledgeable in the area of digital technologies (46 out of 77), which is more than twice as much as in the area of "bio and environment" and "materials and manufacturing".

Table 7: Number of responses per research and innovation field (n=77)

Research and innovation fields	Percentage of 77 respondents [%]	Responses
Bio and environment	28.4	21
Digital	62.2	46
Health	39.2	29
Materials and manufacturing	27.0	20
Total	-	**116**

Survey results

The median of scores along the five-part Likert scale was calculated for all technology families and all five questions in terms of social, economic, and ethical impact. For all questions, the median is in the range of "high" for most technology families. For each question, 1-3 technology families stand out

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with a median in the range of "very high", and 3-5 technology families with a median in the range of "medium".

Respondents considered most of the 16 pre-selected technologies of high interest to industry and investors; with data processing technologies even being attributed a very high level of interest, while synthetic biology, quantum technology, precision farming and space technology were attributed only medium level of interest (Table 8).

A very high impact of the technology family on people's lives was attributed to environmental and climate technologies, data processing technologies, and mobility technologies. In contrast, quantum technology, precision farming and space technology were attributed a medium level of impact on people, while all other technology families a high level of impact (Table 9).

Experts considered only the potential of environmental and climate technologies to have a very high impact on societal challenges (e.g., Sustainable Development Goals, Principles of the European Pillar of Social Rights), while all the other technology families are expected to have a high or medium impact on societal challenges (Table 10).

Concerning the engagement of ethical principles and values, three technology families were assessed as having a very high potential: data processing technologies, cognitive technologies and artificial human / neurotechnologies. All other technologies were considered to have either a high or medium potential to affect ethical principles or values (Table 11).

A very high need for additional guidelines in dealing with ethical aspects of a technology family was indicated for cognitive technologies and artificial human / neurotechnologies. For most other technology families, the need for additional guidance was also high; for additive manufacturing technologies, precision farming and space technology, the need is only medium (Table 12).

In summary, the feedback from the survey respondents largely confirmed the pre-selection of the 16 technology families with a high socio-economic impact. With a few exceptions, the external experts certified the 16 technology families as having a high to very high social, economic, and ethical impact. Only in individual cases - and depending on the question - some technology families are attributed a medium impact. However, due to the majority participation of experts from the field of academic and industrial research, the answers tend to be driven by research rather than any other stakeholder group.

Table 8 Assessment of Question 1 per technology family: The level of interest by industry and investors in the technology family is...

Low: Low interest is indicated by stagnating job growth or job loss, low investments, low profitability expectations, lack of sector-wide effects, etc.
High: High interest is indicated by significant job growth, high investments, high profitability expectations, potential for sector wide transformations, etc.
Median highlighted in blue.

Technology family	Very low	Low	Medium	High	Very high	Responses
BIO AND ENVIRONMENT						
Environmental and climate technologies	1	1	4	9	6	21
Bioengineering & industrial biotech (excl. healthcare)	0	1	3	10	7	21
Synthetic biology	1	2	9	7	2	21
DIGITAL						
Data processing technologies	0	2	3	10	29	44
Quantum technologies	0	8	14	15	6	44
Internet of Things (IoT)	0	1	7	18	17	43
Cognitive technologies	0	1	10	21	12	44
Augmented reality/Virtual reality	0	4	10	19	10	43
HEALTH						
Regenerative medicine	0	0	7	13	8	28
Artificial human / Neurotechnologies	0	1	5	15	7	28
MATERIALS AND MANUFACTURING						
Additive/advanced manufacturing technologies	0	0	3	8	8	19
Autonomous systems	0	0	4	6	9	19
Threat detection and response technologies	0	1	4	10	4	19
Precision farming	0	4	6	7	2	19
Mobility technologies	0	0	3	12	5	20
Space technologies	0	3	8	7	1	19

Table 9 Assessment of Question 2 per technology family: The potential impact of the technology family on people's lives (also considering minority and vulnerable populations) is …

Low: A relatively small impact on people's lives, e.g., how people work, move, transport, interact.
High: A relatively high impact on people's lives, e.g., how people work, move, transport, interact.
Median highlighted in blue.

Technology family	Very low	Low	Medium	High	Very high	Responses
BIO AND ENVIRONMENT						
Environmental and climate technologies	0	1	2	6	12	21
Bioengineering & industrial biotech (excl. healthcare)	1	1	2	11	6	21
Synthetic biology	1	1	6	11	2	21
DIGITAL						
Data processing technologies	0	0	4	13	27	44
Quantum technologies	0	10	13	9	11	43
Internet of Things (IoT)	0	0	8	16	20	44
Cognitive technologies	0	2	5	17	19	43
Augmented reality/Virtual reality	1	4	15	14	9	43
HEALTH						
Regenerative medicine	0	2	3	13	10	28
Artificial human / Neurotechnologies	0	1	5	15	7	28
MATERIALS AND MANUFACTURING						
Additive/advanced manufacturing technologies	0	0	8	9	2	19
Autonomous systems	0	0	3	7	9	19
Threat detection and response technologies	0	2	7	5	5	19
Precision farming	1	2	10	3	3	19
Mobility technologies	0	0	3	6	11	20
Space technologies	4	2	11	2	0	19

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Table 10 Assessment of Question 3 per technology family: The potential of the technology family to have a significant impact on societal challenges (e.g., Sustainable Development Goals, principles of the European Pillar of Social Rights) is …

Low: The technology family has little or no impact on societal challenges (opportunities, threats).
High: The technology family has a large impact on societal challenges (opportunities, threats).
Median highlighted in blue.

Technology family	Very low	Low	Medium	High	Very high	Responses
BIO AND ENVIRONMENT						
Environmental and climate technologies	0	0	2	4	15	21
Bioengineering & industrial biotech (excl. healthcare)	0	1	4	8	8	21
Synthetic biology	0	2	6	8	5	21
DIGITAL						
Data processing technologies	1	1	5	16	21	44
Quantum technologies	0	6	17	9	12	44
Internet of Things (IoT)	0	5	6	13	19	43
Cognitive technologies	0	6	6	19	13	44
Augmented reality/Virtual reality	1	11	12	12	8	44
HEALTH						
Regenerat19ive medicine	0	3	4	14	7	28
Artificial hum13an / Neurotechnolog8ies	0	1	6	12	9	28
MATERIALS AND MANUFACTURING						
Additive/advanced manufacturing technologies	0	1	6	8	3	18
Autonomous systems	0	2	5	8	4	19
Threat detection and response technologies	0	1	6	6	6	19
Precision farming	0	4	5	2	8	19
Mobility technologies	0	1	1	14	4	20
Space technologies	1	5	8	3	2	19

Table 11 Assessment of Question 4 per technology family: The potential of the technology family to significantly affect or engage ethical principles and values is …

Low: The advance of the technology family has limited or no effects on ethical principles and values.
High: The advance of the technology family has big effects on ethical principles and values. Ethical principles and values include e.g., equality, privacy and data protection, autonomy as well as specific concerns related to health, environment, and human interactions.
Median highlighted in blue.

Technology family	Very low	Low	Medium	High	Very high	Responses
BIO AND ENVIRONMENT						
Environmental and climate technologies	0	3	6	8	4	21
Bioengineering & industrial biotech (excl. healthcare)	0	2	5	6	8	21
Synthetic biology	0	2	4	5	10	21
DIGITAL						
Data processing technologies	0	2	7	8	26	43
Quantum technologies	1	9	18	6	9	43
Internet of Things (IoT)	0	3	11	14	15	43
Cognitive technologies	0	2	5	10	26	43
Augmented reality/Virtual reality	2	10	8	13	10	43
HEALTH						
Regenerative medicine	0	2	5	13	8	28
Artificial human / Neurotechnologies	0	1	0	9	18	28
MATERIALS AND MANUFACTURING						
Additive/advanced manufacturing technologies	2	7	6	3	1	19
Autonomous systems	0	2	3	8	6	19
Threat detection and response technologies	1	3	6	5	3	18
Precision farming	3	3	5	5	3	19
Mobility technologies	1	3	5	8	3	20
Space technologies	5	3	8	2	1	19

Table 12 Assessment of Question 5 per technology family: The need for additional guidance in dealing with ethical aspects of a technology family (e.g., not covered by existing guides, standards, regulations) is …

Low: The ethical implications of the technology family could be managed with existing guidelines, standards, and regulations.
High: The ethical implications of the technology family will need new guidelines, standards, and regulations.

Technology family	Very low	Low	Medium	High	Very high	Responses
BIO AND ENVIRONMENT						
Environmental and climate technologies	0	7	3	8	3	21
Bioengineering & industrial biotech (excluding healthcare)	0	4	6	4	7	21
Synthetic biology	0	3	7	4	7	21
DIGITAL						
Data processing technologies	0	1	6	15	20	42
Quantum technologies	0	4	16	11	11	42
Internet of Things (IoT)	0	3	6	18	14	41
Cognitive technologies	0	0	4	16	22	42
Augmented reality/Virtual reality	2	6	11	14	9	42
HEALTH						
Regenerative medicine	1	1	5	12	9	28
Artificial human / Neurotechnologies	0	0	4	8	16	28
MATERIALS AND MANUFACTURING						
Additive/advanced manufacturing technologies	2	5	6	4	1	18
Autonomous systems	0	1	3	6	8	18
Threat detection and response technologies	1	2	2	7	6	18
Precision farming	1	6	4	5	2	18
Mobility technologies	1	2	5	9	2	19
Space technologies	4	3	5	4	3	19

4.3 Impact assessment matrix

The results from the horizon scan steps "identification" (section 3, qualitative desk analysis) and "assessment" (section 4.1 quantitative desk analysis and 4.2 survey), have been condensed in a Multi-Criteria Decision Analysis impact assessment matrix (Figure 3). It represents an interim solution to support the follow-up validation and decision processes including TechEthos internal and external experts.

Figure 3: the MCDA Impact assessment matrix.

Impact & Criteria / List of Technologies		INDUSTRIAL & ECONOMIC			ETHICS		PUBLIC		POLICY	LEGAL
		New and emerging	Enabling	Interest by industry and invertors	Ethical principles and values	Additional guidance in ethical aspects	Societal challenges	People's lives	Policy	Existing legal frameworks
		Desk analysis	Desk analysis	Survey (Q1).	Survey (Q4).	Survey (Q5)	Survey (Q3)	Survey (Q2)	Desk analysis	Desk analysis
R&I field	Technology family			Median	Median	Median	Median	Median		
BIO & ENVIRONMENT	1. Environmental and climate	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	VERY HIGH	VERY HIGH	VERY HIGH	HIGH
	2. Bioengineering & biotech	MEDIUM	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	VERY HIGH
	3. Synthetic biology	VERY HIGH	MEDIUM	MEDIUM	HIGH	HIGH	HIGH	HIGH	HIGH	VERY HIGH
DIGITAL	4. Data processing	MEDIUM	VERY HIGH	VERY HIGH	VERY HIGH	HIGH	HIGH	VERY HIGH	VERY HIGH	LOW
	5. Quantum technologies	HIGH	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM	HIGH
	6. Internet of Things (IoT)	HIGH	VERY HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	VERY HIGH	HIGH
	7. Cognitive technologies*	HIGH	VERY HIGH	HIGH	VERY HIGH	VERY HIGH	HIGH	HIGH	VERY HIGH	HIGH
	8. Augmented & virtual reality	VERY HIGH	HIGH	HIGH	HIGH	HIGH	MEDIUM	HIGH	MEDIUM	HIGH
HEALTH	9. Regenerative medicine	HIGH	LOW	HIGH	HIGH	HIGH	HIGH	HIGH	VERY HIGH	HIGH
	10. Artificial human & neurotech*	HIGH	MEDIUM	HIGH	VERY HIGH	VERY HIGH	HIGH	HIGH	MEDIUM	VERY HIGH
MATERIALS MANUFACTURING	11. Additive & manufacturing	VERY HIGH	VERY HIGH	HIGH	MEDIUM	MEDIUM	HIGH	HIGH	VERY HIGH	HIGH
	12. Autonomous systems	HIGH	VERY HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	VERY HIGH	HIGH
	13. Threat detection & response	HIGH	MEDIUM	HIGH	MEDIUM	HIGH	HIGH	HIGH	VERY HIGH	HIGH
	14. Precision farming	HIGH	LOW	MEDIUM	MEDIUM	MEDIUM	HIGH	MEDIUM	MEDIUM	MEDIUM
	15. Mobility technologies	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	VERY HIGH	VERY HIGH	HIGH
	16. Space technologies	VERY HIGH	VERY HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	VERY HIGH	VERY HIGH

5 Validation and final selection of TechEthos technology portfolio

In this section, we recount the processes of arriving at the final selection of technology families, moving from 16 to 5 to 3 technology families based on iterative inputs from external sources, ADIM Board, and Consortium members. Section 5.1 covers expert input to the selection process, based on six external interviews and a workshop with the ADIM Board. Section 5.2 covers pre-selection of technology families based on a TechEthos consortium. Section 5.3 presents the final selection workshop. Section 5.4 presents the final amendments to the selected technology families, as well as the technology families themselves.

5.1 Expert Inputs to Final Technology Family Selection Process

Expert Interviews

A series of six semi-structured interviews were conducted with external experts and ADIM Board members to generate initial reflections on, and tensions related to the 16 potential technology families, as well as impact assessment criteria. Consortium partners recommended and identified experts in new and emerging technologies and science policy to be interviewed. Participants' informed consent was secured in advance of each interview, as per DMU ethics review. The interview script (Annex B, 9.1) asked participants about "their experiences on horizon scanning, foresight, governance and impact assessment of new and emerging technologies, and [their] opinion of the initial technologies and impact assessment activities conducted by the TechEthos project." Participants were asked to reply to interview questions based on their personal experiences, with a focus on the technologies and innovations that, on reflections, they found most relevant. Interview results included reflections on research fields and technology families, impact assessment criteria, final selection of technology families, important considerations for after selection, and additional resources.

Regarding the technology families, it was unclear to experts why some technology families were narrower or more exclusive than others. For example, Synthetic Biology was noted for its significant heterogeneity—did the project intend to differentiate into categories like human versus plant gene editing? How might we eventually resolve such issues? In addition, the divisions among technology families were not always clear. For example, one interviewee noted the seeming arbitrariness of the Precision Farming technology family—if it consists of robotics, they mused, why not include this option in advanced manufacturing; or, if it would include genetically modified plants, how would it be separated from Synthetic Biology? Why, for that matter, would it be in the materials and manufacturing research field and not the bio and environment field? One interviewee pointed out—the list of technology seemed more an amalgamation of technology and science (synthetic biology and advances materials), global challenges (environmental technologies) and regulations frames (Blockchain). One interviewee found quantum technology specific compared than cognitive technologies, which seems a wrap up of different technologies, computing techniques and science disciplines. Another comment was based in the interoperability of technologies— Some technologies rely on specific foundations, for example, virtual reality, quantum technology and synthetic biology need digital architectures to exist, these are the "foundation" on which other technologies are built on. A similar reflection emerged from Mobility and Precision farming technologies by including IoT approaches, which is based on digital platforms. In general, however, there was also appreciation for the open-endedness of many of these technology families, offering the project flexibility.

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Regarding impact assessment criteria, interviewees wondered how, if experts were to be making assessments of these criteria in the survey, the project might collect additional information on expert confidence-level or certainty-level of their assessments. One interviewee suggested—to underline the time-horizon, ideally for each criterion, at least for the public impact to highlight whether the risk/benefit is short or long-term. Criterion 1.1 was reviewed as rather difficult to answer, as each Technology Family contains many technologies, and any two technologies may be totally different on a spectrum of new and emerging or mostly incremental improvements. Criterion 1.3 was suggested to cross-check with EU and worldwide funding and government development data bases or dashboard to validate our results in terms of market, social barriers, and investments. Criterion 2.1 was noted to significantly depend on a technology and its application—for example solar panels may not be very controversial, but an environmental climate technology like wind turbines may engender more controversy, and geoengineering more still…yet all three represent entries in the environment and climate technology family. The same was observed as problematic with Criterion 2.2. Finally, the ethics criterion 2.1 "ethical principles and values" was considered unclear by some participants: was it intending to identify a principlist approach or was some other distinction being referenced?

Regarding final selection of technology families, one insight elicited was to reflect on where or how TechEthos might do the most good, for example based on how much attention is being paid (or not) to the technology family. For example, within Synthetic Biology, Human Genome Editing might be a very advanced, attractive area for focus…but already crowded with numerous projects and researchers and critical ethical perspectives. Might there be another, lower visibility but still high-impact technology family where TechEthos could have an outsized impact? Another way to inform selection of technology families surfaced though the interviews was to cross-reference important political documents like the EU President's Work Programme document or the Parliament and Council documents of similar weight to attempt to discern major political priorities in which associated technologies might hint at future need for and thus demand, for results of TechEthos work.

The interviews yielded **critical feedback on important factors to keep in mind** even as the project moved beyond the technology family selection phase. One factor was the issue of distributional equity. Once the 3 technology families were selected, one interviewee urged, various distributional effects of technology development, benefit, and negative impacts should be attended to. For example, one could imagine that were the project to choose Digital Technologies, the interviewee mused, there could be wonderful positive impacts in places with cities and infrastructure exist and, if done in certain ways, relegate e-waste and toxic environmental extraction effects to other, less developed regions. In addition to distributional effects in the current state, from a sustainability perspective, the project was also encouraged to adopt a perspective accounting for intergenerational equity—the way future generations might be burdened by the technology development efforts. For example, intergenerational issues could be quite important to address in Space Technology, where one could imagine perspectives to supporting development ranging from "get off this rock" to "fix earth first", and questions of "who gets to go" and "what do people who stay have to deal with."

Finally, **interviewees offered a range of helpful resources to consider**, from technology roadmaps to non-profit foundation reports passing through academy, industry and innovator, government, and policy as well foresight institutions. In addition, interviewees were keen to observe the importance of remembering that surveying documents gives an impression of a "common" in the zeitgeist, but to find weak signals, it would be essential to speak with experts where research is happening, and issues are not yet in the public consciousness.

ADIM Board validation workshop

In a Zoom workshop on 16 June 2021, the TechEthos ADIM Board reflected on the project's impact assessment matrix based on presentation by TechEthos Work Package 1 leader and task leads. After

an initial presentation of the 16 technology families, participants discussed the selection process and impact assessment criteria. The discussion from the workshop generated a range of provocative questions to support the design of a pre-selection process going into the final selection workshop:

- How broad / narrow do we make the technology families? (a clear rationale is essential)
- Do we distinguish an interest in end-point technologies (like augmented and virtual reality) versus the system/infrastructure these technologies leverage (e.g., Internet of Things etc.)?
- In the final selection, do we want to ensure we have technology families represented from each research field?
- Are we interested in helping to structure conditions for future conversations about ethics (e.g., the example of solar radiation management in developing countries), or address rather more popular, near-term subjects?
- Are we interested in cross-over groupings (for example, applications of AI in human genome editing)?
- For a pre-selection, are we interested in overall score or in a key gaps TechEthos could address (i.e., the TechEthos value-add)?
- What are the problems we are trying to solve in this project? Does it relate to competing incommensurable ontologies when assessing / developing technologies?
- Can we select technologies with the most novel attributes and ethical issues for which people are not yet equipped to handle?

These critical questions were accompanied by more direct points. A means of weighting criteria was deemed important. Options for weighting included: Ethics Criteria, specifically 2.2, which points to where ethics guidance may be most needed; and the Policy Criteria, deemed to point to areas where there are gaps in current policies. We were encouraged to arrive at "Catchy names" for technology families to support communication and dissemination. The project was encouraged to see the choice for proceeding as either a) selecting three narrow and well-defined technology families to analyse could be a way to then jump to more general guidelines; or b) pitching the work at a high-level for one selection, and then more narrowly for others. Overall, we were discouraged from selecting technology families where issues are more multi-lateral political or diplomatic, like space technologies, where ethics guidelines might have less of an impact than other interventions.

5.2 Consortium Pre-Selection Process

TechEthos Work Package 1 Preliminary Pre-Selection

Deciding to pre-select technology families

The purpose of the pre-selection was deemed to support final selection of three technology families and orient the remainder of TechEthos work. The Horizon Scan work demonstrated the high potential social and economic impact of all 16 short-listed technologies, along with potential ethical concerns, policy, and legal implications. As such, in one way, any set of technology families could have been further selected and refined and focused upon for an interesting project. However, as the consortium needed to select three in a transparent, reasoned, and justifiable way given the mission of the project, an approach to down-selection was deemed essential. The following goals of selection were determined in conversation among Work Package 1 (WP1) participants:

- Technology families selected should be potentially ethically disruptive and portend high socio-economic impact
- The selections should include examples supportive of generalization to cross-technology applicability
- Selections should reflect a lack of coverage by other projects / agencies
- Final selection should speak to technology families with an impact on the research community, at industrial and economic level, as well as being policy relevant

The way in which these goals speak to factors beyond the five impact assessment criteria necessitated broader discussion among the Consortium, ADIM Board and other external experts. The pre-selection process involved a dialogue between a narrowing-down of focus based on qualitative and quantitative inputs of the horizon-scanning, as well as an opening-up of focus based on the deliberation of "other criteria" for including a technology family. Going into the pre-selection workshop, these "other criteria" included: expression of European Commission interest / political priorities; time-horizon of the technology; scientific /intellectual interest of the consortium; potential TechEthos value-add; other considerations.

Preliminary pre-selection

A key result of the ADIM Board meeting was to advance a "triage" approach to excluding some and including other technology families. While the consortium participants were loath to prematurely exclude technology families (reflected in the way a "remaining pool" of technology families continued to accompany the pre-selection), the pre-selection does present an approach to preferential advancement of certain technology families over others. As such one point raised by the ADIM board was that, if generating actionable ethical guidelines (ethics-by-design guidelines) for three new and emerging technologies then perceived need for ethical guidelines ought to be a prominently weighted criterion (Criterion 2.2). In addition, based on the importance of potential high-impact of technologies, an indicator of reach across industrial and economic sectors was considered reasonable. Therefore, the next highest weighted criteria for advancing certain technologies forward was selected as "interest by industry and investors" (criterion 1.3). Finally, given the call for potential high public impact, the criterion 3.2, impact on people's lives, was included as the third filter. The Work Package 1 team leading the pre-selection process agreed that, once the filtering was completed, preliminary results would be validated by examining additional data on project, patent developments, and expected policy/legal impacts. Such validation helped to ensure that the pre-selection didn't incidentally advance technologies unsupportive of the project goals in other ways.

A final factor in decision-making on pre-selection was to arrive at a number that would make subsequent deliberation feasible. Moving ahead with a pre-selection of ten or even eight technology families was deemed impracticable for the consortium under project constraints. As such, the application of pre-selection considerations needed to yield a number amenable to a daylong deliberative workshop to inform the final selection process.

The Work Package 1 team met to apply the above guidance to craft a preliminary pre-selection of 5 technology families to validate with the Consortium at a 25 June 2021 online meeting. Based on the concept of "triage" advanced by the ADIM Board, three social and ethical impact criteria were deployed as "filters" to remove options from our list of 16 candidate technology families. The resulting five technology families—environmental and climate, data processing, cognitive technologies, artificial human & neurotech, and mobility technologies were taken forward by Work Package 1 and into the 25 June Consortium meeting.

Consortium Pre-Selection Validation

The 25 June 2021 Zoom-based Consortium meeting opened with an input session devoted to reviewing the Work Package 1 task of horizon scanning. Next consortium members were invited to share feedback on the preliminary pre-selection, share thoughts on how to proceed with final selection (e.g., to consider any other criteria), and to openly discuss the pre-selected and remaining technology families.

No major objections were shared to the preliminary pre-selection process as presented, however there was a strong push to be able to have a more open-ended conversation about the technology families themselves, from a substantive dimension. The consortium members encouraged a clearer

elaboration of the purpose of the pre-selection process as well as the terms of weighting of criteria, formulation of each successive "filtering" and the formulation of filters. Consortium members found inconsistent that in the first formulation of the pre-selection triage, in some cases, technology families below a certain score would be *excluded*, and others above a certain score would be *included*. The following re-formulations were adopted to be more uniform with regard to *including* a technology family in the final pre-selection set:

- Baseline: across Ethics, Industrial, and Public criteria, to include a technology, the perceived ranking of a technology family in any one of these criteria must be at least "medium."
- Criterion 2.2: Include any technology families in which the perceived need for ethics guidance is "high" (based on expert survey results). Further, any technology family with a perceived need for guidance of "very high" ought to automatically be included in the pre-selection, regardless of subsequent filters. This serves to ensure that TechEthos considers such technology families in the final selection process.
- Criterion 1.3: Include any technology families associated with a "high" level of perceived industry and investor interest (based on expert survey results and corroborated by desk research)
- Criterion 3.2: Include any technology families associated with a "very high" impact on people's lives. In this final pre-selection filter, considering only "high" scoring technologies would not have afforded enough discrimination, leaving the field to broad to functionally deliberate in any pre-selection or final selection dialogues.

Triage pre-selection filters were modified to all be phrased as "inclusionary" rather than exclusionary (Figure 4).

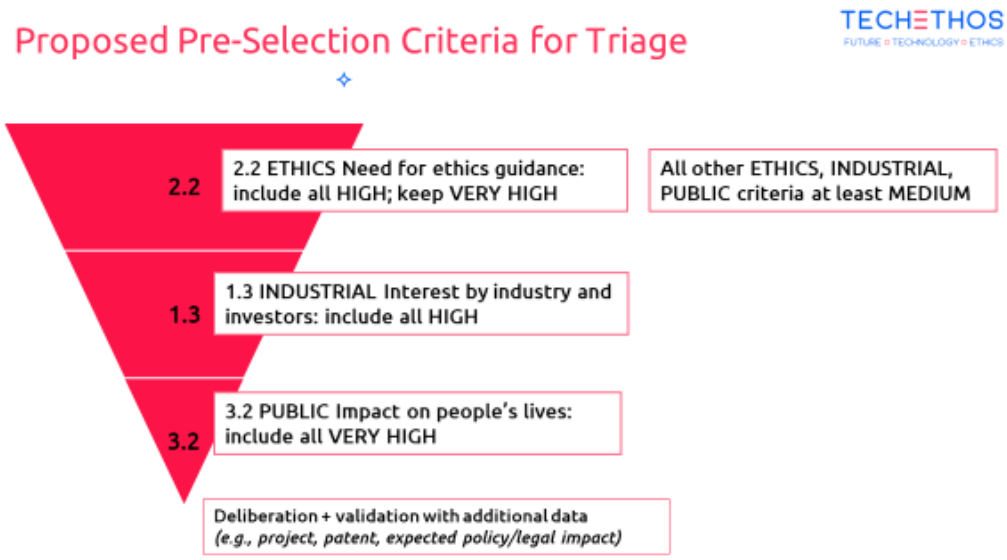

Figure 4: Pre-selection filters applied to technology families before WP1 workshop.

Discussion points throughout the Consortium pre-selection workshop clustered and related to the following major subjects: how broad or coarsely to group technology families; whether to group according to questions of technology function and application or form and design; how TechEthos Consortium expertise ought to factor into final selection; and how the potential for TechEthos to have an impact should be factored into final selection conversations. The details of these discussions are presented in Annex B, 10.2. The details of discussions about the five technology families are also in Annex B, 10.3.

The results of the pre-selection process are summarized in Figure 5.

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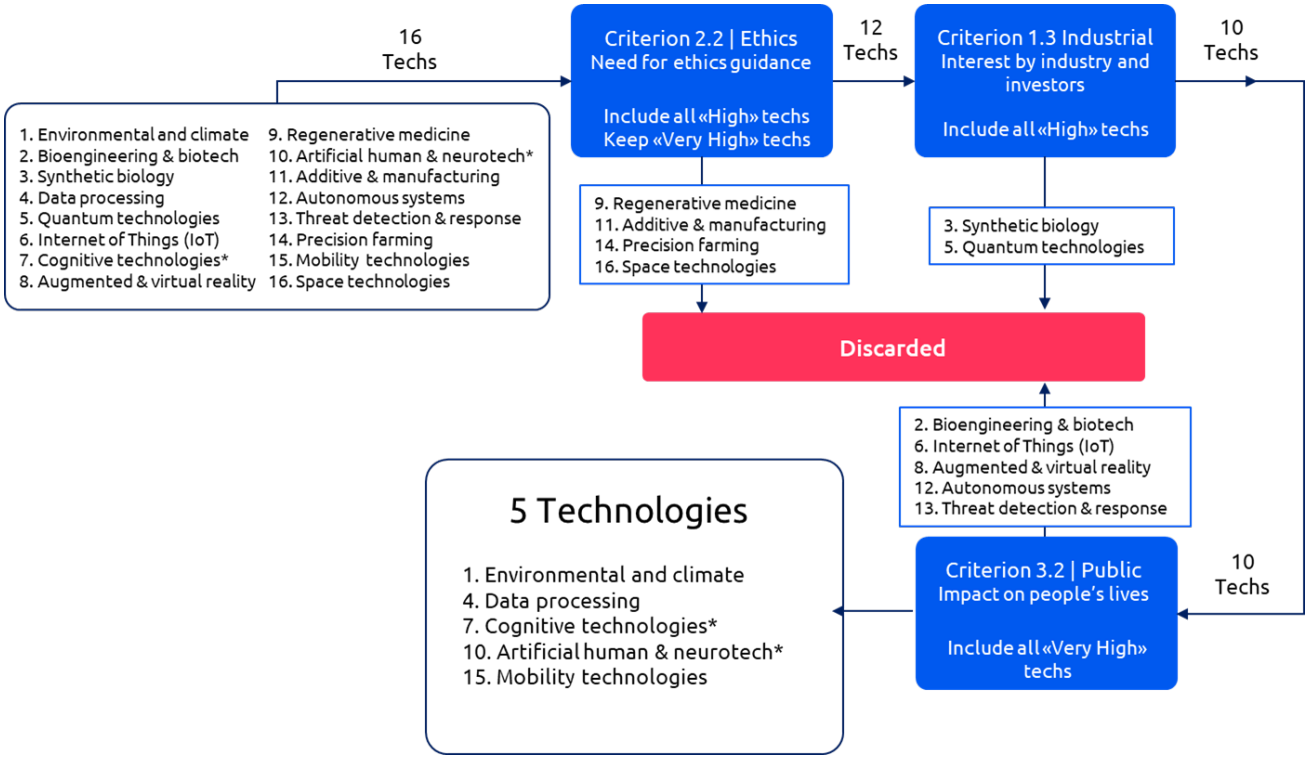

Technology families with an asterisk (*) were kept in the final list regardless of subsequent filters. To see the level of the 16 technologies ("Very-high", "High", "Medium", "Low" and "Very low") as a function of the criteria used for the "filtering" procedure, please refer to Figure 3. More details about the criteria can be found in Table 4.

Figure 5: Representation of the "filtering" procedure carried out for the TechEthos pre-selection process.

Ultimately, for the final selection workshop, the Consortium agreed on the following criteria may to discuss, prioritize, and elaborate to finalize any selection of the TechEthos portfolio of technology family:

- Level of Consortium and ADIM expertise
- Political priority of the technology family
- Potential TechEthos value-add to the development of the technology family
- Potential interest to the consortium
- Impact assessment criteria

Based on discussion of these "other criteria" (supplementing the impact assessment criteria) at the final selection workshop, a group decision could be taken on what a "selection justification" might look like across the "portfolio" of TechEthos technology families.

5.3 Technology Family Portfolio Final Selection Workshop

Leading up to the final selection workshop, the WP1 team met to structure discussion prompts related to breadth / narrowness and technical principle / function of the technology families pre-selected. In addition, the WP1 team worked to prepare materials in such a way as to support participatory deliberation. Intent in structuring the material included a proposal to add a framing to the challenge of selecting a "portfolio of technology families" that satisfies the following criteria – for example:

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- All technology families reflect a political priority
- TechEthos has a chance to influence the conversation about and development of the technology family
- The potential functions / applications of the technology family are clearly elaborated with an eye toward future engagements (e.g., with publics, experts, policy makers)
- Reflect some technology families that the consortium is expert in or, if not, passionate to learn about (e.g., two may be expert areas one may be of high interest; or vice-versa; or some combination thereof)

Overall, one main input, a participatory Mural canvas, and three main activities were designed for the workshop. A mix of facilitated plenary and breakout room sessions, with time for individual reflections, was refined in between the CM meeting and the WP1 selection meeting. The final agenda is presented in Annex B, 10.4. The decision was made to, within the structure of the meeting, keep conversation as open as possible to allow for broad discussion of the technology families. As such, no changes in groupings were made before the workshop.

Workshop design

A total of 28 workshop participants including TechEthos consortium members, ADIM Board members and additional external experts attended a 2 July 2021 online workshop to support final technology family selection for TechEthos. The 'flow' of the meeting channelled conversation toward a discussion of what an appropriate portfolio of technology families could look like for TechEthos and why (see agenda Annex B, 10.4). In service of this objective, the meeting opened with a review of Horizon Scanning results. In this presentation, participants were walked through key considerations of the methodology, introduced to the impact assessment criteria used, presented with the results of the pre-selection and rationale, oriented to results of the horizon scanning survey, and, finally, apprised of the tasks in the remaining time of the workshop.

Subsequently, participants were engaged in a World Café-style session to "**refine**" the pre-selected technology families. In 15-minute increments, participants reviewed and commented on each technology in succession. Using zoom, five breakout groups + the main room were opened. After walking participants through the various sections of the mural, everyone was invited to join a breakout room, each devoted to a different technology family. Each room was hosted by a consistent facilitator to provide "institutional memory" for the duration of the Café. In addition, the Mural served to capture participant refinements of the technology family, specifically with regard to a) the granularity of the technology family and b) different reasons why a particular refinement of the technology family would be suitable for the TechEthos project. To support participants in specifying the granularity of the technology family, material from the Horizon Scanning fact sheets were added to the mural. This material included examples of the technologies involved; examples of applications; examples of potentially related technologies from other technology families; the ethical issues surfaced in the Horizon Scan, and related qualitative results from the survey and 25 June previous consortium meeting. An example of the completed mural for the Environment and Climate Template is presented in Figure 6, below.

Figure 6: Example of World Cafe Mural for the environment and climate technology family.

After lunch and in plenary, participants were invited to "**reflect**" on the completed outcome of the breakout sessions. After participants had a few minutes to scan the results for themselves, each breakout room facilitator distilled a brief overview of key discussion points and any advancements in proposals of a more granular definition or elaboration of the technology family. Notes were made in a "discussion" section of the Mural to ensure data capture. The reflection discussion transitioned into a final discussion at the level of "**selecting**" an appropriate portfolio of technology families to support

TechEthos project ambitions.[5] The prompt was given as follows: “Which three (four) technology families and can make a strong portfolio for TechEthos, to develop guidelines for ethical analysis of new and emerging technologies?” Each participant was first asked to come up with a combination of their own, and then to add their rational to the discussion with a differently coloured ‘sticky-note’ on the Mural. Subsequent plenary discussion elaborated on the portfolios and justifications surfaced.

Workshop results

Reflecting across the technology family, selection, and portfolio discussions on the 2 July Mural and Zoom chat, several points of clarity emerged.

Regarding **selecting a portfolio of technologies**, there seemed a general convergence around environment and climate, data/digital/AI, and human/biotechnologies (cognitive or genetic). The **"appropriate granularity," however, remained an open question**. One approach discussed and favoured in the workshop was to select a "meso-level", like "carbon remediation technologies" within which several technologies or application cases could be considered with a range of associated ethical issues.

Spanning issues of environment and climate, digital, and human/biotechnologies would connect TechEthos to **a rich set of questions around issues of ethics, justice, and trust in human and technical systems.** For example, issues of interest were identified related to environmental, distributional, procedural, and intergenerational justice; responsibility, irreversibility; trust in people, technology, and human systems; balancing individual and collective rights; morality of influence and more. Broadly, this portfolio would make it possible to address concerns including:

- questions of “control and irreversibility” issues of human control, accountability, and responsibility
- issues of technologies that fundamentally change the way human values and ethical concerns themselves get formulated, filtered, expressed, and acted upon.
- cross-cutting interest in in to handle multiple “human-X” interactions: issues of human-internal, human-machine, human-human, human-nature relations being changed

At the close of the workshop, the project was encouraged to **look out more than five years into the future**, not shy from **going deeper into previous work**, and to be sure to remain **connected to societal challenges**. A word of caution did surface not to be distracted by "shiny examples" with potentially less transformative impact than, say more system-wide but less “exciting” attributes. Further discussion on technology family selection was subsequently taken up by the WP1 team, for presentation to the consortium at a 20 July online meeting in the hopes of being able to offer a final selection for proceeding.

Detailed discussion points are presented from the breakout room conversations and plenary sessions in Annex B, 10.5.

Selecting a TechEthos portfolio of three technology families

In the concluding discussion of the workshop, considerations for selecting a portfolio of technologies were discussed. Participants noted that care should be taken to ensure high-potential social and

[5] The project ambitions were repeated and elaborated in the beginning of the input session on the Horizon Scanning Results. Presented as “goals of the selection process” in support of developing ethics-by-design guidelines for three (four) new and emerging technologies, we elaborated interest in seeking: ethically disruptive, high socio-economic impact technologies in areas not covered by other projects or agencies, and possible to offer impact for researcher, industrial, policy, and other communities.

economic impact remains a priority for selection (e.g., not to select based on overly esoteric ethical concerns) to balance the already "baked in" consideration of social scientists and humanists in the Horizon Scan (see section 4.2).

Reflecting across the possible portfolios, one compelling heuristic was to select technology families that each exert strongest influence in different spheres of existence:

- A technology family affecting conception of what it means to be human (e.g., cognitive, or genetic alteration)
- A technology family affecting how we organize as humans (e.g., systems of identity, influence, or organizational forms)
- A technology family affecting human-climate interactions (e.g., carbon remediation systems)

However, arguments could be made that any technology family, studied closely enough, or considered systemically, will affect human-internal, human-human, and human-nature relations. As a heuristic, such a tri-partite division was considered an appealing way to talk about cross-cutting areas of concern.

6 Final TechEthos Technology Family Portfolio

Following the discussions and decisions of the TechEthos process of selection, the following three technology families selected:

- Climate Engineering (interaction with the planet)
- Digital Extended Reality (XR) (interaction with the digital world)
- Neurotechnologies (interaction with the human body)

Work package 1 team members compiled a set of three factsheets for each of these technology families and shared the selection results with the European Commission project and policy officers. Their feedback affirmed the decision on the TechEthos technology portfolio and provided additional comments welcomed by the TechEthos consortium (e.g., to emphasize behavioural technologies within DXR). The revised final TechEthos technology portfolio is outlined below with the attendant factsheets. We do note that the scope and emphasize of the finally selected technology families are expected to continue to change as TechEthos proceeds and new learnings arise.

The TechEthos selection conveys a set of potentially high socio-economic impact technology families with significant ethical implications in the interaction of technologies with the planet, the digital world, and the human body.

- **Climate Engineering** (or geoengineering) technologies can help mitigate climate change on a local and worldwide scale and detect and respond to global threats due to the climate crisis. They represent a group of technologies that 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. This technology family includes, for example, technologies for carbon capture, usage, and storage (CCUS) applications that might help reduce the cumulative anthropogenic carbon dioxide (CO_2) emissions, with consequences on the planet's temperature regulation. Solar geoengineering technologies are another example, raising the possibility of modifying the biosphere's interaction with solar radiation by creating a dense cloud 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 them? What could be the future environmental consequences of their applications?

- **Digital Extended Reality** technologies combine advanced computing systems (hardware and software) that can change how people connect with each other and their surroundings and influence or manipulate human actions through interactions with virtual environments. Digital Extended Reality includes artificial-intelligence-based technologies emulating or connecting with human cognitive functions (e.g., voice, gesture, movement, choices, feelings), as well as human-digital machine interaction 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). This technology family also include computing systems used for Natural Language Processing (NLP) applications, intended to process, and analyse a vast quantity of human natural language information (e.g., voice, text, images) in advanced extended reality situations, extracting the most relevant data to profile and influence behaviours. A typical example is observed in online platforms and social media, influencing consumer opinions and people's behaviour. This might lead to unexpected concerns, such as the "chilling" effect, where people avoid speak or act freely to not be influenced or controlled by digital technologies and online platforms. Potential ethical repercussions of such technologies include cognitive and physiological impacts as well as behavioural and social dynamics, such as user behaviour influencing, people monitoring and supervision, privacy, security, and sensible data management.

- **Neurotechnologies** represent a group of technologies used directly monitoring, assessing, mediating, manipulating and emulating structure, functions, and capabilities of the human brain. These technologies offer possibilities to improve health and well-being. 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 neuro-devices, 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 others. Nevertheless, neurotechnologies products and services are raising concerns about personal data privacy management, integrity and responsibility, access to these systems, and potential off-label and misuse of such technology.

Each of the technology families are presented in additional detail, below, through the completed WP 1 factsheets.

6.1 Technology family factsheet: Climate engineering

TECHNOLOGY FAMILY	CLIMATE ENGINEERING
R&I field	BIO and ENVIRONMENT
Focus	Interaction with the Planet
Description	Climate engineering is a family of technologies that enables the modification of natural processes and human activities looking to detect, mitigate and respond to global threats due to climate change crisis locally and globally.
Key functions and capabilities	**Modification of the chemical/physical/biological processes in the biosphere at regional and global scales (e.g., albedo modification).** **Carbon remediation/CO_2 sequestration and utilization/carbon prevention.**
Key Industrial sectors	Environment; energy; chemicals and materials; biotechnologies.
Examples of technologies	Geoengineering technologies (e.g., solar geoengineering).

	Carbon capture, usage, and storage (CCUS) technologies; carbon dioxide splitting technologies, algae and microorganisms against climate change; artificial photosynthesis.
Examples of applications	Modification of the biosphere interaction with solar radiation globally (e.g., stratospheric aerosol scattering) or locally (e.g., heat reflection to protect and restore snow or glaciers). Enlargement of artificial and natural carbon sinks; large-scale carbon removal; carbon sequestration or fixing (e.g., turning carbon into construction materials), microbes for CO_2 capturing as their sole carbon source.
Time horizon to mass market[1]	Short to medium for small and regional scale deployment, medium to long term for large-scale and global deployment, and most advanced application.

KEY ETHICAL ISSUES	
Irreversibility o Responsibility and Global Scope o Equal access o Precautionary measures o Environment o Health o Safety o Inclusivity o Security	
Consideration on expected industrial and economic Impact	**Consideration on expected public Impact**
Includes radical innovations Enabling in some industrial sectors (e.g., energy and environmental management in the manufacturing industry) Priority by some industrial players in relevant industrial sectors	Some applications (e.g., CCUS) have a limited direct impact on people's lives (business to business applications). Other technologies (e.g., geoengineering) could have large implications for communities and individuals. High impact on the environment and climate **Key SDGs and EPSRs**: Responsible consumption and production; climate action
Consideration on expected policy impact	**Consideration on expected legal Impact**
Priority for most national, EU and global policy organizations (e.g., contribute to EU climate neutrality, target for 2050 in the EU Green Deal)	Requires adaptations in existing frameworks (e.g., impacts/changes on the Emission Trading System - ETS)
Why selected	
Quick overview of impacts: A technology family with the potential to introduce transformations in the access and use of natural resources (energy and environment) by regions, industrial processes, and society at large.	
Desk analysis: ○ *Ethics*: Potential for irreversible transformation, access and inequalities across regions and economies. ○ *Industry and Economy:* Significant investment by sectorial players (energy, environment sectors); large and worldwide potential economic (political) impact. ○ *Public*: Potential large impact on individuals and communities ○ *Policy*: Addressing a very high public and policy priority at the international level. ○ *Law*: Requires adaptations and harmonization across international frameworks ○ *TechEthos portfolio*: work on tangible, existing short and medium-term applications; specific competencies available in the consortium; relevant example for the broader field of environmental ethics. **Survey results**[2]: ○ *Very high impact on*: 3.1 Societal challenges, 3.2 Impact on people's lives. ○ *High impact on*: 1.3 Interest by industry and investors; 2.1 Ethical principles and values, 2.2 Additional guidance in ethical aspects. **Quantitative data:** ○ *High*: Number of patents; Number of EU-FP projects ○ *Medium*: Share of EU patents; Growth of EU-FP projects ○ *Low*: Growth of patents; Industry participation in EU-FP projects	

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6.2 Technology family factsheet: Digital extended reality

TECHNOLOGY FAMILY	DIGITAL EXTENDED REALITY
R&I field	DIGITAL
Focus	Interaction with the digital world
Description	Extended Reality refers to AI-powered digital technologies (hardware and software) capable of perceiving and processing human sensorial outputs, e.g., voice, gestures, language, movement, emotions, and other elements of human communication). By processing such human-related data, extended or mixed virtual scenarios (e.g., visual, audio, linguistic or haptic) can be tailor-made or "customized" based on the user interest and behaviour. These technologies can be used to profile, model, predict, discriminate, and influence the user's behaviour or nudge their choices.
Key functions and capabilities	**It provides a partial or full extension of the user's real-world environment with a digital one through visual, audio, linguistic or haptic human-machine interaction.**
Key Industrial sectors	Aerospace; automotive; machinery and equipment; defence and security; ICT and digital; medical healthcare; space; transport; tourism, arts and cultural heritage; entertainment and recreation; education
Examples of technologies	**Data analysis and software:** virtual, augmented, and mixed reality systems; human digital twins (avatars); nudge and affective computing; applied behavioural analysis and engineering; people profiling; user nudging; biometric and behavioural recognition; AI-based technologies for speech, pattern, and gesture recognition; Natural Language Processing (NLP). **Hardware and data processing**: headsets, contact lenses and glasses; projection mapping; motion sensors; distributed cloud; edge and exa-scale computing; serverless computing (data as-used needs).
Examples of applications	Autonomous data processing; AI-powered chatbots and NLP applications, such as smart and virtual assistants; virtual friends/companions; cognitive and medical training; patient treatment (e.g., anxiety, stress disorder, and phobias); Virtual manufacturing, design, and training (digital twins for the manufacturing industry); personality-profiling; online targeted advertising; "chilling" effects (discourage people from acting freely); user persuasion by AI-algorithms
Time horizon to mass market[3]	Short-medium (initial applications already on the market), medium-long term (more advanced applications).

KEY ETHICAL ISSUES
Human Rights o Integrity o Autonomy o Privacy and Data Protection o Security o Inclusivity o Human supervision/control o Equal Access/Digital Divide o Surveillance o Disempowerment o Dual use/Misuse o Bias o Discrimination

Consideration on expected industrial and economic Impact	Consideration on expected public Impact
Both radical and incremental innovation. Enabling across many sectors. Priority by most industrial players in relevant sectors. Impact on both local and national economies. Costs of storing and processing data will be a major issue.	High Impact on people's life (choices and monitoring); possible impact on people's safety; Impact on jobs. **Key SDGs and EPSRs**: good health and well-being; responsible consumption and production; inclusion of people with disabilities; decent work and economic growth; industry, innovation, and infrastructure; education, training, and life-long learning; healthy, safe, and well-adapted work environment and data protection; access to essential services.

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Consideration on expected policy impact	Consideration on expected legal Impact
Priority for several national, EU and global policy organisations.	Requires adaptations in existing legal frameworks (e.g., transparency and emotional data sharing). Require limited adaptations in existing frameworks in specific applications or digital infrastructure (e.g., digital twin or distributed cloud).
Why selected	
Quick overview of impacts: A technology family with the potential to change the way individuals perceive, live, and interact with their real-world environment. It can influence people's daily habits, the organization of work, jobs, industrial and business models and cultural, policy and political behaviour, throughout our economies and society.	
Desk analysis: ○ *Ethics*: Potential for human supervision and control, human rights, privacy and data protection, surveillance, misuse, and digital divide ○ *Industry and Economy*: Priority by most industrial players in relevant sectors. ○ Impact on both local and national economies, at both global and local level ○ *Public*: High impact on people's life and possible impact on people's safety and jobs ○ *Policy*: Priority for several national, EU and global policy organisations. ○ Law: Requires adaptations in existing legal frameworks (e.g., transparency, accountability security, such as personal data processing) ○ *TechEthos portfolio*: work on tangible, existing medium to long term applications; wide competencies available in the consortium; relevant example for the broader field of digital ethics; opportunity to provide ethics by design recommendations to guide the development and use of these technologies. **Survey results**[4]: ○ *Very high impact on*: 2.1 Ethical principles and values, 2.2 Additional guidance in ethical aspects ○ *High impact on*: 1.3 Interest by industry and investors, 3.1 Societal challenges, 3.2 People's lives **Quantitative data:** ○ *High*: Industry participation in EU-FP projects, Growth of EU-FP projects, Number of EU-FP projects	

6.3 Technology family factsheet: Neurotechnologies

TECHNOLOGY FAMILY	NEUROTECHNOLOGIES
R&I field	HEALTH
Focus	Interaction with the human brain (technologies and the human body)
Description	Health technologies that aim at affecting and emulating human-brain capabilities and functions through artificial replacements or add-ons in a two-way interaction between the brain and the external environment or systems.
Key functions and capabilities	**Interacting, collecting, and transmitting information and stimuli from/into the human brain (e.g., from/to the nervous system) through internal and external devices.**
Key Industrial sectors	ICT and digital; medical healthcare; automotive.
Examples of technologies	Human-brain-machine interaction: artificial synapses; artificial brain; (direct) brain-machine interfaces
Examples of applications	Human-machine symbiosis; brain-to-brain communication; application to mental health diseases cure; brain stimulation to contrast diseases (such as Parkinson); efficient self-repair dysfunctional brain circuits enabled by AI; restoring a lost sense, allowing the brain to interact with the environment; strengthen or reroute information from injured areas of the brain.

Time horizon [5]	Medium to long-term
KEY ETHICAL ISSUES	
Human Rights o Autonomy o Integrity and Human Nature o Responsibility o Privacy and Data Protection o Human Interaction o Dual use/Misuse o Irreversibility o Scientific Integrity o Overstretched Promises o Precautionary Measures o Equal Access	
Consideration on expected industrial and economic Impact	**Consideration on expected public Impact**
Radical innovation. Enable innovation in healthcare and potentially other sectors. Priority by some industrial players in healthcare, Impact on the highly valuable sector. Most of the technologies are far from the market; it is difficult to foresee industrial and economic impacts (potentially high)	Impact on people's health and safety; Affecting average life expectancy. **Key SDGs and EPSRs**: good health and well-being; reduced inequalities; education, training, and life-long learning; health care; inclusion of people with disabilities; long-term care.
Consideration on expected policy impact	**Consideration on expected legal Impact**
Priority for national, EU and global policy organisations that deal with public health. The policy is mostly oriented to support research and prototyping activities.	Significant changes in existing legal frameworks.
Why selected	
Quick overview of impacts: A technology family directly monitoring, assessing, mediating, manipulating and emulating structure, functions, and capabilities of the human brain, including thinking, feeling, and interacting with the world. It could influence personhood and the way we perceive humans. It could disrupt existing healthcare practices.	
Desk analysis: ○ *Ethics*: Potential for infringement of human rights, irreversibility; integrity and responsibility; equal access ○ *Industry and Economy*: Impact on highly valuable sectors (e.g., healthcare); enable innovation in healthcare and potentially in other sectors. ○ *Public:* Impact on people's health and safety ○ *Law*: Significant changes in existing legal frameworks ○ *TechEthos portfolio*: work on long term applications, mostly not yet on the market (opportunity to shape their development); specific competencies available in the consortia; relevant example for the broader field of ethics of (innovative) healthcare and medicine; opportunity to provide ethics by design recommendations to guide the development and use of these technologies. ○ Others: possibility to find synergies with the OECD WPMN-BNCT and their initial work on Neurotechnology in and for society, see here **Survey results**[6]: ○ *Very high impact on*: 2.1 Ethical principles and values, 2.2 Additional guidance in ethical aspects ○ *High impact on*: 1.3 Interest by industry and investors, 3.1 Societal challenges, 3.2 People's lives **Quantitative data**: ○ *High*: Growth of patents ○ *Medium*: Number of patents, Number of EU-FP projects, Growth of EU-FP projects ○ *Low*: Industry participation in EU-FP projects, Share of EU patents	

7 Conclusion and outlook

The TechEthos horizon scanning approach followed a clearly structured path whereby technologies as well as selections (i.e., assessment criteria) have been iteratively identified, refined, and validated within in the entire process. This has been done by using a multi criteria decision analysis (MCDA) with multi-stakeholder participation. The strength of this approach is without doubt its broad and robust empirical evidence combining document and data analysis with expert involvement in interviews and interactive workshops. WP1 will be finalized by reflections and a revised methodology for ethical and social impacts-driven horizon scanning (D1.3).

The technology portfolio “Climate Engineering”, “Digital Extended Reality” and “Neurotechnologies” will be elaborated in detail in the succeeding WPs “ethical analysis” (WP2), “societal analysis” (WP3) and “legal and policy analysis” (WP4). Eventually, the results of these analyses will be condensed in operational ethics guidelines for users such as researchers, research ethics committees and policy makers reconciling the needs of research and innovation and the concerns of society.

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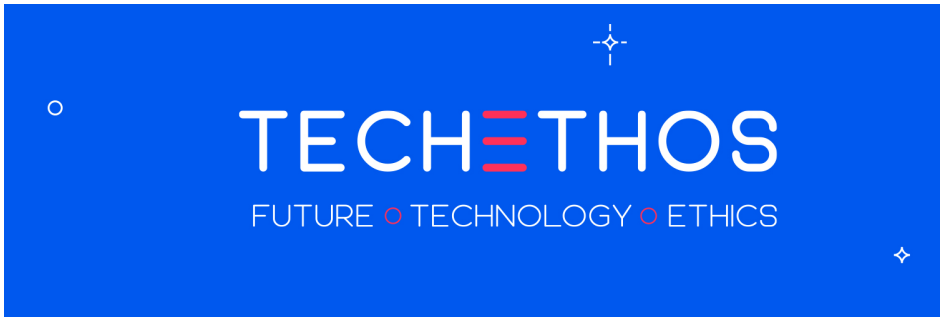
9 Annex A: Survey

9.1 Survey start page



TechEthos is a new EU-funded project that deals with the **ethics of new and emerging technologies anticipated to have high socio-economic impact**. The project aims to facilitate "ethics by design" and will produce operational ethics guidelines for 3-4 selected technology families for users such as researchers, research ethics committees and policy makers. Project results will be available on the website (www.techethos.eu).
In this survey, we are seeking your opinion on the expected impacts of a selection of technology families. In TechEthos, a "technology family" is defined as a set of specific technologies that are linked by one or more of the following aspects:

- technologies that aim to perform similar functions and/or address similar goals/concerns;
- technologies that raise similar ethical issues;
- technologies that are based on similar (scientific) working principles.

The composition and selection of the technology families results from our initial analysis, i.e., scanning, and analysing documents from various national, international, and globally oriented government, policy, industry, and foresight organizations reporting on technology trends, strategies, and impacts. Based on our analysis, factsheets are available for each technology family and each research and innovation field on the following pages. Several technologies (e.g., human genomics & enhancement, robotics, organoids, and technologies with a military dimension) are excluded from this project as they are covered by other H2020 projects on ethics.

Your survey responses will inform our selection of 3-4 technology families.

This survey has the following structure:

1. Select technology families – grouped into research and innovation fields – for assessment, based on your expertise and interest
2. Assess technology families according to their expected impacts
3. Reflect the impact of the selected technology families
4. Demographics

Completion of the questionnaire is voluntary. You can skip questions if you do not wish to answer them. Please note that assessments are only expected at the coarse-grained level of technology families.

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The survey should be completed in one go. Depending on the number of research and innovation fields you select, completing the survey takes approximately 15 to 20 minutes.

Your responses will be kept private, secure, and confidential (see Informed Consent below).

If you have questions concerning the TechEthos project and the survey, please contact the project coordinator Eva Buchinger eva.buchinger@ait.ac.at and the WP leader "Horizon Scan" Andrea Porcari porcari@airi.it; for technical questions please contact Manuela Kienegger Manuela.Kienegger@ait.ac.at.

On behalf of the 10 TechEthos project partners

The TechEthos project – Ethics for Technologies with High Socio-Economic Impact – has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement no. 101006249.

9.2 Overview research and innovation (R&I) fields

Please select one or more of the four research and innovation field(s) and the associated new and emerging technology families that you are interested in/feel confident to assess in the survey:

☐ **Bio and environment** including the following technology families: ● Environmental and climate technologies ● Bioengineering & industrial biotech (excluding healthcare) ● Synthetic biology

☐ **Digital** including the following technology families: ● Data processing technologies ● Quantum technologies ● Internet of Things (IoT) ● Cognitive technologies ● Augmented reality/Virtual reality

☐ **Health** including the following technology families: ● Regenerative medicine ● Artificial human/neurotechnologies

☐ **Materials and manufacturing** including the following technology families: ● Additive/advanced manufacturing technologies ● Autonomous systems ● Threat detection and response technologies ● Precision farming ● Mobility technologies ● Space technologies

If you believe a potentially high socio-economic impact technology family -- specific to one of the above four research and innovation fields -- is missing, please add it to the list below:

Bio and environment: _____

Digital: _____

Health: _____

Materials and manufacturing: _____

R&I field: Bio and environment

Fundamental principles: Impact on: Human rights, Freedom, Autonomy, Integrity, Responsibility, Privacy, Security, Inclusivity
Potential for: Harm, Dual-use, Novelty/radical, Blurring fundamental legal and moral categories, Human supervision/control, Irreversibility

Applied/specific concerns: Impact on: Health, Safety, Data protection, Environment, Sustainability, Human cells, tissues, embryos, Animals and plants, Human interaction, Concerns over: Scientific integrity, Overstretched promises, Precautionary measures

Please assess the following technology families according to the expected economic, social, and ethical impacts (positive or negative) by answering the following questions. Factsheets with qualitative and quantitative background information for each technology family are available (FACTSHEETS).

Q1: The level of interest by industry and investors in the technology family is...

Low: Low interest is indicated by stagnating job growth or job loss, low investments, low profitability expectations, lack of sector-wide effects, etc.
High: High interest is indicated by significant job growth, high investments, high profitability expectations, potential for sector-wide transformations, etc.

	very low	low	medium	high	very high
Environmental and climate technologies	○	○	○	○	○
Bioengineering and industrial biotech (excl. healthcare)	○	○	○	○	○
Synthetic biology	○	○	○	○	○

Q2: The potential impact of the technology family on people's lives (also considering minority and vulnerable populations) is …
Low: A relatively small impact on people's lives, e.g., how people work, move, transport, interact.
High: A relatively high impact on people's lives, e.g., how people work, move, transport, interact.

	very low	low	medium	high	very high
Environmental and climate technologies	○	○	○	○	○
Bioengineering and industrial biotech (excl. healthcare)	○	○	○	○	○
Synthetic biology	○	●	○	○	○

Q3: The potential of the technology family to have a significant impact on societal challenges (e.g. Sustainable Development Goals, ***principles of the*** European Pillar of Social Rights***) is …***

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Low: The technology family has little or no impact on societal challenges (opportunities, threats).
High: The technology family has a large impact on societal challenges (opportunities, threats).

	very low	low	medium	high	very high
Environmental and climate technologies	○	○	○	○	○
Bioengineering and industrial biotech (excl. healthcare)	○	○	○	○	○
Synthetic biology	○	○	○	○	○

Q4: The potential of the technology family to significantly affect or engage ethical principles and values is …

Low: The advance of the technology family has limited or no effects on ethical principles and values.
High: The advance of the technology family has big effects on ethical principles and values.
Ethical principles and values include e.g., equality, privacy and data protection, autonomy as well as specific concerns related to health, environment, and human interactions.

	very low	low	medium	high	very high
Environmental and climate technologies	○	○	○	○	○
Bioengineering and industrial biotech (excl. healthcare)	○	○	○	○	○
Synthetic biology	○	○	○	○	○

Q5: The need for additional guidance in dealing with ethical aspects of a technology family (e.g., not covered by existing guides, standards, regulations) is …

Low: The ethical implications of the technology family could be managed with existing guidelines, standards, and regulations.
High: The ethical implications of the technology family will need new guidelines, standards, and regulations.

	very low	low	medium	high	very high
Environmental and climate technologies	○	○	○	○	○
Bioengineering and industrial biotech (excl. healthcare)	○	○	○	○	○
Synthetic biology	○	○	○	○	○

Please share any additional comments on this research and innovation field, e.g., the technology families, their expected impacts including ethical and other disruptions.

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R&I field: Digital

Please assess the following technology families according to the expected economic, social, and ethical impacts (positive or negative) by answering the following questions. Factsheets with qualitative and quantitative background information for each technology family are available (OPEN THE FACTSHEETS).

Q1: The level of interest by industry and investors in the technology family is ...

Low: Low interest is indicated by stagnating job growth or job loss, low investments, low profitability expectations, lack of sector-wide effects, etc.
High: High interest is indicated by significant job growth, high investments, high profitability expectations, potential for sector-wide transformations, etc.

	very low	low	medium	high	very high
Data processing technologies	○	○	○	○	○
Quantum technologies	○	○	○	○	○
Internet of Things (IoT)	○	○	○	○	○
Cognitive technologies	○	○	○	○	○
Augmented reality/Virtual reality	○	○	○	○	○

Q2: The potential impact of the technology family on people's lives (also considering minority and vulnerable populations) is ...

Low: A relatively small impact on people's lives, e.g., how people work, move, transport, interact.
High: A relatively high impact on people's lives, e.g., how people work, move, transport, interact.

	very low	low	medium	high	very high
Data processing technologies	○	○	○	○	○
Quantum technologies	○	○	○	○	○
Internet of Things (IoT)	○	○	○	○	○
Cognitive technologies	○	○	○	○	○

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Augmented reality/Virtual reality	○	○	○	○	○

Q3: The potential of the technology family to have a significant impact on societal challenges (e.g. Sustainable Development Goals, principles of the European Pillar of Social Rights) is …

Low: The technology family has little or no impact on societal challenges (opportunities, threats).

High: The technology family has a large impact on societal challenges (opportunities, threats).

	very low	Low	medium	high	very high
Data processing technologies	○	○	○	○	○
Quantum technologies	○	○	○	○	○
Internet of Things (IoT)	○	○	○	○	○
Cognitive technologies	○	○	○	○	○
Augmented reality/Virtual reality	○	○	○	○	○

Q4: The potential of the technology family to significantly affect or engage ethical principles and values is …

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Ethical principles and values include e.g., equality, privacy and data protection, autonomy as well as specific concerns related to health, environment, and human interactions.

	very low	Low	medium	high	very high
Data processing technologies	○	○	○	○	○
Quantum technologies	○	○	○	○	○
Internet of Things (IoT)	○	○	○	○	○
Cognitive technologies	○	○	○	○	○
Augmented reality/Virtual reality	○	○	○	○	○

Q5: The need for additional guidance in dealing with ethical aspects of a technology family (e.g., not covered by existing guides, standards, regulations) is …

Low: The ethical implications of the technology family could be managed with existing guidelines, standards, and regulations.
High: The ethical implications of the technology family will need new guidelines, standards, and regulations.

	very low	Low	medium	high	very high
Data processing technologies	○	○	○	○	○

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Quantum technologies	○	○	○	○	○
Internet of Things (IoT)	○	○	○	○	○
Cognitive technologies	○	○	○	○	○
Augmented reality/Virtual reality	○	○	○	○	○

Please share any additional comments on this research and innovation field, e.g., the technology families, their expected impacts including ethical and other disruptions.

R&I field: Health

Please assess the following technology families according to the expected economic, social, and ethical impacts (positive or negative) by answering the following questions. Factsheets with qualitative and quantitative background information for each technology family are available (OPEN THE FACTSHEETS).

Q1: The level of interest by industry and investors in the technology family is ...

Low: Low interest is indicated by stagnating job growth or job loss, low investments, low profitability expectations, lack of sector-wide effects, etc.
High: High interest is indicated by significant job growth, high investments, high profitability expectations, potential for sector-wide transformations, etc.

	very low	low	medium	high	very high
Regenerative medicine	○	○	○	○	○
Artificial human/neurotechnologies	○	○	○	○	○

Q2: The potential impact of the technology family on people's lives (also considering minority and vulnerable populations) is ...

Low: A relatively small impact on people's lives, e.g., how people work, move, transport, interact.
High: A relatively high impact on people's lives, e.g., how people work, move, transport, interact.

	very low	low	medium	high	very high
Regenerative medicine	○	○	○	○	○

Artificial human/neurotechnologies	○	○	○	○	○

Q3: The potential of the technology family to have a significant impact on societal challenges (e.g. Sustainable Development Goals, principles of the European Pillar of Social Rights) is …

Low: The technology family has little or no impact on societal challenges (opportunities, threats).
High: The technology family has a large impact on societal challenges (opportunities, threats).

	very low	low	medium	high	very high
Regenerative medicine	○	○	○	○	○
Artificial human/neurotechnologies	○	○	○	○	○

Q4: The potential of the technology family to significantly affect or engage ethical principles and values is …

Low: The advance of the technology family has limited or no effects on ethical principles and values.
High: The advance of the technology family has big effects on ethical principles and values.
Ethical principles and values include e.g., equality, privacy and data protection, autonomy as well as specific concerns related to health, environment, and human interactions.

	very low	low	medium	high	very high
Regenerative medicine	○	○	○	○	○
Artificial human/neurotechnologies	○	○	○	○	○

Q5: The need for additional guidance in dealing with ethical aspects of a technology family (e.g., not covered by existing guides, standards, regulations) is …

Low: The ethical implications of the technology family could be managed with existing guidelines, standards, and regulations.
High: The ethical implications of the technology family will need new guidelines, standards, and regulations.

	very low	low	medium	high	very high
Regenerative medicine	○	○	○	○	○
Artificial human/neurotechnologies	○	○	○	○	○

Please share any additional comments on this research and innovation field, e.g., the technology families, their expected impacts including ethical and other disruptions.

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R&I field: Materials and manufacturing

Please assess the following technology families according to the expected economic, social, and ethical impacts (positive or negative) by answering the following questions. Factsheets with qualitative and quantitative background information for each technology family are available (OPEN THE FACTSHEETS).

Q1: The level of interest by industry and investors in the technology family is ...

Low: Low interest is indicated by stagnating job growth or job loss, low investments, low profitability expectations, lack of sector-wide effects, etc.

High: High interest is indicated by significant job growth, high investments, high profitability expectations, potential for sector-wide transformations, etc.

	very low	low	medium	high	very high
Additive/advanced manufacturing technologies	○	○	○	○	○
Autonomous systems	○	○	○	○	○
Threat detection and response technologies	○	○	○	○	○
Precision farming	○	○	○	○	○
Mobility technologies	○	○	○	○	○
Space technologies	○	○	○	○	○

Q2: The potential impact of the technology family on people's lives (also considering minority and vulnerable populations) is ...

Low: A relatively small impact on people's lives, e.g., how people work, move, transport, interact.

High: A relatively high impact on people's lives, e.g., how people work, move, transport, interact.

	very low	low	medium	high	very high
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Autonomous systems	○	○	○	○	○
Threat detection and response technologies	○	○	○	○	○
Precision farming	○	○	○	○	○
Mobility technologies	○	○	○	○	○
Space technologies	○	○	○	○	○

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Q3: The potential of the technology family to have a significant impact on societal challenges (e.g. Sustainable Development Goals, principles of the European Pillar of Social Rights) is …

Low: The technology family has little or no impact on societal challenges (opportunities, threats).
High: The technology family has a large impact on societal challenges (opportunities, threats).

	very low	low	medium	high	very high
Additive/advanced manufacturing technologies	○	○	○	○	○
Autonomous systems	○	○	○	○	○
Threat detection and response technologies	○	○	○	○	○
Precision farming	○	○	○	○	○
Mobility technologies	○	○	○	○	○
Space technologies	○	○	○	○	○

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Additive/advanced manufacturing technologies	○	○	○	○	○
Autonomous systems	○	○	○	○	○
Threat detection and response technologies	○	○	○	○	○
Precision farming	○	○	○	○	○
Mobility technologies	○	○	○	○	○
Space technologies	○	○	○	○	○

Q5: The need for additional guidance in dealing with ethical aspects of a technology family (e.g., not covered by existing guides, standards, regulations) is …

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High: The ethical implications of the technology family will need new guidelines, standards, and regulations.

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	very low	low	medium	high	very high
Additive/advanced manufacturing technologies	○	○	○	○	○
Autonomous systems	○	○	○	○	○
Threat detection and response technologies	○	○	○	○	○
Precision farming	○	○	○	○	○
Mobility technologies	○	○	○	○	○
Space technologies	○	○	○	○	○

Please share any additional comments on this research and innovation field, e.g., the technology families, their expected impacts including ethical and other disruptions.

9.3 Final reflections

Please share any additional comments on the survey and the factsheets. Your feedback will help us improve the subsequent work in the project.

- Are any new or emerging technology families with ethical implications missing?
- In what way was the background information (factsheets) helpful for the completion of the survey? In what ways could they be improved?
- Anything else?

9.4 Demographics

Gender

- ○ Female
- ○ Male
- ○ Other - Please specify: _____
- ○ Prefer not to answer

Country

Select country from Drop down menu

Stakeholder category (multiple answers possible)

- ☐ Academic Research
- ☐ Civil society organisation (CSO)
- ☐ Ethics body (Research Ethics Committee; Research Integrity body,...)
- ☐ Funding organisation
- ☐ Industry & Industrial Research
- ☐ Policy maker / Decision maker
- ☐ Other - Please specify: _____

Professional background/experience (multiple answers possible)

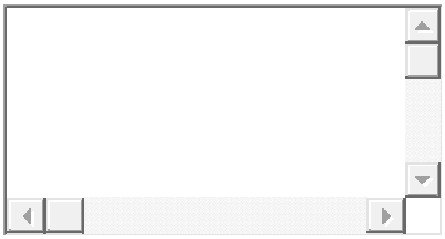
- ☐ Computer science
- ☐ Engineering
- ☐ Environmental sciences
- ☐ Life sciences
- ☐ Material sciences or manufacturing
- ☐ Mathematical sciences
- ☐ Physical sciences
- ☐ Research and Technology Assessment

☐ Social Sciences & Humanities

☐ Ethics

☐ Other - Please specify:

Would you like to provide additional feedback to the project team?



Thank You!

Thank you for taking part in the survey. Your response is very important to the TechEthos project.

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10 Annex B: Validation and Final Selection

10.1 Expert Interview Questions

The following 7 questions were asked in the expert interview script, developed collaboratively among WP1 participants:

Part 1: Horizon scanning of high socio-economic impact, ethically relevant technologies

1. *Tell me about your experience and interest in the themes of this interview, namely horizon scanning/foresight and assessment of (ethical, social, economic) impact of technology innovation (and the combination of these two types of analysis).*
2. *After a preliminary assessment, about 16 technologies have been short listed (see the annex B). Based on your experience, could you comment on this list, in terms of clarity, missing elements, socio-economic impact and relevant ethical concerns? (feel free to focus only on specific technologies)*
3. *Our (meta) analysis is limited by several factors, including the intrinsic uncertainty of any of the foresight analysis we refer to, the diversity of information on each of the technologies identified, and the number and type of documents analysed. Do you have any suggestion on how to improve the reliability of our results?*
4. *Is there any specific source (e.g., from government, policy, industry, and foresight organizations) you would recommend for our analysis?*

Part 2: Criteria to assess socio-economic and ethics impacts

5. *What is your opinion on the (draft) criteria we selected to assess the socio-economic impacts and ethical implications of new and emerging technologies? (see annex B)*
6. *The type and level of information collected on both the technologies and the criteria for the assessment, is limited and will only allow for a very qualitative assessment. Is there any priority or weight you would give to the different criteria, to improve, or simplify, the assessment?*
7. *TechEthos is looking at different kind of impacts (industrial & economic, policy, public and ethics impact). In the final selection of the technology families to focus on, there might be a risk to underestimate or overestimate one impact against the other (e.g., underestimate ethics implications due to the low industrial and policy impact of a technology). Do you have any suggestion on the best criteria to make our final selection?*

10.2 Results of Consortium Discussion on moving from pre-selection to final selection: process considerations

The Consortium considered a range of points in the pre-selection workshop, organized into the following clusters:

Cluster 1: Broad and coarse-grained or narrow and fine-grained?

An active sub-topic related to cluster 1 included a discussion of whether to select technology families and seek to be broad (e.g., speaking to a range of technologies) or specific and, through being narrow, better specify the ethical issues from which to generalize. For example, to start with a broad technology family like Cognition and narrow down, or start with a rather narrower, symbolic name, like blockchain, and then broaden. **One perspective urged was to arrive at a mid-level, practicable technology family neither too broad nor too specific**—the example offered being artificial synapses being too broad, but natural language processing offering a more contained yet still expansive subject. The Consideration of breadth/narrowness was noted as relevant, too, to any legal conversation, as anything overly broad would be unlikely to yield insights of legal relevance, but too narrow and the legal insights would remain provisional. **An alternative perspective was to select some technology families at a broad level and others at a narrow level, and then afford TechEthos a comparison in the possible difference in approaches to developing ethical guidelines.**

Cluster 2: Technology function and application or form and design?

Closely related to the question of coarse- or fine-grained technology family grouping was the point that one could approach technology family as a means of the function (for what it is used or could be used) or the technology principles underlying use (e.g., how the technology works). The two were noted as coupled, as how a technology is designed implicates potential useability, but the pathway to ethical analysis might differ depending on what is foregrounded in the technology family grouping (e.g., function or form). A key tension here being that in some cases, the scientific direction of orientation in design of form may differ drastically from actual use. Similarly, the core functionality of a technology may also implicate objectionable applications (the example offered blockchain in money laundering and energy intensity).

A discussion also emerged around "other criteria" to consider, including in how far TechEthos **consortium members expertise** ought to be included, as well as how **potential for TechEthos impact** ought to be considered. Clusters related to this topic of conversation included:

Cluster 3: Should TechEthos consortium expertise factor into the decision?

This cluster surfaced the question of whether technology families ought to be ruled out based on the absence of partner expertise on a topic. Conversely, the question was raised whether high levels of partner expertise on a topic should favour selection of an associated technology family (for example

because of the attendant benefits of being connected to other experts, full awareness of topical issues, etc). Areas of expertise identified in the consortium include digital and health technologies, the question of nature as a subject of ethical concern, environment and climate issues, mobility, and natural language processing. One member noted starting a new project on the ethics of VR/AR and engagement in another project on ethics concerns associated with quantum technologies. On the other hand, consortium members expressed that having "fresh topics" could also be invigorating and prove of worthy pursuit and not insurmountable at all. **In the end, expertise was not deemed to be a deciding factor in eventual technology family selection, but may be something to factor in, for example not selecting technology families that are either all endemic to or all new to consortium partners.**

Cluster 4: How should the potential for TechEthos impact be considered?

A final cluster emerged around the importance of selecting a technology family in which the project may have a high impact. For example, one partner asked whether there was interest in selecting a technology family that bridges to the political priority of "post-pandemic society", recovery, resilience, and future pandemic-management / risk management? Related was the point of not selecting technology families already subject to ethical analysis in other projects (e.g., organoids and artificial organs); not repeating already completed work (e.g., of SIENNA or SHERPA projects). A key point here is that looking to Commission interests is one way of identifying potential impact areas, as once the Commission has started conversation on a topic it may already be of importance. But a key point is that conversations may need to be at a certain level of ripeness to be influenceable (for example AI and data-processing legal issues are active areas of conversation not likely to end soon; other aspects might be less evergreen with windows closing sooner than later). **One consortium member indicated plans to look into Parliamentary Committee conversations to see what kinds of technology and legal conversations are starting to surface, indicating potentially ripe areas of focus.**

10.3 Results of the Consortium Discussion on the 5 pre-selected Technology Families

The table below combines qualitative feedback on the pre-selected technology families shared by Consortium Members on 25 June 2021

	Political priorities	Potential TechEthos Value-add	Scientific/intellectual interest	Time-horizon	Other
1. Environment and Climate	European political priorities Green and Digital transitions Can highlight ethical issues to help address a priority area (e.g., CCS moral hazard)	Specific expertise on ethical evaluation of geoengineering technologies Elevate the ethical concerns in this policy agenda and provide guidance	Nature as a subject of ethical concern is a very interesting topic. Impacts on global south vs. global north and potential description of ethical concepts would be interesting to consider	Largely long-term and intergenerational Likely to see a large increase in solar geoengineering research in the coming years	Broad policy reliance on IAMs on untested and speculative CDR technologies Separate geoengineering from climate remediation Lots of solar geoengineering interest based on NASEM report Irreversibility concerns very strong in this topic
2. Data Processing	A lot of existing regulation (GDPR)	Possibly covered quite a			May overlap with IoT or AR/VR

	Opportunity to influence policies on issues of availability, access, transparency, ethics associated with big data use Issue of distributed responsibility in data ownership is a new legal, industrial, ethical domain	bit by other projects, particularly related to AI High visibility of the topic means many interested parties in EU and globally			technology families
7. Cognitive technologies			Unpacking ethics associated with sharing, influencing attitudes or emotions through cognitive and neurotech seems quite ripe for analysis		Can likely separate out NLP and affective computing and AR/VR and merge with artificial and neurotech and data processing
10. Artificial Human & Neurotech			High scientific interest but many other projects covering (e.g., brain-computer interfaces well covered) Confusing name and possibly off putting	Very long-term	Many issues covered already by SIENNA under human enhancement
15. Mobility Technologies	A high industrial impact and economic impact sector Connected to Green and digital transition political priorities (if focus on sustainable mobility)	Sharing economy models might be interesting for ethical reflection—overlapping with distributed responsibility issues in data ownership and processing, as well as with autonomous systems	Desirable to have at least on "materials and manufacturing" research field reflected?		This is defined by function and not technical principle. Overlaps with IoT, data processing, and environment and climate techs

Comments on the other technologies not included:

2. Bioengineering & biotech – important but too broad

3. Synthetic biology – significant efforts already made on societal awareness (e.g., Synenergene). Gene editing / gene drives important and socially visible

5. Quantum technologies—should just be included in the digital field

6. Internet of Things (IoT)—high socioeconomic tech area with possibility to integrate in pre-selected tech families like mobility, climate and environment, and data processing

8. Augmented & virtual reality—should just include in Cognitive technologies or digital. The concept of digital twins could bring quite profound socio-economic changes

11. Additive & manufacturing—should be somehow considered in any technology family that entails production

12. Autonomous systems—need to reflect on technologies related to manufacturing—so important as enabling of other sectors and implicating jobs. This will likely be something needed to integrate in a technology family in some way—whether mobility or data processing.

14. Precision farming—seems a subtheme of digital technologies (or environment and climate, depending on the value proposition explored underneath)

10.4 Final agenda of WP1 Technology Family Selection Workshop

1000 – 1015	Welcome and Introductions
1015 – 1100	**Technology horizon scanning results up to now**
	15' Presentation of horizon scan results
	15' Discussion and Q&A
	15' Mural orientation
1100 – 1230	**Refining five pre-selected technology families (group interactive work)**
	MURAL 1: Refine, regroup (narrow down) our selected technology families, also considering elements from the other (not selected) families (including break)
	MAIN HOST – Michael (keeps time, balances rooms (min. 4 / max. 8)
	FACILITATORS
	Environment & Climate – Manuela
	Data Processing – Giuliano
	Cognitive Technologies – Daniela
	Artificial human & Neuro Tech – Andrea
	Mobility - Eva
	1100 Round 1 | 1115 Round 2
1130 – 1145	Break
	1145 Round 3 | 1200 Round 4 | 1215 Round 5
1230 – 1320	Lunch
1320 – 1430	**Reflecting joint outcome of group interactive work (plenary)**
	MURAL 2: Why should TechEthos work on this technology family?
1430 – 1500	**Selecting the right technology families (plenary)**
	Which three (four) technology families and can make a strong portfolio for TechEthos, to develop guidelines for ethical analysis of new and emerging technologies?

10.5 Final Selection Workshop Breakout and Plenary Discussions In-Depth

Individual technology family refinements

Throughout the breakout sessions at the 2 July 2021 workshop, a range of high-level refinements were proposed to each technology family. These are presented in table 14, below. Proposals presented continue to span a spectrum from broad (e.g., geoengineering, to more specific, e.g., prosthetics).

Table 13: Technology Family refinements discussed in World Cafe sessions

Technology family	Refinements discussed
Environment and climate	○ climate technologies that intervene in the earth and climate systems ○ climate related to geoengineering ○ genetic engineering of organisms to reduce environmental impact ○ some connection to logistical systems, materials, and manufacturing, and autonomous systems ○ manipulating earth and atmospheric systems to 'manage' climate impacts
Data processing	○ automated data processing ○ algorithmic rationality and automatization ○ digital identities technologies (broadly, where applications that take control away from individuals affected by the decisions) that may take control outside of the individual ○ digital humans ○ deepening AI of previous projects for the next 10 years (e.g., NLP, digital identity, VR/AR) ▪ in Annex III of the proposed AI regulation for "high-risk" areas. The definitions/limits are vague and leaves a lot for further discussion ○ Cybersecurity in the person/IoT as it relates to data processing, possibly also quantum ○ Data processing and autonomous systems ▪ Data for developing optimal, individual healthcare products (Ethical impact: only available in rich countries?)
Cognitive technology	○ "influencing technologies", which are high-risk AI but vaguely defined and not well-explored ethically ○ Extended-mind technologies / nudging / behavioural technologies
Artificial human & neuro-technologies	○ Brain-computer interfaces ○ gene editing that can cause irreversible changes in plant and animal genome (prefers even specifically gene drive) ○ Prosthetics ○ Virtual friends ○ Digital twins and avatars ○ tech engaging with the categories of human itself. With the brain being one core of human nature
Mobility	○ Technologies of tourism ○ Technologies of resource transportation ○ Technologies for moving people ○ Connected and automated mobility ○ Social and technical infrastructures of moving people under conditions of climate change

In plenary discussion following lunch, several additional considerations were noted regarding the level of granularity of the final selected technology families. In these discussions it was noted that it is unlikely a single technology will be a useful object of study (i.e., too narrow). Instead, a level of granularity that affords TechEthos the chance to identify a "spectrum of technologies", with diverging or diverse ethical concerns even within a technology family, seems useful. In this context, the challenge discussed was how to identify a level of granularity that allows for differentiation of a smaller set of specific technologies and application cases. For example, environment and climate techs enabling systemic intervention in the climate system, even within carbon removal, vary drastically in associated ethical challenges (e.g., carbon pulling machines (ambient) are very different than credit systems that allow forests to turn into biochar, which are each different from single-actor SRM interventions).

Reasons for selecting technology families

A range of considerations for selecting technology families—at the individual level—were offered. These are presented in aggregate rather than for individual technologies because of the way in which data were collected. Because technology families were not refined in a uniform manner, the different justifications for the proposals were also of variable specificity. As such, the "reasons for selection"

below are highlights from the plenary discussion held after lunch, as well as selected entries from the technology-family-specific sections of the mural.

The below are expressed as specific elaborations of the considerations for selection shared by facilitators in advance, namely: a) EC commission interest / political priorities; b) potential TechEthos value-add; c) scientific / intellectual interest; d) time horizon. Additional reasons for selecting a technology family discussed include:

- Continued specification of existing guidelines—going deeper— is an acceptable focus for the project, for example with AI to focus on sector or application specific considerations.
- Consideration of cross-technology convergence and challenges is an acceptable focus for the project
- Connection to societal challenges seems important to make explicit for any technology family selected
- Existing or future EC funding for a technology does not preclude TechEthos focusing on said technology family (e.g., EC and Quantum or AR/VR investments in Horizon Europe
- The project is encouraged to "look" more than five years into the future. The Horizon Scan intent was to surface a range of such technologies. The utility of the project's scenarios and ethical guidance will be in supporting the EC to meaningfully prepare and shape trajectories of such technologies.
- It may be that the less "exciting" the technology, the most potential impact in society and, if the project uncovers these, for the project. There is for example a lot of work on "Automation of Systems" that overarches AI but often goes unquestioned

Issues for further study in technology families

Although granularity of technology families was not consistently refined across the breakout sessions, each conversation surfaced a range of diverse topics of relevance to future TechEthos consideration. These potential topics of inquiry are presented in Table 14, below.

Table 14: Presentation of topics of concern raised by participants about the technology families pre-selected and discussed

Technology Family	Considerations that a technology family selected could speak to
Environment & Climate	Nature as a subject of ethical concern Issues of social, environmental, distributional, intergenerational justice - Global "north" versus global "south" concerns Dimensions of decarbonization, resource intensity, land-use intensity, emissions Cost of inaction Irreversibility
Data Processing	Trust / algorithmic decision making Data solidarity Data sovereignty Role of government and industry Equity and justice Data collection, storage, access, and use Personalized medicine (for whom) Data rights of vulnerable groups; consent Information security and sharing
Mobility	Distributional justice - Urban / rural, inclusive exclusive; Global north / global south - Issues of fairness Rights of mobility / environmental impacts of freedom of movement Tracking, transportation, and automatization Mobility as a service Jobs Infrastructure What can and cannot be handled virtually

	What ethical framework/values will underpin autonomous decision making? (e.g., utilitarianism, virtue ethics etc.)
Cognitive Technologies	Introduction of major healthcare benefits and inequalities (e.g., based on costs of treatments) Trust in technology and/versus people Intergenerational care Limits of what is acceptable to influence and how Abuse of anthropomorphic concepts Emotional manipulation Profiling Manipulation of democratic outcomes "big brother issues" Questions of proprietary information
Artificial Human and Neurotechnologies	Irreversibility How do you show that implants do no harm? Healthcare versus human enhancement Issues of insurance (individual v collective interests) Issues of cost and distributional justice / who benefits - The cost of human enhancement for medical reasons needs to be balanced against the need and expectation management - acceptance of these technologies as a 'right' as a treatment option could have significant impacts on resource allocation in the health system. What it means to be human

Technology Family Portfolios Proposed

A general convergence among participants emerged around three research and innovation fields of interest, in the broadest sense:

- Environment and Climate
- Data/digital
- Human/Bio (e.g., cognitive and/or genetic) technology

Specific manifestations of these three fields are visible in the technology family portfolios, pulled from the Mural, below (Table 15). In general, the above three technology families and many of the below may still be too general for selection, but at least the clarity of the trio of research and innovation fields helps to advance the selection process.

Table 15: Results of the 16 potential technology portfolio options for the TechEthos project

- climate related to geo-engineering - deepening AI of previous projects with a time horizon of the next ten years (check NLP, digital identity, VR) - Data Solidarity not only data sovereignty	- Intentional climate interventions - Human-AI enhancement tech: ER - Cybersecurity in the person/IoT as it relates to data processing, possibly also quantum	- Data processing related to human behaviours - Climate change technologies that affect people - Health related digital human
- Data processing related to human behaviours - Climate change technologies that affect people - Health related digital human	- Climate technologies (other than mobility) e.g., geoengineering - AI-quantum computing OR virtual reality - artificial reproduction	- Climate Tech as a case that is relevant now; - quantum Tech as a future case to prepare for; - Cognitive Tech because it is fun/interesting to reflect on
- Either carbon or solar climate intervention - Human/machine interface - gene editing	- Climate technologies, - data processing (maybe with connections to autonomous systems), - Cognitive technologies	- Climate Technology - Data processing, - Cognitive technologies
- Behavioural techs - human-machine techs (neuro included) - Climate techs	- climate tech that intervenes - AR/VR - enhanced human (human-machine interfaces)	- autonomous algorithms / automated control via language - alternative climate energies - data storage, capture, and formation of new knowledge systems
- data sovereignty versus data solidarity - climate engineering including solar radiation management	- Data Processing - Environmental Technologies	- Nat. Language Processing; - Gene Editing; - Broadly-defined Climate Technologies

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- Artificial intelligence in making autonomous decisions	- Cognitive Technologies (with some tech symbiosis)	

Final discussion in plenary revolved around how the suite of technology families ought usefully to illuminate a set of core questions of interest. Such coherence was expressed as favourable for project management as well as potential project impact. For example, core concerns about:

- How to handle questions of "control and irreversibility" issues of human control, accountability, and responsibility
- How to handle "ethically disruptive" technologies
    - issues of technologies that fundamentally change the way human values and ethical concerns themselves get formulated, filtered, expressed, and acted upon.
- How to handle multiple "human-X" interactions, as noted above (e.g., human-internal, human-human, human-nature relations being change)

Could be considered as part of the portfolio selection or elaborated soon after.

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@TechEthosEU

TechEthosEU

www.techethos.eu

info@techethos.eu