TECHETHOS

FUTURE ○ TECHNOLOGY ○ ETHICS

D1.1 Description of selected high socio-economic impact technologies

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D1.1 Description of selected high socio-economic impact technologies			
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TechEthos Project

Short project summary

TechEthos is an EU-funded project that deals with the ethics of the new and emerging technologies anticipated to have a 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. The project will produce operational ethics guidelines for three to four 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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Abbreviations

Table 1: List of Abbreviations

Term	Explanation
AI	Artificial Intelligence
AR	Augmented Reality
ARML	Augmented Reality Markup Language
B2B	Business to Business
CBRN	Chemical, Biological, Radiological and Nuclear
CCAM	Connected Cooperative Automated Mobility
CID	Cruel, Inhuman and Degrading treatment
C-ITS	Cooperative Intelligent Transport Systems
CRISPR	Clustered Regularly Interspaced Short Palindromic Repeats
DLT	Distributed Ledger Technology
DoW	Description of Work
DRM	Disaster Risk Management
DRR	Disaster Risk Reduction
EPO	European Patent Office

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EPSR	European Pillar of Social Rights
ETS	Emission trading system
EU	European Union
EU-FP	European Framework Programmes
EUPRO	A database developed by the Austrian Institute of Technology, comprising information on R&D projects and all participating organisations funded by the EU Framework Programmes (FP). It covers information on R&D projects and details of participating organisations.
H2020	HORIZON 2020
ICT	Information and Communication Technology
IoT	Internet of Things
IPR	Intellectual Property Rights
IT	Information and Technology
MaaS	Mobility as a Service
MCDA	Multi-criteria decision analysis
NACE	Nomenclature statistique des activités économiques dans la Communauté Européenne
NLP	Natural Language Processing
OECD	Organization for Economic Co-operation and Development
PATSTAT	A database by the EPO European Patent Office, contains bibliographical data relating to more than 100 million patent documents from industrialised and developing countries.
PC	Project Coordinator
R&D	Research and Development
R&I	Research and Innovation
RFID	Radio-Frequency Identification
RTD	Research and Technology Development
RTD	Research and Technology Development
SDGs	Sustainable Development Goals
SME	Small and Medium Enterprise
SoL	Self-organising Logistics
VR	Virtual Reality
VRML	Virtual Reality Modelling Language
WP	Work Package

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Executive Summary

This report describes the process and the result of a horizon scan exercise on new and emerging technologies and their socio-economic impacts carried out as part of the TechEthos project. The horizon scanning aids to:

- Identifying, selecting, and describing a set of 16 technology families with significant socio-economic impact and ethical dimensions that are expected to be developed and deployed in Europe and worldwide in the next five to ten years. The analysis will be used to ensure that the ethics framework and guidelines developed by TechEthos will be relevant and applicable for a wide range of new and emerging technologies.
- Informing the choice of a subset of 3 technology families that will form a TechEthos technology portfolio on which the project will undertake in-depth ethical, social, policy and legal analyses. This subset will be used as case studies to develop operational ethics guidelines for these specific technologies.

This report describes the overall set of technology families, while the impact assessment leading to the choice of these technologies and the final selection of the technology portfolio will be the focus of two upcoming TechEthos reports.

The horizon scan is based on (i) desk analysis, taking advantage of existing updated horizon scanning, technology assessment and socio-economic analysis from research, policy, business, and industry organisations at international, EU and national level (ii) quantitative data on technology development from patents and projects databases, and (iii) an iterative consultation and review process involving experts from different disciplines (e.g., technology assessment, ethics, policy, social and socio-economic sciences, sustainability).

The TechEthos horizon scan contributes to a novel approach in grouping and clustering families of technologies, based on the functions, applications, ethical and societal challenges addressed, and the identification of criteria for assessing potential socio-economic impacts of these technology families.

Given the qualitative and dispersed nature of the information collected, a multi-criteria decision analysis (MCDA) has been introduced to compare, assess, and select the technology families. For this purpose, specific impact assessment criteria have been identified, refined, and improved over the course of the analysis.

The scanning exercise identified a first 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.

The choice of technologies is instrumental for developing evidence-based, practical ethics guidance that could serve the dynamic and fast-developing nature of new and emerging technologies.

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

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

- Environment & climate technologies
- Bioengineering & industrial biotech (excluding healthcare)
- Synthetic biology
- Data processing technologies (excluding quantum techs)
- Quantum technologies
- Internet of things (IoT)
- Cognitive and behavioural technologies
- Virtual/Augmented reality
- Regenerative medicine
- Artificial human/neuro-technologies
- Additive, advanced manufacturing technologies
- Autonomous systems
- Threat detection and response technologies
- Precision farming
- Mobility technologies
- Space technologies

A review of resources and selection criteria and the rationale of the methodological approach are explained in section 2 of the report. In section 3, this subset of 16 technology families is 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.

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1. Introduction

This study aims to conduct a thorough scanning of the technology horizon to identify new and emerging technologies with a high socio-economic impact and significant ethics dimensions that are expected to be developed and deployed in Europe and worldwide in the next five to ten years. Results will feed into the next phases of the TechEthos project, aiming to develop ethics guidelines for new and emerging technologies.

The horizon scanning activities and outcomes will be illustrated in three reports. This is the first of the series, aiming to:

- Describe the set of identified technology families. The analysis will be used to ensure that the ethics framework and guidelines developed by TechEthos will be relevant and applicable for a wide range of new and emerging technologies
- Inform the choice of a subset of 3 technology families that will form a TechEthos technology portfolio on which the project will undertake in-depth ethical, social, policy and legal analyses. This subset will be used as case studies to develop operational ethics guidelines for these specific technologies

This report outlines the TechEthos horizon scan process and describes in detail the identified set of 16 technology families with high socio-economic impact and ethical relevance. Two follow-up reports (that will be published in January 2022) will describe the impact assessment analysis in detail, the further selection steps leading to the TechEthos technology portfolio and will reflect on the pros and cons and the learnings of the horizon scanning analysis.

The horizon scan methodology consists of an iterative process, based on desk analysis and experts' consultations, that made it possible to:

- Identify from literature a wide number of specific technologies expected to be developed and deployed in the EU and worldwide in the next 5 to 10 years
- Develop a set of qualitative and multi-parametric criteria for the assessment of socio-economic impacts of technologies across five dimensions (industrial & economical, ethics, public, policy, legal)
- Group and filter specific technologies retrieved from literature in about 35 technology families
- Perform a qualitative assessment of these families, based on the identified multi-parametric criteria, leading to a set of 16 high socio-economic impact technology families
- Refine and validate these families and their impacts by engaging a panel of experts from different disciplines and types of organizations (research, industry and policy).
- Condense the analysis in factsheets that describe each of the 16 technology families

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2. Methodology

In this section, a brief description of the process leading to identifying, selecting, and describing a set of new and emerging technologies with a high socio-economic impact and significant ethics dimensions is provided. Further details and reflections will be provided in the other reports (Deliverable 1.2 and Deliverable 1.3) of the TechEthos project.

2.1 Initial assumptions

The TechEthos analysis has specific constraints in terms of focus, time, and resources. In particular, some of the key assumptions (starting points) of our approach include:

- Use existing experience and knowledge from available horizon scanning, foresight, technology assessment and socio-economic analysis, dealing with technology development of future innovations
- Make a mostly qualitative analysis based on desk analysis as well as expert consultation and judgment
- Combine a multi-dimensional assessment of aspects of the technological, ethical, policy dimensions and socio-economic impacts of the technology families under examination
- Focus on the most policy and society-relevant technology families, which are more likely to have short to medium-term impacts
- Consider that the final choice of technology families is instrumental in developing a practical ethics guide for deploying new and emerging technologies

Some limitations and constraints have been identified and are acknowledged since the beginning of the analysis. These will be made explicit and taken into consideration in the final selection, i.e.:

- The type and level of information collected on both the technology families and the criteria for the assessment were limited and varied in a wide range according to the specific technology.
- The assessment of the technology families is qualitative and relies on partners' and experts' experience and judgment
- The analyses are oriented toward selecting specific technologies and thus might miss trends toward convergence of technology families

In the TechEthos horizon scan, we use the term **new and emerging technologies** to identify any type of technology[1] 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 (adapted from the Organization for Economic Co-operation and Development, OECD 2017). The definition of Key Enabling Technologies from the European Commission has also been used as a reference for the analysis and definition of impact assessment criteria[2].

In the context of TechEthos, the term "**technology family**" is defined as a set of specific technologies that are characterised by one or more of the following aspects:

- Aim to perform similar functions

[1] The broad concept of "technology" refers to the state of knowledge on how to convert resources into outputs. This includes the practical use and application to business processes or products of technical methods, systems, devices, skills and practices. (OECD, 2017)
[2] Key Enabling Technologies are: knowledge-intensive technologies associated with high R&D intensity, rapid innovation cycles, high capital expenditure, and high-skilled employment. They enable innovation in processes, goods, and services throughout the economy. They are systemically relevant and multidisciplinary, cutting across many technology areas, with a trend towards convergence and integration. (European Commission, High-Level Strategy Group on Industrial Technologies, 2009 and 2018)

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- Address similar goals/concerns/trends
- Raise similar ethical issues
- Are based on similar (scientific) working principles

2.2 Horizon scan and technology family selection approach

Horizon scan of technologies is a well-established field of activities aiming to anticipate future technological developments and innovations and help mitigate technological surprise[3]. Institutions, companies and other organisations routinely dedicate significant efforts to the early detection of the scientific and technological innovations that can significantly impact society. Such procedures might represent essential information for policy, industry, and economic operators. These stakeholders could adapt their plans and strategies accordingly to increase the efficacy of their action and mitigate risks, among other reasons.

The TechEthos approach takes advantage of the available results from existing, updated, and authoritative technology horizon scan exercises, comparing their methodologies and outcomes and combines them. The goal is to identify new and emerging technologies and determine criteria to define and assess the potential socio-economic impacts of these technologies.

The TechEthos horizon scan and technology family selection process is based on desk analysis and experts' consultation. It uses a step-wise approach, comprising four different phases and a final reflection stage:

1. **A scan of resources and selection criteria** for the analysis, based on desk research and interviews with selected experts, resulting in a "raw technology list" (including more than 150 specific technologies) and a "first list of impact assessment criteria" (Task 1.1 of Work Package 1 of TechEthos)
2. **A systematic review of selected resources** to produce (a) a "draft technology family list" of new and emerging technologies (i.e., 35 technology families) on which "refined impact assessment criteria" are applied; resulting in (b) a "revised technology family list" (i.e., 16 technology families) via the grouping and clustering and selection of technology families, based on areas of application, societal challenges addressed, and a preliminary assessment of potential impacts and ethics dimension (Task 1.2)
3. **An assessment and expert review of the expected socio-economic impact** to (a) develop an impact evaluation matrix to prioritize technology families using identified qualitative review criteria; and (b) apply the impact evaluation matrix through an online survey (Task 1.3, will be described in TechEthos Deliverable 1.2)
4. **A final selection of a portfolio of 3 technology families** based on the survey results in workshops involving project partners and selected experts from the previous steps (Task 1.3, will be described in TechEthos Deliverable 1.2)
5. **Reflection and method generalisation**, to identify key elements needed to integrate the ethics dimension in technological development, based on the technologies identified, their application areas, trends and factors, and socio-economic impacts (Task 1.4, will be described in TechEthos Deliverable 1.3)

[3] For a definition of horizon scanning, see http://www.foresight-platform.eu/community/forlearn/how-to-do-foresight/methods/analysis/horizon-scanning/

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This report describes the technology families identified based on the activities performed in steps 1 and 2 and step 3 up to factsheets of the revised list of 16 TechEthos technology families. Inputs collected from experts in steps 3 and 4 have also been used to refine and validate the information on the technology families, leading to the final factsheets included in this report. The 16 factsheets then served as a basis for selecting the final TechEthos portfolio of 3 technology families. This final selection and the full process undertaken in steps 3, 4 and 5 will be described in detail in the next TechEthos reports (D2.2 and D2.3). Figure 1 shows the timeline of the horizon scanning analysis.

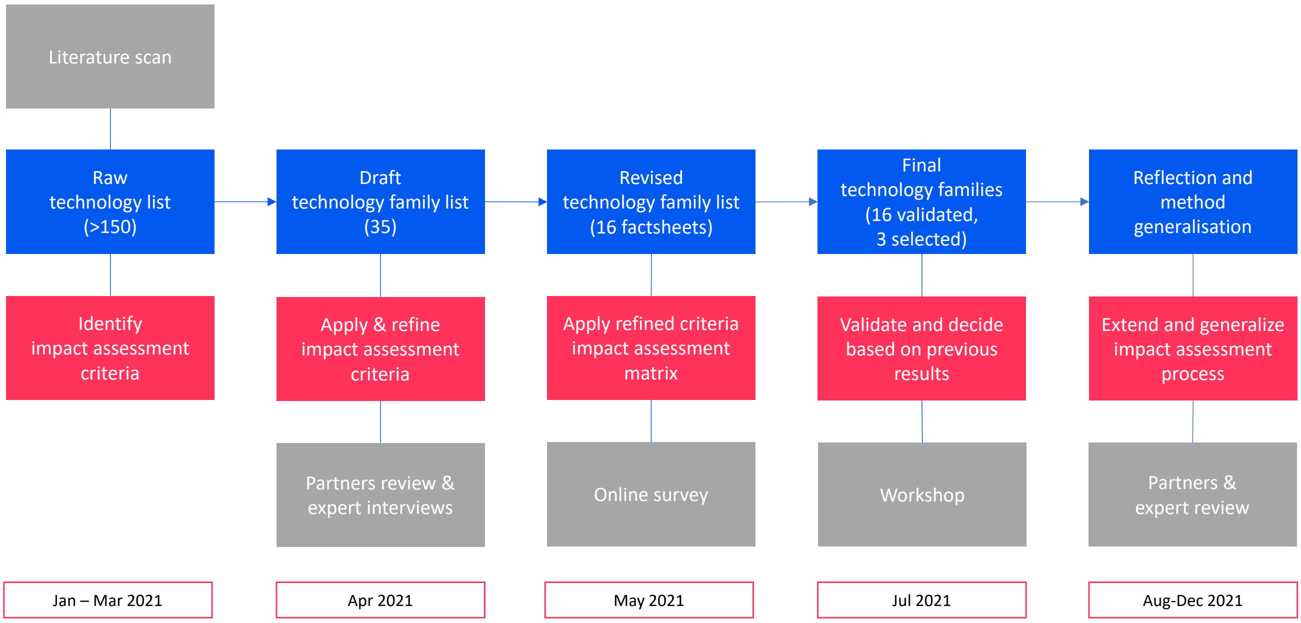

Figure 1: TechEthos horizon scan and technology family identification and selection process

Given the qualitative and dispersed nature of the information collected, multi-criteria decision analysis (MCDA) is being used to compare, assess, and select technology families (Linkov, 2006; Porcari, 2020: Zhang, 2021). MCDA relies on multi-dimensional impact assessment criteria that have been refined and improved during the analysis (see Figure 1 and Table 2).

The TechEthos horizon scan approach combines (1) an analysis of available resources and (2) the collection of experts' judgments:

1) The resource analysis compares and combines outcomes from existing updated and authoritative horizon scan, foresight, technology assessment, and socio-economic analysis studies. It aims to collect information on a broad range of technologies with significant socio-economic impacts. In detail:

- A qualitative part is based on a literature scan leading to a raw list of specific technologies, a structuring of the technologies into a draft technology family list, and a preliminary assessment of their impacts to filter them into a revised technology family list (see section 2.5)
- A quantitative part to evaluate R&D outcomes on the revised technology families list. It is based on data analysis of EU R&D projects (EURPRO data) and global patents (PATSTAT data) (details in section 2.5).

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On this basis, a more detailed assessment of socio-economic impacts was made (Table 2), and integrated into the factsheets. Such factsheets describe the functions, specific technologies, applications, and impact for each of the technology families of the revised list.

2) Expert's judgment was collected from internal (TechEthos) and external experts from different disciplines (e.g., technology assessment, ethics, policy, social and socio-economic sciences, sustainability) and type of organization (research, industry, policy) to validate the choice of technology families and their socio-economic impacts as described by the factsheets. This collection was organized as:

- Iterative review amongst project partners with the aim of:
    - Reviewing the technology families lists and the impact assessment criteria
    - Applying the impact assessment criteria to select the technologies to include in the revised technology family list (see section 3 and annex 6.1 with the list of technologies excluded)
    - Elaborate and review the factsheets
- Interviews with external experts to validate the impact assessment criteria, the technology families, and the factsheets
- An online survey with external experts to validate and integrate the technology families and the impact assessment (will be described in D1.2)
- An open discussion in a workshop with experts of the Advisory Board of the project to discuss the intermediate results (will be described in D1.2)
- A series of workshops, including project partners, the Advisory Board members, and selected external experts to review the technology families and their impact assessment and gathering inputs for the final selection of technology families (will be described in D1.2)

The collected inputs led to validated factsheets of the 16 technology families presented in this report.

2.3 Resources for the horizon scan

The starting point of the analysis are the outcomes from a comprehensive literature analysis (see section 5[4]). This includes existing, updated, and authoritative technology assessment, and horizon scan, and socio-economic analysis from international organizations, think thanks, industry, governments, and other key research, technology and business actors at EU and national level. Several general and sectorial horizon scan and technology foresight reports are published every year. In this study, we mainly focus on authoritative European and worldwide reports published in the last two years.

This phase was used to build a comprehensive list of new and emerging technologies, and to collect data and information to identify relevant impact assessment criteria, and to collect references of experts in different disciplines to assess the impacts of the technologies.

Technology develops in a world that has its drivers and trends, and thus a thorough horizon scan should look at the different types of resources, considering both technology developments and societal expectations. In fact, different drivers are at the core of the next decade's changes.

[4] In section 5 the large part of the references is related to technology developments and informed the identification of technologies. Most are from the period 2018-2020, though for specific fields also some older relevant resources have been included. A limited set of resources refer specifically to horizon scanning methodology and have been used to inform the design of the TechEthos methodology.

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Technological innovation will move the economy and people relations in unexplored territory. This will happen regarding global societal trends, such as contrasting demographic patterns and planetary power shifts. At the same time, humanity's growing ecological footprint is reshaping the political agenda of most policy makers.

Therefore, part of the resources identified, mainly from international policy organizations and institutions, has been selected to clarify the interplay between these new geopolitical, geo-economic and geo- technological drivers. A second series of resources, mainly from academia, look at medium to long-term scientific and technical evolution. A third part, mainly from industrial and business actors, looks at foresight studies analysing short-term trends in industrial-relevant technologies.

2.4 Impact assessment criteria

The assessment of the socio-economic impact of new and emerging technologies has been performed based on specific dimensions of our evaluation:

1. **Industrial and economic impact:** the extent to which technologies could enable innovative applications with impact in valuable and relevant industrial and economic sectors
2. **Ethics impact**: the extent to which technologies enhance or undermine (EU, international) fundamental values (e.g., human rights)
3. **Public impact:** the extent to which technologies could enable innovative applications with potentially significant impact on the life of people and broader societal trends.
4. **Policy impact:** the extent to which technologies are seen as significant/high-priority by policy makers at regional, national, international levels
5. **Legal impact:** the extent to which technologies could challenge existing legal and normative frameworks

The assessment dimensions have been substantiated by a set of qualitative criteria, complemented by ways to qualify (describe) and measure them, as shown in Table 2.

Table 2: Impact assessment dimensions and criteria

	Description and qualification	Qualification/quantification
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
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

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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, the potential for sector-wide transformations, etc.
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 large effects on ethical principles and values
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
PUBLIC IMPACT		
3.1	The potential of the technology family to have a significant impact on **societal challenges** (e.g., Sustainable Development Goals[5], principles of the European Pillar of Social Rights)[6] 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)
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
POLICY IMPACT		
4.1	**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, as reported in documents such as strategies, action plans, foresight exercises, etc. • High: Many/prioritised policy activities as reported in documents such as strategies, action plans, foresight exercises, etc.

[5] https://sdgs.un.org/goals
[6] https://ec.europa.eu/info/strategy/priorities-2019-2024/economy-works-people/jobs-growth-and-investment/european-pillar-social-rights_en

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LEGAL IMPACT		
5.1	The potential of the technology family to significantly affect **existing legal frameworks** is...	• Low: No nor very limited changes in existing legal frameworks • High: Significant changes in existing legal frameworks (e.g., creating new laws; establishing new legal bodies)

Given the time, resources, number of technologies and multi-dimensional criteria concerned with the analysis, the impact assessment has been broad and qualitative. The criteria reported below are indicative, meant to guide and support the qualitative assessment. In particular, the impact assessment performed at this stage of the project considers both positive and negative impacts against each of the criteria listed in Table 2. A more in-depth analysis of impacts will be performed in the next phases of the TechEthos project.

A guideline to interpret and use these criteria, particularly concerning ethical and legal issues, has been developed during the analysis and is provided in annex 6.2.

2.5 TechEthos high socio-economic impact technology families

The scanning exercise identified a draft list of 35 technology families, integrating a wide number of specific technologies retrieved from the literature review. These 35 families have been further selected and refined to a list of 16, based on iterative review amongst project partners and inputs gathered in the experts' interviews. The 16 selected families are reported in this section, while the 19 excluded families are reported in annex 6.1, with a short description of the reasons for the exclusion.

The 16 families have been grouped in research and innovation fields (Table 3), broadly identified based on scientific disciplines and European policy fields[7] to facilitate their overall presentation and description.

In naming and describing the technology families and the individual technologies, in some cases, widely acknowledged terms were adopted. In others, new terms have been used for the purpose of this analysis. Given the broad character of the analysis, a mix of different approaches has been used, including descriptions that are sectoral-oriented (e.g., precision farming), concerns-related (e.g., climate technologies, threat detection and response), application-based (mobility), and technology-based (e.g., quantum technologies, synthetic biotechnologies).

Note that in selecting the 16 technology families, one of the most important criteria has been the need for additional guidance in dealing with ethical aspects of a technology family (criteria 2.2), as a specific requirement of the TechEthos project is to complement the work on ethics analysis done by other initiatives.[8] However, some of the excluded technologies might have been considered within the specific examples of technologies of a family, as they can be used in combination with the other technologies as an enabler of relevant new applications (not covered by existing initiatives).

[7] See for example the definition of Key Enabling Technologies, and the H2020 and Horizon Europe work programme for research and innovation.
[8] See in particular the Sienna and Sherpa projects at www.sienna-project.eu and www.project-sherpa.eu, dealing with ethical analysis of the following technology domains: human genomics & enhancement, robotics, artificial intelligence, human genomics, and human enhancement

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The technology families might include overlaps in terms of specific technologies and application areas, and their description might be partial, given their breadth and the focus of TechEthos analysis (new and emerging and ethically relevant technologies).

Table 3: The shortlisted 16 technology families

R&I field	No	Technology families
Bio and environment	1	Environmental & climate technologies
	2	Bioengineering & industrial biotech (excluding healthcare)
	3	Synthetic biology
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
Health	9	Regenerative medicine
	10	Artificial human/neuro-technologies
Materials and manufacturing	11	Additive, advanced manufacturing technologies
	12	Autonomous systems
	13	Threat detection and response technologies
	14	Precision farming
	15	Mobility technologies
	16	Space technologies

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2.6 Structure of the TechEthos technology family factsheets

Based on the information collected and criteria presented in section 2.5, factsheets have been compiled for each of the 16 technology families.

The factsheets condense the data and information collected for each technology family from the desk analysis and impact assessment activities. As described in section 2.2, draft factsheets were prepared, reviewed by partners, and validated by the experts who participated in the interviews, online survey and workshops. These consultations confirmed the choice of technology families and suggested additional elements and details for refining the 16 factsheets.

The final version of the factsheets forms the core of this report and describes the 16 high socio-economic impact technology families identified by the horizon scan. The factsheets are meant to provide a description of the technology families, their most relevant features, and their potential socio-economic impacts. In detail, the structure consists of the following elements

Descriptive fields

These fields are compiled based on a qualitative assessment using desk analysis and review by experts:

- **Name of the technology family**
- **Description** of the characteristics, functions, and uses of the technology family
- **Key functions and capabilities** of the technology family, indicating if the family refers to hardware and/or software developments
- **Key industrial sectors** of current and/or potential uses and applications of the technologies within the family, considering both traditional and innovative (research-intensive) industrial sectors. A reference list has been developed based on the NACE 2 standard classification for economic sectors and other policy-oriented classifications (see annex 6.3).[9]
- **Examples of specific technologies** clustered within the family. Technologies are classified within a family if they are characterised by one or more of the following aspects: they perform similar functions, are based on similar (scientific) working principles, or address similar goals/concerns/trends (see section 2.1)
- **Examples of applications** enabled by the technologies within the family. These include current and potential expected uses of the technologies across different industrial sectors, considering both business-to-business and business to consumer applications[10]
- **Time horizon to mass market**[11]**,** considering the following indicative time scale short (1-3 years); medium (3-5 years): long (>5 years). The assessment refers to at least one of the specific technologies of the family (e.g., briefly indicate that at least one specific technology within the family is close or already on the market).

[9] The one from the European Commission area Internal Market, Industry, Entrepreneurship and SMEs: https://ec.europa.eu/growth/sectors_en
[10] This field is intended to provide few representative examples of use of technologies, for the purpose of better describing them. However, it cannot be in anyway considered complete. The enabling character, the level of development, and the uncertainties connected to any innovation process, make not possible to foresee all potential applications of a new and emerging technology.
[11] The time to market has been preferred compared to the technology readiness level, as the evaluation of the latter for the wide range of technology analysis was much more difficult and uncertain, based on available resources.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101006249.

Impact assessment fields

These fields are compiled based on a qualitative assessment of the technologies within the family against the impact assessment criteria provided in section 2.4.[12]:

- **Key ethical issues** identified considering the functions and capabilities, technologies, applications listed in the descriptive field, and criterium 2.1 and the guidance provided in annex 6.2.
- **Expected industrial and economic impact**, concerning the key industrial sectors, technologies and applications listed in the descriptive part, and the criteria 1.1 and 1.2 and 1.3.
- **Expected public impact** concerning criteria 3.1 and 3.2 and the guidance provided in annex 6.2.
- **Expected policy impact** concerning the specific technologies and applications listed in the descriptive part, and criterium 4.1.
- **Expected legal impact** concerning criterium 5.1 and the guidance provided in annex 6.2.

Quantitative data

In addition to the qualitative fields, a set of quantitative indicators have also been identified to complement the impact assessment.
The desk analysis process provides the search strategies to identify and quantify these indicators, using keywords identified for each technology family and related to the specific applications within the family.
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.
The quantitative assessment was limited by the set of keywords and the data available. More information is provided in annex 6.2.
The quantitative indicators have been used to support the qualitative assessment and final selection of technology families, taking into account the limitations of the analysis.

Expected industrial and economic impact (quantitative indicators)

- **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.
- **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)

[12] Note that the impact assessment criteria 2.2. (Table 2.2) is not represented in the factsheets. This criterion has been used for the first selection of technology families (from 35 to 16, see section 2.5) and for the final selection leading to the TechEthos technology portfolio (from 16 to 3).

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technological readiness level of the technology family (based on the assumption of low industry participation in basic research).

Expected policy impact (quantitative indicators)

- **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.

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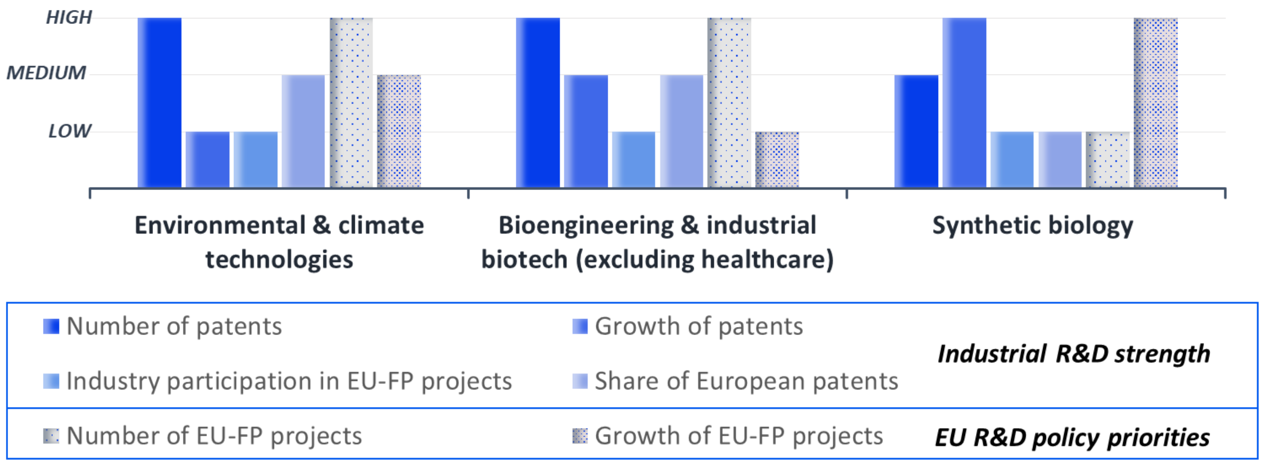
3. Factsheets

3.1 R&I field: Bio & Environment

QUANTITATIVE INDICATORS FOR R&I FIELD: BIO & ENVIRONMENT

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



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.

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TECH FAMILY	1. ENVIRONMENTAL & CLIMATE TECHNOLOGIES
Description	A series of technologies focused on the large-scale use of renewable energy and removing carbon dioxide from industrial processes or the biosphere, including geoengineering techniques, aiming to clean air and clean water and protect and regenerate the biosphere.
Key functions & capabilities	Hydrogen production; CO_2 sequestration and utilisation; Renewable energy storage; Regenerate environmental systems and resources.
Key industrial sectors	Environment; energy; chemicals and materials; biotechnologies.
Examples of technologies	**Carbon capture, usage and storage (CCUS); solar geoengineering technologies; green hydrogen; splitting carbon dioxide; algae and microorganisms against climate change; wastewater nutrient recovery; water splitting; gene editing concerning plants and animals; advanced sensing technologies and data sciences.**
Examples of applications	Renewable energy production and storage; enlargement of artificial and natural carbon sinks; large-scale carbon removal; carbon sequestration or fixing (e.g., turning carbon into construction materials); biorefineries, stratospheric aerosol scattering; microorganisms for cleaning up waste and contaminated sites (bioremediation), microbes for CO_2 capturing as their sole carbon source; microbes that generate energy from light; reflective aerosols.
Time horizon to mass market	Short to medium term for most of them (e.g., Green hydrogen, some Carbon Capture and Storage processes, wastewater treatment).

KEY ETHICAL ISSUES

Irreversibility ▯ Responsibility ▯ Equal access ▯ Animals and plants ▯ Precautionary measures ▯ Environment ▯ Health ▯ Safety

Expected industrial and economic impact	Expected public impact
Includes radical innovations Enabling in several industrial sectors (e.g., manufacturing industry) Priority by most industrial players in relevant industrial sectors Green hydrogen is expected to facilitate a transition towards renewable energy in EU Industrial Strategy.	Limited direct impact on people's lives (most are business to business applications). High impact on the environment and climate *Key SDGs and EPSRs:* affordable and clean energy; sustainable cities and communities; responsible consumption and production; climate action; life on land; healthy, safe and well-adapted work environment.

Expected policy impact	Expected legal impact
Priority for several national, EU and global policy organisations (e.g., contribute to EU climate neutrality, target for 2050 in the EU Green Deal); Energy independence.	Requires adaptations in existing frameworks (e.g., impacts/changes on the Emission Trading System - ETS)

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TECH FAMILY	2. BIOENGINEERING & INDUSTRIAL BIOTECH
Description	Bioengineering applies the design, analysis and knowledge principles and techniques of engineering to biological areas and disciplines. It can be combined with genetic modification of plants and microorganisms for manufacturing purposes (industrial biotechnologies).
Key functions & capabilities	Bioengineering aims to reproduce, imitate or improve biological systems by creating procedures and products (e.g., based on enzymes and microorganisms) that can replace, augment, sustain or anticipate physical-chemical and mechanical bioprocesses.
Key industrial sectors	Agriculture; biotechnology; chemical and materials; food and beverage; environment and energy.
Examples of technologies	**Biologically inspired engineering, including biohybrids; bionics and exoskeleton; bio-inspired materials (e.g., smart biomaterials), bio-inspired electronic systems (e.g., biological-computer interfaces and parts), bio-inspired computing architectures, such as massive parallelism or swarm computational intelligence; bioinformatics & AI in 'omics' data to understand industrial biological processes.**
Examples of applications	Industrial processing (e.g., bioprocess engineering, biocatalysts, bioproducts and biofuels); Self-organised computing systems using nature-from algorithms; gene structure prediction, sequencing, simulation and assembly using advanced computing methods; enhanced food; biological data processing to produce bioproducts, such as crops(against pests, diseases, stressful ambient).
Time horizon to mass market	Short to medium term for few (e.g., self-healing materials, exoskeleton), medium to long term for most techs (e.g., biohybrids, swarm intelligence).

KEY ETHICAL ISSUES

Human rights ▯ Autonomy ▯ Responsibility ▯ Irreversibility ▯ Animals and plants ▯ Environment ▯ Health ▯ Safety

Expected industrial and economic impact	**Expected public impact**
Both incremental and radical innovations Enables innovation in several industrial sectors Priority for some EU and global industrial players.	Medium impact on people's lives (most are B2B applications). Impact on people's safety. *Key SDGs and EPSRs:* Zero hunger; Good health and Well-Being; Industry, Innovation and Infrastructure; Health care
Expected policy impact	**Expected legal impact**
Priority for some national, EU and global policy actors.	Requires both adaptations (e.g., biological material manipulation) and significant changes in existing frameworks (e.g., biohybrid components).

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TECH FAMILY	3. SYNTHETIC BIOLOGY
Description	Design, synthesise and assemble biological parts, circuits, pathways, cells, and genomes to produce a wide range of products.
Key functions & capabilities	Design genetic sequences; data storage; energy production.
Key industrial sectors	Agriculture; biotechnology; environment; food, beverage; medical healthcare
Examples of technologies	**Synthetic food; Alternative proteins (in vitro meat); Artificial photosynthesis; Plant communication, Genome synthesis; DNA synthesis machines.,**
Examples of applications	Support plant and animal breeding processes; develop products with an enhanced nutrient profile or other health-promoting characteristics; data storage; air purification; harvesting of renewable energy; fuel processing; plants as sensors to monitor the environment.
Time horizon to mass market	Short for most of them (e.g., synthetic food/alternative proteins), medium for several others (e.g., DNA synthesis machines).
KEY ETHICAL ISSUES	
Human rights ▯ Irreversibility ▯ Dual-use/misuse ▯ Scientific integrity ▯ Equal access ▯ Human reproduction ▯ Human cells, tissues, embryos ▯ Animal and plants Precautionary measures ▯ Environment ▯ Health ▯ Safety	
Expected industrial and economic impact	**Expected public impact**
Mostly radical innovation Enable innovation in some industrial sectors Priority by some industrial players in relevant industrial sectors Strong impact on agriculture, food processing industry, food prices.	High impact on public health and environment (e.g., water and land use); Impact on people's lives: safety, health, food prices; *Key SDGs and EPSRs:* Zero hunger; Good health and well-being; Sustainable consumption and production;
Expected policy impact	**Expected legal impact**
Priority for some national, EU and global policy actors in relevant sectors. Large public investments on the sustainability of food value chains.	Requires adaptations (e.g., food safety, food frauds) and significant changes or new laws (e.g., screening procedures on DNA synthesis to check biosecurity and innovation risks).

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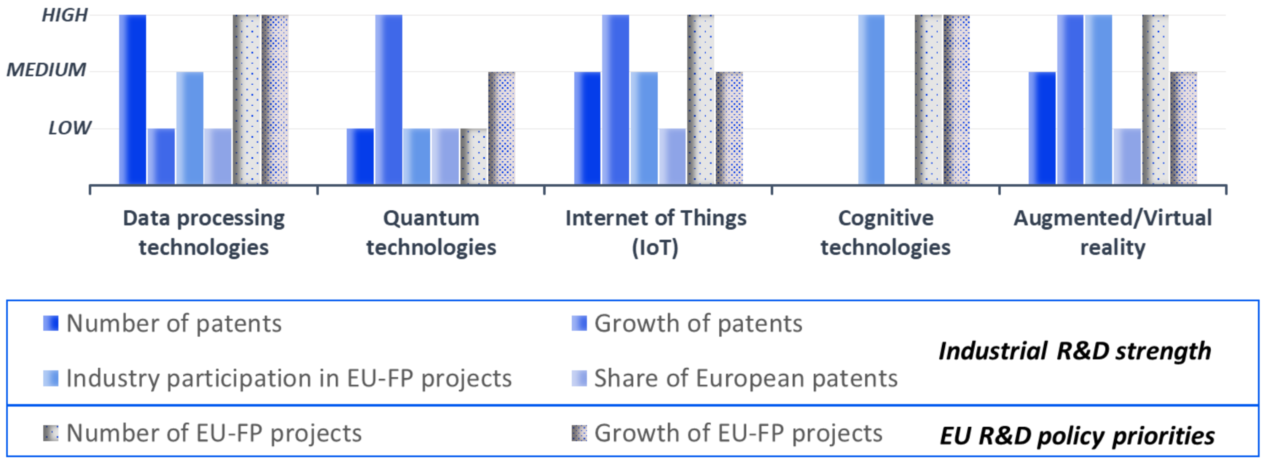
3.2 R&I field: Digital

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.

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TECH FAMILY	4. DATA PROCESSING
Description	Data processing is the rule by which data is collected, elaborated, filtered, sorted, stored, and converted into practical information. Data scientists process large volumes of raw data to generate easier-to-interpret information in an efficient route.
Key functions & capabilities	Set of technologies (hardware and software) that execute specialised algorithms and statistical calculations for elaborating, organising, and structuring a vast amount of disarray data (e.g., personal information, financial transactions and images).
Key industrial sectors	Aerospace; agriculture; automotive; biotechnology; chemicals and materials; defense and security; electric and electronics; energy; environment; finance; ICT and digital; maritime; medical healthcare; space; transport; tourism, arts and cultural heritage.;
Examples of technologies	**Edge and exascale computing (huge calculation/processing power); cybersecurity; distributed cloud; serverless computing (data based on as-used needs not by a fixed bandwidth); neuromorphic computing, distributed ledger technologies and blockchain (digital structural design to process and transmit data encrypted in a decentralised system); chem-puting and 3D printing of molecules.;**
Examples of applications	Data processing: Big data analysis, data science and storage, Privacy-enhancing computation; DLTs (e.g., Blockchain): products traceability; digital currency; transactions safety; digital identity; anti-counterfeiting; supply chain and value chain monitoring; Smart assistants; NLP and chatbots; Chem-puting and 3D printing of molecules: a robotic platform that can accomplish different chemical and material synthesis; edible electronic devices, once eaten can send info from the patient for medical use.
Time horizon to mass market	Short to medium term for most applications (data processing is already a key asset for the economy and our societies).
KEY ETHICAL ISSUES	
Integrity ▯ Security ▯ Inclusivity ▯ Privacy and Data Protection ▯ Dual-use/Misuse ▯ Bias ▯ Discrimination	

Expected industrial and economic impact	**Expected public impact**
Both incremental and radical innovations Enabling in several industrial sectors Priority by some industrial players in relevant sectors Costs of storing and processing data will be a major issue.	Limited impact on people's lives (most are business to business applications) *Key SDGs and EPSRs:* 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.
Expected policy impact	**Expected legal impact**
Priority for several national, EU and global policy organisations.	Require limited adaptations in existing frameworks in most cases, apart from changes required by specific applications (e.g., blockchain)

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TECH FAMILY	5. QUANTUM TECHNOLOGIES
Description	Based on quantum bits that can be zero and one simultaneously and on instantaneous correlations across the device, a quantum computer acts as a massively parallel device with an exponentially large number of simultaneous computations. There already exist algorithms overcoming the speed and capacity of any classical supercomputer.
Key functions & capabilities	Quantum computing, quantum simulation and modeling, big data analysis, route finding problems, quantum sensing, quantum key distribution in encryption, decryption, quantum metrology and quantum imaging, quantum information transfer, quantum long-distance correlation.
Key industrial sectors	Biotechnology; chemicals and materials; defence and security; finance; ICT and digital
Examples of technologies	**Quantum computing, Quantum Internet, Quantum sensors**
Examples of applications	ICT: communication links whose security is underwritten by unbreakable laws of physics (breakthrough compared to conventional encryption); Mining: Ultra-sensitive detection of leakage and faults, Detection of reservoirs; Finance: optimise trading algorithms, Precise clocks for high-speed trading; Defense & Security: Gravity sensor that can spot hidden nuclear submarines, Simulating new materials for lighter and stiffer airplanes or satellites; Health: An improved MRI that works 40 times faster at 25% of the cost; Selecting promising drug candidates from scientific literature; Big Data: Sifting through impractically large data sets; Better machine learning and deep learning/quantum artificial intelligence; Un-hackable internet: An internet system based on end-to-end quantum technology
Time horizon to mass market	early applications on the market, medium to long term for mass market

KEY ETHICAL ISSUES
Security ▯ Privacy and Data Protection ▯ Dual-use/Misuse ▯ Human supervision/control ▯ Equal Access ▯ Bias ▯ Discrimination ▯ Overstretched Promises

Expected industrial and economic impact	Expected public impact
Radical innovations Enable innovation across many sectors Priority by some industrial players in relevant industrial sectors Impact on highly valuable sectors (e.g., finance).	Limited impact on people's lives (most are business to business applications) *Key SDGs and EPSRs:* good health and well-being; healthy, safe and well-adapted work environment and data protection.
Expected policy impact	**Expected legal impact**
Priority for several national, EU and global policy organisations	Requires adaptations in existing legal frameworks (e.g., transparency and accountability of quantum computation processes, comparable to Artificial Intelligence).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101006249.

TECH FAMILY	6. INTERNET OF THINGS (IoT)
Description	IoT refers to a complex network of interactive and technical components clustered around three key elements: sensors, informational processors, and actuators. It represents a global infrastructure for the information society.
Key functions & capabilities	Enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.
Key industrial sectors	IT & communications; enables transformations in all the other sectors.
Examples of technologies	**Advanced sensing technologies; processors, and actuators; Advanced ICT technologies (e.g., 5G), data processing and data analysis technologies**
Examples of applications	Production: smart factories, process management, control and automation; Construction: Smart homes; buildings monitoring; Agriculture: autonomous farming, precision farming; Energy and environment: smart meters, environmental monitoring, emergency systems; Consumers: traceability of goods, counterfeiting, optimisation of consumes; Transport: vehicular communication systems, autonomous driving, smart traffic control, smart cities, shipping containers and logistics tracking; Healthcare: physical prevention and assistive techs; wearable health monitors
Time horizon to mass market	Short to medium term for some applications (e.g., production, construction, energy); medium to long term market for more complex applications.

KEY ETHICAL ISSUES
Autonomy □ Responsibility □ Inclusivity □ Privacy and Data Protection □ Data Ownership □ Security □ Equal Access/Digital Divide □ Surveillance □ Disempowerment □ Safety

Expected industrial and economic impact	**Expected policy impact**
Both incremental and radical innovations Enabling across all the industrial and business sectors Priority by most industrial players in relevant sectors Expected impact on local and national economies (e.g., costs, productivity, processes optimisations, new services enabled).	High impact on people's lives (e.g., new products, monitoring activities, use of resources) alters people and technologies' interaction. *Key SDGs and EPSRs:* Industry, innovation and infrastructure); Sustainable cities and communities; Social dialogue and involvement of workers; Healthy, safe and well-adapted work environment and data protection; Inclusion of people with disabilities; Access to essential service.
Expected policy impact	**Expected legal impact**
Priority for several national, EU and global policy organisations.	Requires adaptations in existing legal frameworks (e.g., cybersecurity threats)

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TECH FAMILY	7. COGNITIVE & BEHAVIORAL TECHNOLOGIES
Description	Cognitive technologies allow data collection from people (from different sources such as voice, movements, choices) and analyse them to model, predict or influence their behavior.
Key functions & capabilities	Gathering, processing, and analysing any data and information to monitor, study, and influence human behavior (e.g., object identification, image classification). Understand behavior and cognitive capacities of humans (behavioral engineering and applied behavioral analysis).
Key industrial sectors	Aerospace; automotive; biotechnology; chemicals and materials; defence and security; electric and electronics; finance; ICT and digital; machinery and equipment; medical healthcare; transport
Examples of technologies	**Chatbots and smart assistants; data mining; pattern recognition; Artificial Intelligence (AI) techs (speech recognition; Gesture recognition; Natural language processing, rules-based AI systems); Human-machine interfaces;**
Examples of applications	Multipurpose internet of behavior: processing of data to influence human behavior based on personal profiling (e.g., facial recognition, location tracking and big data); nudge and affective computing; cybersecurity applications; Healthcare: digital health systems, and digital health analytics. Consumers: monitor and analyse customers behaviours and buying processes, tracking users interactions with devices; personalised marketing; use of individuals emotions for commercial and public purposes; Transports: driver cab panels, passenger seat controls; access control (door opening); emergency call panels; monitoring and guiding driving behaviours;
Time horizon to mass market	Short to medium for few applications, medium to long term for most complex applications.
KEY ETHICAL ISSUES	
Human Rights ▯ Integrity ▯ Autonomy ▯ Privacy and Data Protection ▯ Security ▯ Human Interaction ▯ Equal Access/Digital Divide ▯ Surveillance ▯ Disempowerment	

Expected industrial and economic impact	Expected policy impact
Both radical and incremental innovations Enabling across many sectors Priority by most industrial players in relevant sectors Impact on both local and national economies.	High impact on people's lives (behaviors, choices, interaction with the environment); possible impact on people's safety; impact on jobs *Key SDGs and EPSRs:* good health and well being); responsible consumption and production; education, training and life-long learning; inclusion of people with disabilities.
Expected legal impact	**Expected public impact**
Priority for several national, EU and global policy organisations.	Requires adaptations in existing legal frameworks (e.g., cybersecurity, transparency, accountability security, emotional data sharing).

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TECH FAMILY	8. VIRTUAL/ AUGMENTED REALITY
Description	Virtual reality (VR) is used to create a simulated and immersive experience similar or completely different from the real world. Augmented reality (AR) provides an enhanced digital version of real-world physical components. It allows real and virtual world combination that responds to user's inputs in real-time. Digital twins are real-time interactive digital replicas of living or non-living entities.
Key functions & capabilities	VR provides a partial/full replacement of the user's real-world environment with a simulated or digital one. AR provides an alteration of the user's ongoing perception of the real-world environment.
Key industrial sectors	Aerospace; automotive; defense and security; electric and electronics; ICT and digital; healthcare; manufacturing; space; tourism, art and culture heritage;
Examples of technologies	**Software technologies: computer and algorithms for coding/modeling, such as Virtual Reality Modeling Language (VRML) or Augmented Reality Markup Language (ARML). Hardware technologies, such as headsets, smart glasses, contact lenses, projection mapping, motion sensors, tracking, control; haptics devices: wired gloves, 3D mice, optical sensors, speech and gesture recognition.**
Examples of applications	Healthcare: support in surgical and other delicate medical conditions; treat therapeutic needs such as anxiety, stress disorder, and phobias. Multi-purpose: virtual manufacturing, all-virtual design. Digital twins, to create, build, and test processes, materials and components in a virtual environment (e.g., industrial production, military, space, mining, architecture, education and training) Online product selling (3D visualisation); virtual business meetings; archeology; education, artistic and cultural tours; Video games, virtual social worlds; fitness, sports
Time horizon to mass market	Short to medium term for most applications

KEY ETHICAL ISSUES

Human Rights ▯ Integrity ▯ Human Interaction ▯ Privacy and Data Protection ▯ Human Control ▯ Dual-use/Misuse ▯ Equal Access/Digital Divide ▯ Equality and Discrimination

Expected industrial and economic impact	Expected public impact
Both radical and incremental innovations Enabling across several sectors Priority by some industrial players in relevant sectors.	High impact on people's lives (entertainment, education, commerce, social networking, sport and health). Impact on jobs. *Key SDGs and EPSRs:* good health and well-being; education, training and life-long learning; inclusion of people with disabilities.
Expected policy impact	**Expected legal impact**
Priority for some national, EU and global policy organisations.	Requires adaptations in existing legal frameworks (e.g., digital twin)

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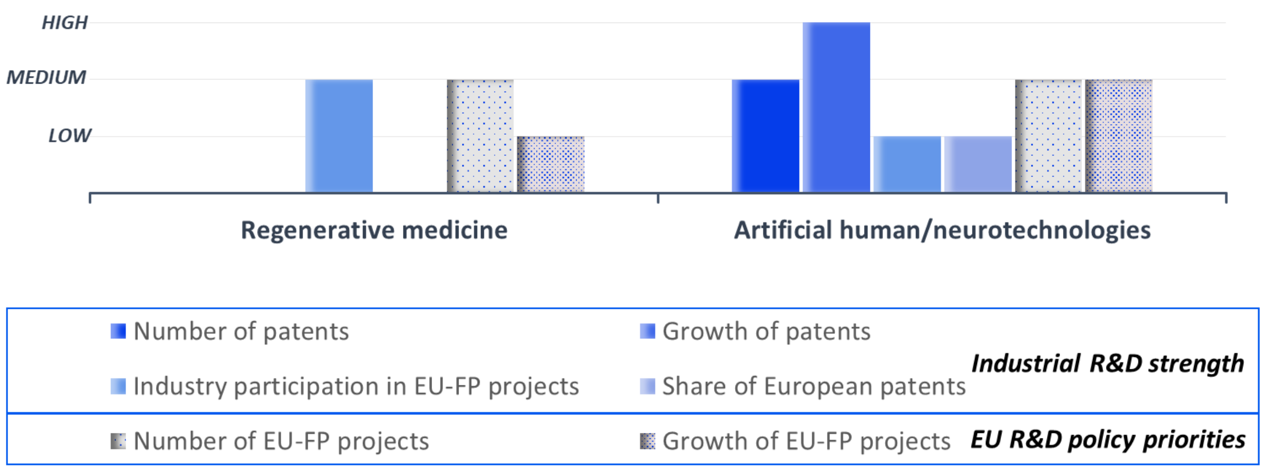
3.3 R&I field: Health

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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TECH FAMILY	9. REGENERATIVE MEDICINE
Description	It focuses on restoring, regrowing or replacing the normal function of human or animal cells, tissues, and organs damaged by disease, congenital issues, or trauma. Includes improved methods for cell differentiation, cell culture, and tissue engineering.
Key functions & capabilities	Group of technologies that provide tools and methods to repair, restore and replace human/animal components such as organs, tissue units and cells.
Key industrial sectors	Biotechnology; chemicals and materials; medical and healthcare
Examples of technologies	**Tissue engineering and biomaterials; cells therapies; medical devices and artificial grown tissues and organs**
Examples of applications	Transplantation of laboratory-grown organs and tissues into the patient body, including the growth of human-compatible organs in animals for transplantation (xenotransplantation); biodegradable implants; cell therapies methods, Immuno-modulation therapy, immune system regeneration, damaged brain tissue repair; bone regeneration therapies. Intelligent biohybrid systems, i.e., integration of bioengineered brain tissue, neuromorphic microelectronics, and artificial intelligence to develop efficient self-repair dysfunctional brain circuits; Bioprinting, 3D printing of cell-based components to develop fully functional and patient-personalised humans/animal biological units.
Time horizon to mass market	Short to medium term for some applications (e.g., tissue engineering), medium to long term for most advanced applications.

KEY ETHICAL ISSUES
Responsibility ▯ Integrity ▯ Irreversibility ▯ Human Cells, Tissues, Embryos ▯ Dual-use/Misuse ▯ Equal Access ▯ Harm ▯ Scientific Integrity ▯ Overstretched Promises ▯ Precautionary Measures

Expected industrial and economic impact	Expected policy impact
Radical innovations Enable innovation in healthcare Priority by industrial players in the healthcare Impact on highly valuable sector.	High impact on people's health and safety; game-changing paradigm for a wide range of many incurable diseases, access to health treatments *Key SDGs and EPSRs:* good health and well-being; health care; inclusion of people with disabilities; long-term care.
Expected legal impact	**Expected public impact**
Priority for national, EU and global policy organisations dealing with public health	Adaptations in existing regulatory frameworks, (harmonisation, patients' rights keep pace with technology advances)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101006249.

<table>
<tr><th>TECH FAMILY</th><th>10. ARTIFICIAL HUMAN/NEURO-TECHNOLOGIES</th></tr>
<tr><td>Description</td><td>Aim to replace parts of the human body or affect human capabilities. They can interface with living tissues for a two-way interaction between the body and the external environment or systems.</td></tr>
<tr><td>Key functions & capabilities</td><td>Collecting information from and feeding it into the human body (e.g., brain); recording the activity of the body (or parts of it) and transmitting stimuli (e.g., from/to the nervous system); enabling object, voice and gesture recognition; emotion and health analytics;</td></tr>
<tr><td>Key industrial sectors</td><td>ICT and digital; medical healthcare; defence and security; automotive;</td></tr>
<tr><td>Examples of technologies</td><td>Artificial uterus; artificial synapse; artificial brain; wearable organs; (direct) brain-machine interfaces; neuromorphic engineering; neuromorphic chips and computing; the neuroscience of creativity; bionics; neurostimulation.</td></tr>
<tr><td>Examples of applications</td><td>Restoring a lost sense, enabling the body (e.g., the brain) to interact with the environment; strengthen or reroute information from injured areas of the brain; gene drive (CRISPR)[13] and gene editing; man-machine symbiosis; brain-to-brain communication; application to mental health diseases cure; brain stimulation to contrast diseases such as Parkinson's; cognitive training to maintain cognitive functions during aging; human organs (or tissues) replacement; organoids; intelligent biohybrid;</td></tr>
<tr><td>Time horizon to mass market</td><td>Medium to long term</td></tr>
<tr><td colspan="2">KEY ETHICAL ISSUES</td></tr>
<tr><td colspan="2">Human Rights □ Autonomy □ Integrity □ Responsibility □ Privacy and Data Protection □ Human Interaction Human Reproduction □ Dual-use/Misuse □ Irreversibility □ Scientific Integrity □ Overstretched Promises □ Precautionary Measures □ Equal Access</td></tr>
<tr><td>Expected industrial and economic impact</td><td>Expected public impact</td></tr>
<tr><td>Radical innovations
Enable innovation in healthcare and potentially other sectors
Priority by some industrial players in the healthcare
Impact on highly valuable sector
Most of the technologies are far from the market, so it is difficult to foresee industrial and economic impacts (potentially high).</td><td>Impact on people's health and safety; Increase in 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.</td></tr>
<tr><td>Expected policy impact</td><td>Expected legal impact</td></tr>
<tr><td>The policy is mostly oriented to support research and prototyping activities.</td><td>Significant changes in existing legal frameworks</td></tr>
</table>

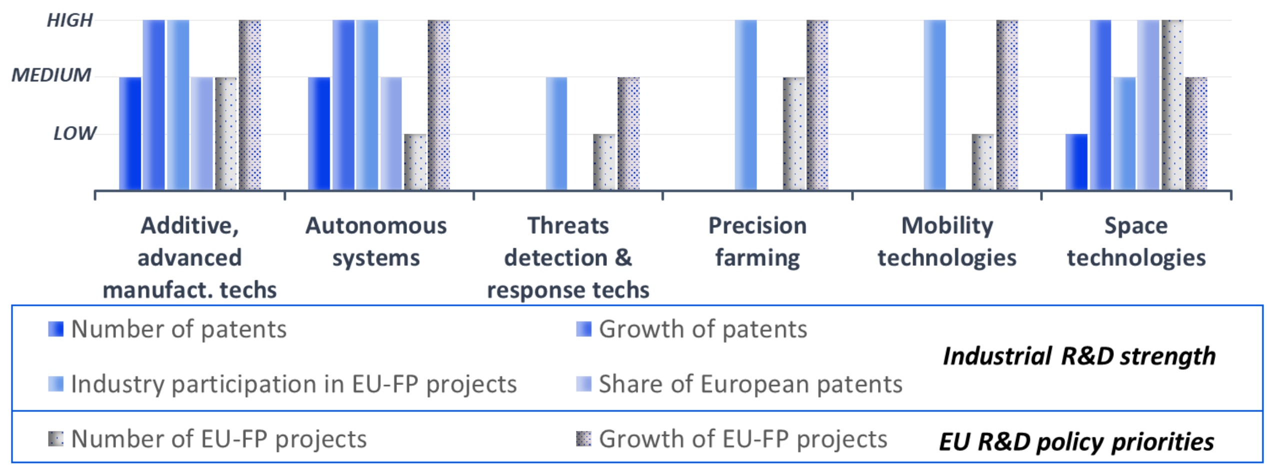
[13] CRISPR is a new method of gene therapy or gene editing. Source: European Commission (2019a) 100 Radical Innovation Breakthroughs for the future (RIBRI) and The North Atlantic Treaty Organization (NATO) (2020) Science & Technology Trends 2020-2040.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101006249.

3.4 R&I field: Materials & Manufacturing

QUANTITATIVE INDICATORS FOR R&I FIELD: MATERIALS & MANUFACTURING

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



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.

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TECH FAMILY	11. ADDITIVE & ADVANCED MANUFACTURING TECHNOLOGIES
Description	Additive manufacturing refers to a group of technologies that allow the fabrication of objects by the selective and consecutive addition of material (e.g., ceramic, plastic, metal, concrete, food, or living components).
Key functions & capabilities	It allows the production of complex objects by the addition of material.
Key industrial sectors	Aerospace; automotive; machinery and equipment; biotechnology; chemicals and materials; construction; food and beverage; medical and healthcare; transport; tourism, arts and cultural heritage; space; textile; crafting; hobby and arts
Examples of technologies	**3D printing of food, glass, large objects and buildings, organs; microfluidic platforms, optical devices; metal and ceramic parts.**
Examples of applications	Producing complex-shaped and tailored structures; soft robotics, sensor and actuators and 4D systems; customised, modular components (e.g., machinery, construction). Food: Synthetic foods (such as meats) by cultivating and printing cells. Healthcare: organs and other biological components by raw materials containing biological units; medical implants, tissue engineering; point-of-care devices; drug delivery; patient-specific parts.
Time horizon to mass market	Short for a few of them (e.g., machinery, automotive), medium to long term for other sectors and most advanced applications.

KEY ETHICAL ISSUES

Responsibility ▯ Inclusivity ▯ Autonomy ▯ Security ▯ Dual-use/Misuse ▯ Safety ▯ Health ▯ Equal Access ▯ Overstretched Promises

Expected industrial and economic impact	Expected public impact
Both incremental and radical innovations Enable innovation in most industrial sectors Priority by most industrial players at local, national and global levels Changing business models (e.g., self-production of goods).	Pervasive impact on many daily life products and services, directly affecting citizens; possible impact on worker's safety; *Key SDGs and EPSRs:* Zero hunger); Good health and well-being; Industry, innovation and infrastructure; Healthy, safe and well-adapted work environment; Health care.
Expected policy impact	**Expected legal impact**
Priority for several national, EU and global policy organisations.	Requires adaptations in existing frameworks (e.g., (IPR violations due to unauthorised distribution of digital files, use for dangerous purposes) and significant changes or new laws (e.g., error or misprinting in medical applications).

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TECH FAMILY	12. AUTONOMOUS SYSTEMS
Description	Autonomous systems are multidisciplinary scientific and technological fields for implementing complex systems with cognitive capabilities that automatically respond to real-world conditions. This differs from traditional automation that requires predictable conditions to operate. Often based on artificial intelligence for modeling complex and intricate environments.
Key functions & capabilities	A class of methods and technologies developed to respond to real-world conditions automatically and (near)independently.
Key industrial sectors	Aerospace; agriculture; automotive; constructions; defense and security; ICT and digital; machinery and equipment; maritime; medical and healthcare; space; transport
Examples of technologies	**Autonomous vehicles (car, aircraft, drones), autonomous industrial machines and robots, adaptive assurance of autonomous systems; hyper-automation**
Examples of applications	a large variety of uses, industrial automation and logistics systems, maintenance, precision farming, autonomous driving, space exploration, surveillance, emergency and rescue, commercial services, health care, rehabilitation, assistive living, entertainment, education and social interaction; autonomous decision-making machines; intelligent infrastructures, products that automatically respond to different conditions (e.g., smart windows).
Time horizon to mass market	Short to medium term for less advanced systems (e.g.-industrial automation, agriculture, automotive, medical healthcare). Medium-term for more sophisticated systems and mass applications.

KEY ETHICAL ISSUES

Freedom ▯ Privacy ▯ Security; Autonomy ▯ Data Protection Harm ▯ Dual-use/Misuse ▯ Blurring Fundamental Legal and Moral Categories ▯ Equal Access ▯ Precautionary Measures ▯ Health ▯ Safety ▯ Environment

Expected industrial and economic impact	Expected public impact
Radical innovations High industrial impacts in several sectors (disruptive change of strategies and processes) High economic impacts (productivity, jobs).	Impact on people's safety and lives, pervasive across wide sectors of society. Impact on public and private services and industrial automation. Key SDGs and EPSRs: Good health and well-being); Sustainable cities and communities); Industry, innovation and infrastructures; Healthy, safe and well-adapted work environment and data protection; Health care; Access to essential services.
Expected policy impact	**Expected legal impact**
Priority for several national, EU and global policy organisations. A vast quantity of standard work for autonomous systems.	Require adaptations of the existing frameworks (e.g., safety, security and privacy, labour, criminal law and procedure).

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TECH FAMILY	13. THREATS DETECTION AND RESPONSE TECHNOLOGIES
Description	Multi-tech and multidisciplinary approaches to deal with complex, large, and cascading risks, ranging from pandemic disease to cyber-attacks, accidents and disruptive events (climate change, financial crises, among others). Requires a combination of various scientific and technological disciplines, such as hydrology, geology, geophysics, seismology, volcanology, meteorology and biology, and sociology, humanities, political sciences and management science.
Key functions & capabilities	Prevent, manage and mitigate multi-factor and interdependent risks, including animal and plant diseases, atmospheric, geological, hydrological events, nuclear and radiological accidents, disruption of critical infrastructures, industrial accidents, terrorism and cyber threats.
Key industrial sectors	Defense; aerospace; chemicals and materials; ICT and digital; biotechnology
Examples of technologies	**Combined development and use of multi-sensor technologies, software and IC technologies; unmanned monitoring and surveillance systems (e.g.drones, robots); centralised data management and analytics; decontamination management; doppler radar; disaster-resilient materials and electricity resistant measuring techniques (geological investigations). All these will benefit in combination with AI.**
Examples of applications	Disaster risk reduction (DRR), disaster risk management (DRM) and chemical, biological, radiological and nuclear (CBRN).
Time horizon to mass market	Short to medium for several applications, but time to market could completely change depending on the application and whether incremental or radical innovation is required.

KEY ETHICAL ISSUES

Human Rights ▯ Responsibility ▯ Inclusivity ▯ Autonomy ▯ Data Protection ▯ Security ▯ Dual-use/Misuse ▯ Harm ▯ Equal Access ▯ Non-discrimination

Expected industrial and economic impact	**Expected public impact**
Both incremental and radical innovations If connected to large government investment may drive industrial developments in diverse tech sectors Improve the resilience of economic systems (preventing and mitigating risks).	Potential wide impact on the population, in mitigating risks for mass casualty events, disease outbreaks, natural disasters. Potential large impact in risk perception, attitudes of people. Large Impact on health care and public health systems and infrastructures. *Key SDGs and EPSRs:* Decent work and economic growth; Equal opportunities; Health care; Access to essential services.
Expected policy impact	**Expected legal impact**
Priority for most EU and global economies. The EU is updating its strategy for disaster management and will likely include most of the technologies described.	Require adaptation of existing frameworks (e.g., the transnational dimension of global threats, requires coordination among the national legal frameworks).

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<table>
<tr><th>TECH FAMILY</th><th colspan="2">14. PRECISION FARMING</th></tr>
<tr><td>Description</td><td colspan="2">Use digital and other new techs to develop new products, services or applications along the agriculture value chain.</td></tr>
<tr><td>Key functions & capabilities</td><td colspan="2">Improve yield, efficiency, safety, and profitability</td></tr>
<tr><td>Key industrial sectors</td><td colspan="2">Agriculture; food; health; transport (biofuels).</td></tr>
<tr><td>Examples of technologies</td><td colspan="2">Pervasive automation by large-scale robotic and microrobots, soil and water sensors, RFID, weather tracking, satellite imaging, minichromosomal technology, vertical farming, genetic and synthetic biology methods for multiple purposes (e.g., plants modification, in vitro meat).</td></tr>
<tr><td>Examples of applications</td><td colspan="2">Checking and maintaining crops at the plant level via large-scale robotic and microrobots and sensors; real-time traceability and diagnosis of the crop; livestock and farm machine states and food may benefit directly from genetic tailoring and potentially producing meat directly in the labs.</td></tr>
<tr><td>Time horizon to mass market</td><td colspan="2">Short term for most applications (e.g., for automation and tracking).</td></tr>
<tr><td colspan="3">KEY ETHICAL ISSUES</td></tr>
<tr><td colspan="3">Human Rights ▯ Autonomy ▯ Harm ▯ Animals and Plants ▯ Environment ▯ Equal Access</td></tr>
<tr><td colspan="2">Expected industrial and economic impact</td><td>Expected public impact</td></tr>
<tr><td colspan="2">Most innovations are incremental
Enable innovation in few industrial sectors
In the focus of sectoral industrial strategies and investments
Potential for large and disruptive impact on local and national economies (e.g., large, automated, high productivity farms, in vitro meat)
Deployment strongly depends on the context.</td><td>High impact on nutrition (and basic survival needs) and food security, and the environment. Decreased use of water, fertilizer, and pesticides, which in turn keeps food prices down. Potential impact on inequalities (e.g., small farmers, large corporations). Impact on worker safety and jobs.
Key SDGs and EPSRs:
zero hunger; clean water and sanitation; decent work and economic growth); life on land; wages; healthy, safe and well-adapted work environment and data protection.</td></tr>
<tr><td colspan="2">Expected policy impact</td><td>Expected legal impact</td></tr>
<tr><td colspan="2">Relevant technology, at least for some national, EU and global policy actors.</td><td>It could require adaptations of existing frameworks.</td></tr>
</table>

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TECH FAMILY	15. MOBILITY TECHNOLOGIES
Description	Novel methods and technologies to achieve a shift from vehicle ownership to vehicle use (sharing economy models), improve efficiency, safety, sustainability, flexibility, congestion, and the comfort of all transport modes (i.e., road, rail, shipping and aviation).
Key functions & capabilities	'Custom–fit' mobility and transport services, sustainable and safe mobility, reducing its carbon footprint and aiming for zero casualties
Key industrial sectors	Transport; automotive; aerospace; maritime; railway; environment; tourism
Examples of technologies	**Combined development of different emerging technologies, such as smart sensors, connectivity, blockchain, big data, digital platforms, artificial intelligence; autonomous vehicles, electric vehicles, flying vehicles; position tracking ;**
Examples of applications	Includes Cooperative Intelligent Transport Systems (C-ITS), Connected Cooperative Automated Mobility (CCAM). Mobility as a Service (MaaS), Self-organising Logistics (SoL); optimised transportation
Time horizon to mass market	Short to medium term for early innovations, wide deployment in the medium to long-term.

KEY ETHICAL ISSUES
Responsibility ▯ Inclusivity ▯ Safety ▯ Security ▯ Equal Access ▯ Human Supervision/Control

Expected industrial and economic impact	Expected public impact
Incremental and radical innovations Enable innovation in several sectors High industrial impacts (disruptive change of strategies and processes) High economic impacts (productivity, jobs)	Impact on infrastructures, physical spaces of humans, and people's lives (e.g., position tracking). Impact on the environment (e.g., emissions) and safety. *Key SDGs and EPSRs:* Sustainable cities and communities; equal opportunities; inclusion of people with disabilities; access to essential services.
Expected policy impact	**Expected legal impact**
Priority for most national, EU and global policy organisations.	Requires adaptations in existing frameworks (safety, digital infrastructure, data standards, privacy and security solutions, barriers to enter markets, legislative harmonisation)

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TECH FAMILY	16. SPACE TECHNOLOGIES
Description	A group of technologies developed for space flight or space exploration, including spacecraft, satellites, space stations, and supporting infrastructure equipment. Spill-over in several economic sectors and services benefits
Key functions & capabilities	They enable outer space flights and explorations, and scientific and technological developments in different fields, and their transfer to economic and industrial sectors
Key industrial sectors	Aerospace; agriculture; automotive; biotechnology; chemicals and materials; construction; defense and security; electric and electronics; energy; finance; ICT and digital; machinery and equipment; medical and healthcare; maritime; space; minerals and forest-based resources; tourism; arts and cultural heritage; textile; transport; food and beverage
Examples of technologies	**Combined development of robotics, AI, sensors, ultralight and adaptive materials and structures, advanced systems for integration; ICT, storage, and energy distribution.**
Examples of applications	Planetary and solar exploration technologies; space propulsion systems techs for the use of space resources (e.g., asteroid mining), refueling, maintenance, transport and removal of satellites/debris in orbit, "next-generation" atomic space clocks.
Time horizon to mass market	Short to medium term for several technologies (e.g., monitoring and tracking). Other technologies (e.g., exploration and observation of distant/deep space zones) are long-term.

KEY ETHICAL ISSUES

Integrity ▯ Privacy ▯ Responsibility ▯ Data Protection ▯ Security ▯ Dual-use/Misuse ▯ Equal Access ▯ Overstretched Promises

Expected industrial and economic impact	Expected public impact
Mostly incremental innovations Enabling in several industrial sectors (e.g., manufacturing) High cross-sectorial discipline involving different scientific and industrials areas.	Impact on public services (e.g., communications) and public security. Spill-over applications might have a large impact on people’s lives. Potential large impact on public opinion (risk perception, attitudes toward techs). *Key SDGs and EPSRs:* Good health and well-being industry, innovation and infrastructure, access to essential services.
Expected policy impact	**Expected legal impact**
A priority with high policy impact for several national, EU and global policy organisations.	Requires significant changes to many international regulatory and legislative changes to create a safe environment for space exploration (e.g., outer space operations and exploration consequences, such as rights on external space resources and space debris).

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4. Conclusions & outlook

In this study, the horizon scan has been based on the combination of analysis of authoritative European and worldwide reports, published in the last two years, and review and validation of results by a panel of experts in different disciplines, including technology assessment, ethics, policy, social and socio-economic sciences, sustainability, and from various type organizations (research, industry and policy). The overall results provide a comprehensive and updated picture of technologies with a high socio-economic impact and significant ethical dimension, expected to be developed and deployed in Europe and worldwide in the next five to ten years.

Horizon scan and technology foresight is a particularly complex activity. Comparison among different resources has been challenged by the lack of a standard taxonomy for new and emerging technologies, as some sources aggregate technologies based on disciplinary contiguity, while others aggregate considering the application fields. Once a comprehensive list of new and emerging technologies has been put in place, impact assessment criteria have been developed to select those technologies with the highest expectation regarding socio-economic impact, combined with ethical relevance.

It hardly needs to be said that the work comes with limitations because of the qualitative nature of most of the desk analysis and the complexity in the relations between technologies to come, and the effects of society. Eventually, the outcome of this sensitive filtering brought a new granularity in grouping the technologies.

A final stage of the horizon scan is being undertaken to select a portfolio of 3 technology families to focus on in the rest of the TechEthos project and to analyse and reflect on the process and outcomes of the horizon scan and distil recommendations and learnings for the ethical analysis of new and emerging technologies of relevance for the project and practitioners and decision-makers policy, industry, civil society. These will be described in the next reports (planned by January 2022):

- D1.2 Assessment and expert review of the expected socio-economic impact to (a) develop an impact evaluation matrix to prioritize technology families using identified qualitative review criteria, and (b) apply the impact evaluation matrix through an online survey. (c) A final selection of a portfolio of 3 technology families based on the survey results in workshops involving project partners and selected experts from the previous steps.
- D 1.3 Reflection and method generalization to identify key elements needed to integrate the ethics dimension in technological development, based on the identified technology families, application areas, trends and factors, and socio-economic impacts.

The challenge of future work will be played out mostly on the terrain of the scenarios created by the reciprocal influences that the various technology families will exercise between them. These can have socio-economic impacts that cannot be extrapolated from studying the applications of individual technologies. To favour the definition of these potential scenarios and the consequent reflection on their ethical implications, the choice of technologies in this first phase of the project has maintained a wide granularity. The goal of the future work will be the development of specific guidelines and a broader framework that is possibly applicable to other technologies and scenarios.

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6. Annex

6.1 Merged or excluded technology families

Table 4: List of merged or excluded technology families (see section 2.5)

R&I Field	No	Technology family	Reason for merging/exclusion
Bio & Environment	17	Bioproducts	Excluded: novelty and ethics impact limited (criteria 1.1, 2.1); at least partially covered by existing ethics guidance (criteria 2.2)
	18	Human enhancement	Excluded: already covered by existing ethics guidance, such as guidelines from Sienna and Sherpa project (criteria 2.2)
Digital techs	19	Advanced computing	Merged with the Data processing technology family
	20	Artificial intelligence	Excluded: partially covered by existing ethics guidance, such as guidelines from Sienna and Sherpa project (criteria 2.2). Specific uses and applications integrated in different technology families.
	21	Cybersecurity techs	Merged with the Data processing technology family
	22	Human behaviour technologies	Partially covered by existing ethics guidance, such as guidelines from Sienna and Sherpa project (criteria 2.2). Elements merged in Cognitive and behavioural techs
	23	Human-machine interfaces	Partially covered by existing ethics guidance, such as guidelines from Sienna and Sherpa project (criteria 2.2). Elements merged in Cognitive and behavioural techs and other technology families
Health	24	Genetic Technologies	Excluded: already covered by existing ethics guidance, such as guidelines from Sienna and Sherpa project (criteria 2.2)
	25	Personalised medicine	Excluded: sectorial (not enabling across sectors, criteria 1.2); partially covered by existing ethics guidance (criteria 2.2)

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Materials and manufacturing, techs	26	Advanced materials	Excluded: too broad definition, and ethics impact limited (criteria 2.1). Relevant elements integrated into the technology families within the Materials and manufacturing field
	27	Critical infrastructure technologies	Excluded: sectorial (not enabling across sectors, criteria 1.2); ethics impact limited (criteria 2.1); relevant elements integrated into the Threats detection and response technology family
	28	Energy storage and production technologies	Merged with the Environmental and climate technology family
	29	Industrial automation	Merged with the Autonomous systems technology family
	30	Materials and production systems for the circular economy	Merged with the Environmental and climate technology family
	31	Military, defence, security technologies	Excluded: out of the scope of the project (all EU framework program funded research must have an exclusive focus on civil applications, thus excluding military and defence applications, but including issues of civil security)
	32	Molecular engineering	Excluded: ethics impact limited (criteria 2.1)
	33	Nanotechnologies and nanomaterials	Excluded: partially covered by existing ethics guidance (criteria 2.2)
	34	Robotics	Excluded: partially covered by existing ethics guidance, such as guidelines from Sienna and Sherpa project (criteria 2.2). Specific uses and applications integrated into the Autonomous systems technology family
	35	Sensing and imaging technologies	Partially merged with the Environmental & climate technologies, Internet of Things, and Threats detection and response technology families

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6.2 Guidance on ethical, legal and public impact assessment

Further parameters in assessing the relevance of each technology were ethical, legal, and public impact.

ETHICAL IMPACTS
Fundamental principles:

1. Impact on: human rights, freedom, autonomy, integrity, responsibility, privacy, security, inclusivity.
2. Potential for: harm, dual-use/misuse, novelty/radical, blurring fundamental legal and moral categories, human supervision/control, irreversibility.

Applied/specific concerns:

3. Impact on: health, safety, privacy and data protection, environment, sustainability, human cells, tissues, embryos, animals and plants, human interaction, human reproduction.
4. Concerns over: scientific integrity, overstretched promises, preventive measures, equal access.

LEGAL IMPACTS:
List of fundamental principles of democracy & rule of law:

5. Non-derogable fundamental rights: right to life; right to be free from torture and CID; right to be free from retroactive application of penal law
6. Definition of personhood
7. Transparency and accountability of governments
8. Access to legal redress mechanisms
9. Equality before the law and rights of minority groups
10. Fairness/non-discrimination under the law
11. Free and fair elections

List of legal domains for the assessment of legal impact:

12. Human beings, human cells or tissues, human embryos & foetuses (conduct of research law), research on animals (animal law), privacy, data protection, IPR, criminal law/criminal procedure, contracts law, environmental and natural resources law, health law (including drug and devices testing and approvals), labour law, family law, ICT law, outer space law, corporate/tax law, trade/customs law, immigration law, int'l law (humanitarian, law of armed conflict), products liability, insurance law, dispute resolution/judicial systems.

PUBLIC IMPACT:

13. Sustainable Development Goals:

1. No poverty; 2. zero hunger ; 3. good health and well-being; 4. quality education; 5. gender equality; 6. clean water and sanitation; 7. affordable and clean energy; 8. decent work and economic growth; 9. industry, innovation and infrastructure; 10. reduced inequalities; 11. sustainable cities and communities; 12. responsible consumption and production; 13. climate action; 14. life below water; 15. life on land; 16. peace, justice and strong institutions; 17. partnerships for the goals.

14. *20 principles of the European Pillar of Social Rights:*

1. Education, training and life-long learning; 2. gender equality; 3. equal opportunities; 4. active support to employment; 5. secure and adaptable employment; 6. wages; 7. information about employment conditions and protection in case of dismissals; 8. social dialogue and involvement of workers; 9. work-life balance; 10. healthy, safe and well-adapted work environment and data protection; 11. childcare and support to children; 12. social protection; 13. unemployment benefits; 14. minimum income; 15. old age income and pensions; 16. health care; 17. inclusion of people with disabilities; 18. long-term care; 19. housing and assistance for the homeless; 20. access to essential services.

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6.3 Classification of industrial sectors

Classification used for the key industrial sector field., based on NACE[14] 2 standard classification for economic sectors, and other more policy-oriented classifications, such as the one from Internal Market, Industry, Entrepreneurship and Small and Medium Enterprises (SMEs): https://ec.europa.eu/growth/sectors_en

Definition of industrial sectors:

- Aerospace
- Agriculture
- Automotive
- Biotechnology
- Chemicals and Materials
- Construction
- Defence and Security
- Electric and electronics
- Energy
- Environment
- Finance
- Food and beverage
- ICT and digital
- Machinery and equipment
- Maritime
- Medical healthcare
- Minerals, forest-based
- Space
- Textile
- Tourism, arts, culture heritage
- Transport
- Wood, paper, printing

[14] NACE is the statistical classification of economic activities in the European Community and is the subject of legislation at the European Union level, which imposes the use of the classification uniformly within all the Member States. It is a basic element of the international integrated system of economic classifications, which is based on classifications of the UN Statistical Commission, Eurostat as well as national classifications; all of them strongly related each to the others, allowing the comparability of economic statistics produced worldwide by different institutions. Source: https://datacollection.jrc.ec.europa.eu/wordef/nace

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