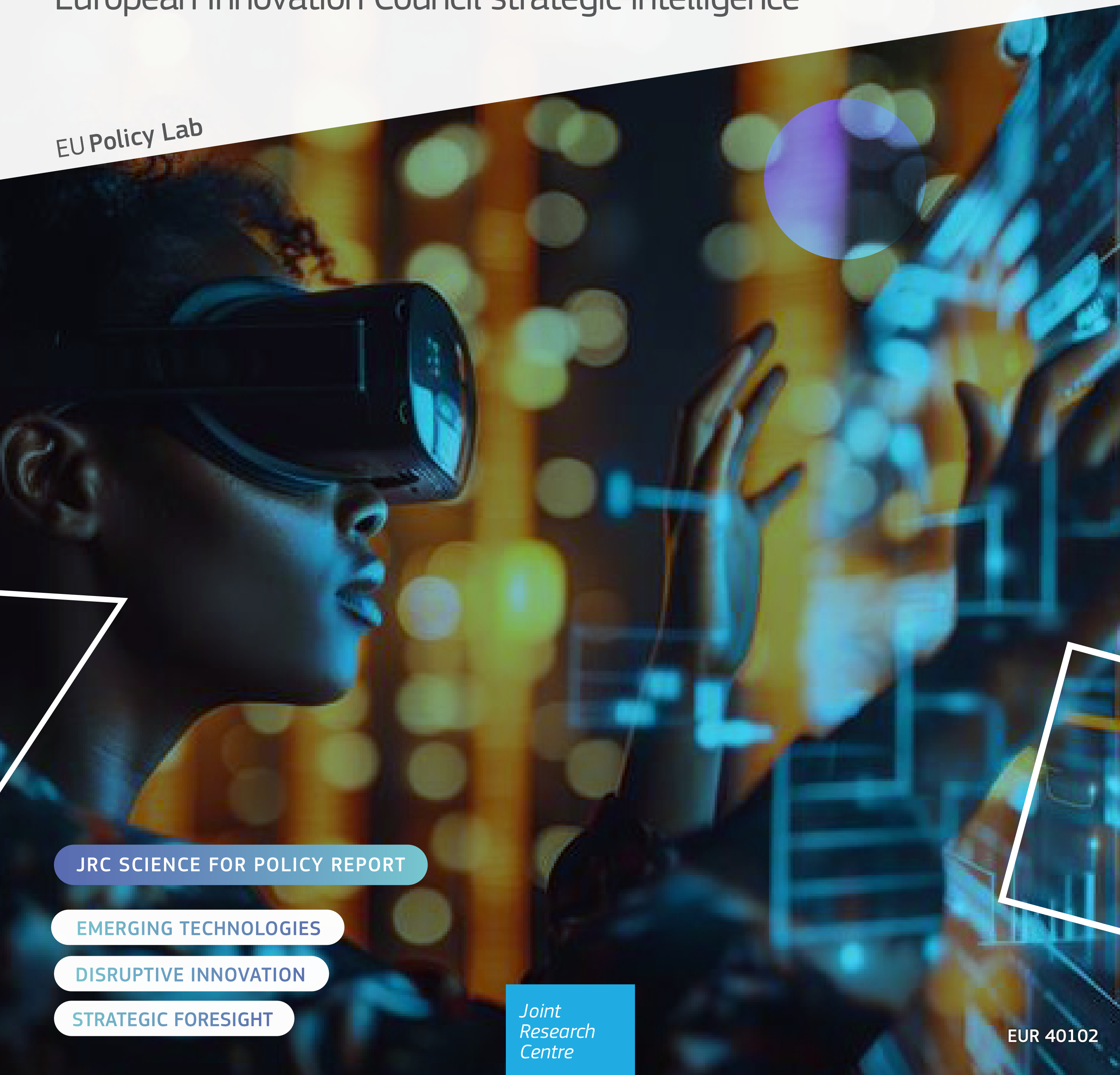
ISSN 1831-9424

European Commission

EYES ON THE FUTURE:

Signals from recent reports on emerging technologies and breakthrough innovations to support European Innovation Council strategic intelligence

EU Policy Lab



JRC SCIENCE FOR POLICY REPORT

EMERGING TECHNOLOGIES

DISRUPTIVE INNOVATION

STRATEGIC FORESIGHT

Joint Research Centre

EUR 40102

Contact information
EU Policy Lab
Unit S.1 - EU Policy Lab: Foresight, Design and Behavioural Insights
Joint Research Centre, European Commission, Brussels, Belgium
JRC-FORESIGHT@ec.europa.eu

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC139313

EUR 40102

Print	ISBN 978-92-68-21776-4	ISSN 1018-5593	doi:10.2760/9536236	KJ-01-24-128-EN-C
PDF	ISBN 978-92-68-21775-7	ISSN 1831-9424	doi:10.2760/7083666	KJ-01-24-128-EN-N

Luxembourg: Publications Office of the European Union, 2024

How to cite this report: European Commission, Joint Research Centre, Farinha, J., Mochan, A. Riveong, D., Bailey, G. and Polvora, A., Eyes on the Future - Signals from recent reports on emerging technologies and breakthrough innovations to support European Innovation Council strategic intelligence - Volume 2, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/7083666, JRC139313.

EYES ON THE FUTURE

Signals from recent reports on emerging technologies

and breakthrough innovations to support

European Innovation Council strategic intelligence

Volume 2

Authors:

João FARINHA (JRC)

Antonia MOCHAN (JRC)

Daniel RIVEONG (External Expert)

Gwendolyn BAILEY (JRC)

Alexandre PÓLVORA (EISMEA)

This report is part of the project FUTURINNOV, (FUTURe-oriented detection and assessment of emerging technologies and breakthrough INNOVation), a collaboration between the European Commission's (EC) Joint Research Centre (JRC) and the European Innovation Council (EIC), the EC's flagship program for deep tech, implemented by the European Innovation Council and SMEs Executive Agency (EISMEA).

EU **Policy Lab**

The EU Policy Lab is a space for cross-disciplinary exploration and innovation in policymaking. We apply collaborative, systemic and forward-looking approaches to help bringing the scientific knowledge of the Joint Research Centre into EU policy making.

We experiment with the new, the unprecedented and the unknown. We seek to augment our understanding of the present, challenge and reinvent the way we think about the future.

The EU Policy Lab is also a mindset and a way of working together that combines stories and data, anticipation and analysis, imagination and action. We bring new practical and radical perspectives to tackle complex problems in a collaborative way. Together, we explore, connect and ideate to create better policies.

policy-lab.ec.europa.eu

Contents

Abstract

This report, part of the FUTURINNOV project—a collaboration between the European Commission's Joint Research Centre and the European Innovation Council and SMEs Executive Agency—provides the second literature review of third-party reports, in a continuous workstream that surfaces periodically cross-sector emerging technologies and breakthrough innovations.

It summarises findings in a final selection of 30 signals and trends through an iterative methodology focused on their potential impact and novelty.

These findings are categorised and analysed across the 10 critical technology areas defined by the European Commission, as well as through other frameworks such as the Strategic Technologies for Europe Platform and the EIC's portfolios and specific taxonomy.

The report concludes with a cross-cutting analysis and offers recommendations to support the EIC's strategic intelligence, particularly in prioritising innovation funding.

Additionally, it aims to raise awareness among EU policymakers about technological developments that may not yet be widely known.

Executive summary

Brief description

The report highlights key signals of emerging technologies and breakthrough innovations that have been identified through a systematic review of relevant publications.

These signals are examples of the diversity of technological developments and innovation across 10 critical technology areas.

The report offers insights that can inform the prioritisation of funding for novel, emerging and close-to-market technologies for the European Innovation Council (EIC), the EC's flagship program for emerging deep tech and breakthrough innovation, implemented by the European Innovation Council and SMEs Executive Agency (EISMEA).

Project context

This report is developed in the context of the project FUTURINNOV (FUTURe-oriented detection and assessment of emerging technologies and breakthrough INNOVation).

It is the second literature review report and follows the publication of Volume 1 in June 2024 (Bailey, Farinha, Mochan, & Polvora, 2024). As part of a workstream to surface cross-sector emerging technologies and breakthrough innovations periodically, Volume 2 is centred on a new set of trends and signals.

FUTURINNOV supports the EIC in building strategic intelligence capacity via foresight and other anticipatory approaches. In this way, it addresses activities focused on funding targets, programme design, policy feedback, and institutional governance.

This is the second collaboration between the European Commission's (EC) Joint Research Centre (JRC) and the EIC, using technology foresight with a focus on innovation funding priorisation.

Policy context

As in Volume 1 (Bailey, Farinha, Mochan, & Polvora, 2024), the present document contains signals and insights that can inform funding decisions, particularly in areas of relevance to EU economic security as well as technical areas of general high uncertainty and complexity. The analysis in the report underscores the importance of taking into consideration in policymaking the interconnectedness of different technologies and their systems.

The report aims to provide actionable insights not only to executive agencies providing funding support for deep tech but also to policymakers in areas related to critical and strategic technologies. To deliver this aspect, the authors have considered European initiatives related to these strategic areas in their signal analysis.

Investing in technology, particularly in largely unexplored and uncertain domains, is a challenge faced by many types of organisations. Technology foresight uses structured processes and gathers evidence to address this challenge. This report aims to contribute by providing insights into areas where uncertainty often exceeds current knowledge.

Methodology

For Volume 2, the authors reviewed more than 50 reports (free and available online) and websites, ranging from general to sector-specific and specialised sources.

As already highlighted in Volume 1, in addition to drawing on secondary sources such as reports, and considering previous publications (Farinha, Vesnic-Alujevic, Alvarenga, & Polvora, 2023), it is necessary to supplement this kind of literature review with journal articles and scientific studies to surface additional novelty in certain domains.

Therefore, in addition to the reviewed reports and websites, a significant number of scientific and news articles as well as other documented sources (all referenced in the section References) were used to verify and describe the signals and trends. These additional sources were obtained through both references from the initial ones, as well as through search in specialised websites and scientific journals.

An internal database of signals created for FUTURINNOV was continuously supplemented via this literature review exercise as well as through the thematic horizon scanning workshops, part of another workstream of FUTURINNOV.

Considering all these sources and parallel workstreams, the authors have captured over 1000 signals[1]. Based on desk research, deep dives, and qualitative assessments, 42 of these signals were short-listed and 30 selected as final for publication in this report. The methodology and the selection criteria are included in chapter 2.

These key signals are grouped according to the EU's list of 10 critical technology areas (European Commission, 2023). All signals were also labelled according to the EIC Taxonomy (see Annex 1), The EU's Strategic Technologies for Europe Platform (STEP) (see Annex 3) and EIC PM Portfolios[2].

The signals are examples of technology developments that illustrate the diversity of innovation efforts in the 10 critical technology areas.

Main findings and conclusions

The analysis of the 30 selected signals highlights several thematic areas crucial for the EU and deserving further Research, Development, and Innovation (R&D&I) opportunities.

These thematic areas provide valuable insights for the European Innovation Council's (EIC) strategic intelligence, suggesting potential approaches for portfolio expansion or cross-thematic challenges. These are particularly visible in the following cross-cutting domains:

Computing and the Green Transition: While sustainability and the green transition remain central to research, there is a growing focus on scaling artificial intelligence (AI) computing, particularly due to concerns about energy consumption. The EIC could continue its investment in responsible and sustainable electronics, as well as consider a systematic support for AI. Additionally, energy-efficient at-the-edge computing in other domains such as Space, Health, and Agriculture should be prioritised.

Energy Innovation: The signals indicate a diversification in energy-related technologies, with both incremental and disruptive innovations emerging. The EIC could focus support on a variety of early-stage solutions to fully capitalise on these innovations and avoid premature narrowing.

Advanced Materials and Biotechnologies: Advanced materials and biotechnologies, while perhaps having a lower profile than AI and semiconductors, are emerging as critical enablers of new technologies. The EIC could explore a cross-portfolio approach to Advanced Materials and consider a renewed focus on biotechnology to cover various applications, including bio-computing and pollution control.

Robotics and Autonomous Systems: These technologies drive innovation across sectors

[1] Approximate number of signals in the project database, collected between October 2023 and August 2024.

[2] The 11 EIC PM Portfolios considered for this report are: Advance Materials; Agriculture & Food; Architecture, Engineering and Construction, Energy Systems; Health and Biotechnology; Medical Technologies and Medical Devices; Quantum Technologies; Renewable Fuels and Chemicals; Responsible and Sustainable Electronics, Space and Medical Imaging & AI. The EIC PM portfolio names used throughout this report are a simplification of the official denomination, agreed with the EIC Strategic Intelligence Team.

such as manufacturing, healthcare, and mobility, and are vital for the EU's strategic autonomy, due to their dual-use potential in civil and defence applications. Given the evolving geopolitical landscape, the EIC could expand its scope to include innovations with dual-use applications, potentially establishing a portfolio that integrates Mobility, Robotics, and related enabling technologies.

1 Introduction

1.1 Anticipation and signals

The present-day framework of increasing volatility, uncertainty, complexity, and ambiguity (VUCA[3]) poses significant challenges to decision-making, namely for policy design and implementation, which in turn requires preparedness and strategic planning.

Anticipatory thinking is crucial in this context to assess signals and trends from short- to long-term futures, along with their potential challenges and opportunities. This requires a mix of evidence-based methods and participatory approaches, delivered in a systematic manner and aimed at gathering a wide range of perspectives and identifying a broader array of new patterns.

Core anticipatory fields such as future-oriented technology assessment and technology and innovation foresight emerge at the forefront of provision of actionable insights for today's and tomorrow's questions. They can be framed as a "systematic exercise aimed at looking into the longer-term future of science, technology and innovation in order to make better-informed policy decisions" (Pietrobelli & Puppato, 2016).

These systematic exercises have an important role to play in enabling a better understanding of the complexity of technology developments and applications (Warnke & Heimeriks, 2008) as well as related societal impacts, and can shape potential technological change in the future (Pietrobelli & Puppato, 2016). They serve the purpose of reflecting about upcoming research needs, future technology applications, possible future regulations and standards, and other relevant topics. In turn, they can also provide insights on drivers, opportunities and challenges related with research, development, and adoption of technologies and innovations.

The concept of signals is key to this framework, and it is one that changes upon context or use case (Rossel, 2012; van Veen & Ortt, 2021) . In this report, the term 'signal' is understood as nascent but tangible manifestations of novelty, not only in science, technology, innovation, or markets, but also other areas such as media or artistic practices, even if these last domains are not the focus of this report.

Signals can also be described as raw informational matter that drives our focus towards certain possibilities of the future instead of others. Aiming for a better understanding, we can place them next to the other anticipatory concept of trends, as both are usually drawn from novel scientific literature, industrial reports, media outputs, etc, on early research developments, patents, and other data sources.

Trends are often derived from patterns of novelty with upward or downward directions and are more easily identifiable in terms of velocity and duration due to strength. Moreover, trends also have clearer boundaries connected to more defined technology and/or innovation landscapes, while signals can be derived from single occurrences in these same landscapes.

Therefore, it can be considered that trends are more directly inferred from quantitative views of big data and qualitative observations of thick data, while signals are more represented by thin data and related to smaller sets of data points or references with less rich contextual meaning (Mortati, 2023).

[3] The acronym VUCA was first used by Bennis and Nanus (1987) to describe the world at the end of 1980s and its use increased in the last decades in anticipation, foresight and futures studies. An alternative acronym is TUNA (Turbulant, Uncertain, Novel and Ambiguous).

1.2 Report context and goals

This report is developed in the context of the project FUTURINNOV - FUTURe-oriented detection and assessment of emerging technologies and breakthrough INNOVation. The project is a collaboration between the European Commission's Joint Research Centre (JRC) and the European Innovation Council (EIC), the EC's flagship program for emerging deep tech and breakthrough innovation, implemented by the European Innovation Council and SMEs Executive Agency (EISMEA).

The JRC's mission is to provide evidence-based advice to policy, which includes anticipation and technology foresight.

FUTURINNOV is the second such collaboration between the JRC and the EIC[4]. It supports the EIC in building strategic intelligence capacity via foresight and other anticipatory approaches. In this way, it addresses activities focused on funding targets, programme design, policy feedback, and institutional governance.

Following the publication of the literature review in the context of the previous collaboration with the EIC, the JRC and EIC agreed to improve the systematic review of forward-looking information on technology and innovation signals captured in third-party reports[5].

The current report is the second literature review published in 2024 in the context of the FUTURINNOV project. Volume 1 (Bailey, Farinha, Mochan, & Polvora, 2024) was published in June 2024 containing 34 signals and a brief qualitative analysis. As part of a workstream to surface cross-sector emerging technologies and breakthrough innovations periodically, Volume 2 is centred on a new set of trends and signals.

The FUTURINNOV project also delivers parallel support to EIC portfolios and other specific policy and economic areas, via thematic (vertical) Horizon Scanning workshops. The results of these exercises providing specific insights into narrower domains are published separately.

In the context of this report, signals have been extracted from third-party sources to provide a horizontal perspective across a wide set of technological, environmental, societal, policy and economic areas. The aim is not to provide a full illustration of the most significant developments expected in those areas, but rather to provide examples that highlight the current diversity of emerging technologies and breakthrough innovations.

The analysis can inform priority-setting from novel (TRL[6] 1 to 3) to emerging (TRL 4-6) and close-to-market (TRL 7 to 9) deep tech and innovation. The authors' understanding is that novelty can occur at all maturity levels, in particular if we look at innovative combinations of established technologies or incremental innovation.

With this report the authors aim to support the EIC in answering questions such as:

[4] The previous collaboration with the EIC was framed under project ANTICIPINNOV - Anticipation and monitoring of emerging technologies and disruptive innovation. In this context three reports were published: a literature review on 3rd party reports (Farinha, Vesnic-Alujevic, Alvarenga, & Polvora, 2023); a summary of the horizon scanning exercises (Farinha, Vesnic-Alujevic, & Pólvora, 2023) and a report on methods and best practices for technology foresight (Dannemand Andersen, et al., 2023).

[5] Reports published outside EU institutions by research and technical organisations, industrial and market consultants, businesses, think tanks, public entities, and other relevant bodies.

[6] Technology Readiness Levels (TRL) serve as a system for evaluating the development stage of a specific technology. Every technology project undergoes assessment according to the criteria established for each level, resulting in the assignment of a TRL score that reflects the project's advancement. The scale comprises nine levels, with TRL 1 indicating the earliest stage of development and TRL 9 representing the most advanced stage.

- Which of these signals should be on the EIC's radar for anticipatory intelligence?
- Which signals connect emerging deep tech and breakthrough innovations with a likely impact on and criticality for the EU's future?

To succeed in answering these questions, the current report is structured according to the EU's 10 critical technology areas[7], set up by the European Commission's Recommendation of 3 October 2023 on critical technology areas for the EU's economic security for further risk assessment with Member States (European Commission, 2023).

This is the most visible difference with the organisation of Volume 1, which was structured according to a previous version of the EIC taxonomy. Through this new methodological and editorial guideline, the literature review provides more focus on which emerging technologies could be prioritised.

On top of this categorisation this report offers several methodological updates (compared to previous literature reviews). Chapter 2 provides a complete explanation of the process.

For the current report, the authors have:

- Continued to feed the project's internal database of signals via this literature review as well as the horizon scanning exercises.
- Reviewed more than 50 reports and websites, ranging from general to sector-specific and specialised sources, supplemented by dozens of scientific articles.
- Considered more than 1000 signals[8], of which 42 were short-listed and 30 selected for this report.
- Connected the selected signals with the EU's list of 10 Critical Technology Areas; the three target investment areas of the STEP initiative; the 11 EIC PM portfolios and the new EIC taxonomy.
- Analysed the signals and drawn conclusions to support the EIC's funding prioritisation and additionally, provide reflections on EIC portfolio setting.

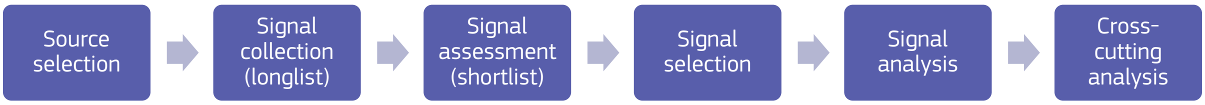
[7] The 10 critical technology areas are: advanced semiconductors technologies; artificial intelligence technologies; quantum technologies; biotechnologies; advanced connectivity, navigation and digital technologies; advanced sensing technologies; space & propulsion technologies; energy technologies; robotics and autonomous systems; advanced materials, manufacturing and recycling technologies. See bibliographic reference (European Commission, 2023) and Annex 2 for more details on each area, including non-exhaustive examples.

[8] Approximate number of signals in the project database, collected between October 2023 and August 2024.

2 Methodology

The methodology used in this study is a six-step iterative process, as outlined in Figure 1. Each of the six steps can be reiterated; however, the three initial steps were the most frequently iterated, as further explained and detailed in the decision tree (see Annex 4).

Figure 1. Simplified diagram of the flow and methodology used in this literature review. See annex 4 for more details regarding the collection, assessment, and selection steps.



Source: Authors.

2.1 Source selection and signal collection

The literature review process began by gathering reports through online search that could provide signals covering all 10 critical technology areas (see Annex 2).

Beyond this main criterion, the signals were selected based on the following criteria (no quantified weighting was attributed to any criteria nor was there any specific order):

— Relevance to the mission of the EIC and fitting within at least one of the 11 primary categories of the new EIC taxonomy (see Annex 1);

— Relevance to at least one of the three target investment areas of the STEP initiative (see Annex 3);

— Relevance to EIC funding mechanisms, namely Pathfinder, Transition and Accelerator[9], considering information on the TRL or an initial qualitative assessment of the maturity of the signal;

— Technologies that demonstrate novelty or contain novel aspects which may enable or accelerate the development of other emerging technologies or innovations.

— Examples of technology developments that illustrate the diversity of innovation efforts in a specific field.

Preference was given to sources that contained/provided the following:

— A diversified geographic scope, perspectives, and authors, including but not limited to multi-state international organisations, forums or think tanks, research and technology organisations and public agencies;

— Recent publications, with an emphasis on sources published between 2022 and 2024;

— References to published scientific research.

For the specific purpose of this literature review, over 50 third-party reports (free and available online) and websites were selected.

In parallel, the project's internal database of signals was also supplemented through thematic horizon-scanning exercises carried out in the context of FUTURINNOV.

These two workstreams have to date provided

[9] For more information on the specificities of each mechanism, check: https://eic.ec.europa.eu/eic-funding-opportunities_en

over 1000 signals[10]. The identified reports and websites were complemented by dozens of scientific articles, that were either quoted in those initial sources, or were considered important by the authors for cross-checking and understanding certain aspects of the technologies and innovations.

As mentioned in Volume 1, it is worth noting that many of the types of 3rd party reports referenced in the first Literature Review conducted by the JRC for the EIC (Farinha, Vesnic-Alujevic, Alvarenga, & Polvora, 2023) have become too generic for the purposes of this project.

For this cycle of literature reviews, novelties were more effectively surfaced when investigating sector-specific reports (published with a focus on a single domain or industry) and, to a greater extent, journal articles and scientific studies.

This highlights the need to go beyond the numerous generic technology foresight reports published by a significant number of organisations today, which often contribute to inflated hype cycles — a phenomenon certain technologies undergo. The authors acknowledge this risk and emphasise that their aim is to surface specific breakthrough applications that may not yet be widely known by most policymakers.

In addition to the original sources, a significant number of scientific and news articles as well as other documented sources (all referenced in the section References) were used to verify and describe the signals and trends.

These additional sources were obtained by retrieving original citations in documented sources, as well as a detailed investigation in specialised scientific content..

2.2 Signal assessment

Every signal collected for this project was entered into the internal database built specifically for this initiative and categorised according to several dimensions, with the following being particularly noteworthy:

- Connection with one or two critical technology areas;
- Connection with the STEP's target investment areas;
- Connection with EIC PM Portfolios;
- Connection with the EIC Taxonomy;
- Maturity.

Regarding maturity, a signal was assigned 'novel' (TRL 1-3) status when it was referenced in a recent academic article or patent. The signal was assigned 'emerging' (TRL 4-6) status when it was referenced in publications and reports, with references to prototypes or early pilots, facing technology development challenges. The signal was assigned 'close-to-market' (TRL 7-9) status when examples of mature pilots or demonstrations were available. In summary, a signal was categorised based on R&D&I developments that were either mentioned in the sources or identified through additional research.

2.3 Signal selection

From the more than 1000 signals in the database (with a particular focus on those collected specifically for this literature review which constitute the longlist as mentioned in Figure 1 and Annex 4) the authors shortlisted 43 signals and subsequently selected the final 30 signals presented and detailed in Chapter 3.

For this selection process, the authors improved the qualitative review process used in Volume

[10] Approximate number of signals in the project database, collected between October 2023 and August 2024.

1 to assess each collected signal's impact and novelty, namely by making these concepts clearer for all reviewers and introducing additional iterations and feedback loops in the process.

The impact rating refers to the potential contribution of the technologies present in the signal to the EU's technological development and leadership[11]. The novelty dimension refers to the signal's uniqueness, meaning the probability of containing developments that are unknown to the wider public, independent of the maturity level of the technologies behind it [12].

It was imperative to ensure that each of the 10 critical technology areas had at least 2 signals, and a minimum diversity of maturity across all signals. This meant a balance between at least 2 different clusters (e.g. novel and emerging).

Finally, it was important to avoid where possible referring more than once to the same enabling technologies or combination of enabling technologies applied in the same field. Annex 4 contains a summary of the decision tree and process flow.

2.4 Signal analysis and cross-cutting analysis

The last two steps of the methodology include:

— a deeper analysis and description of each individual signal, providing insights that highlight its novelty;

— an analysis of each critical technology area as well as complementary information regarding some key technologies (see introductions to Chapters 3.1 to 3.10 and Boxes 1 to 10), complemented with a cross-cutting analysis across all selected signals (see Chapter 4).

During this stage, the signals were categorised with the tertiary (technologies/applications) and vertical (when applicable) levels of the EIC taxonomy (see Chapter 4.1.5 and Annex 1 for more details).

[11] For this impact assessment the authors considered key EU policy initiatives, including the ones referenced in the report's introduction: 10 critical technology areas, STEP as well as the EC priorities (2019-2024 and 2024-2029).

[12] It's the authors understanding that novelty can appear at all stages of technology maturity, namely by combining through innovative means already known technologies and by expanding those to new application fields or through new business models.

3 Selected signals

The following subsections depict the 30 signals organised by each of the 10 critical technology areas. When a signal relates to more than one area, it has been filed under the most significant one.

The introduction to each subsection includes a brief summary of the novelties found across these signals as well as additional support information (in boxes), that the authors consider important for a non-expert reader.[13]

Table 1. Summary list of key signals presented in the following pages.

Critical Tech Area (main)	Signal number and title	
Advanced semiconductors technologies	**01**	New-hybrid chip architecture for highly efficient AI chip
	02	High-energy efficiency, light-based chiplet
Artificial intelligence technologies	**03**	More energy-efficient LLM using spike neural networks
	04	Neuromorphic chip optimised for energy efficient AI workloads
Quantum technologies	**05**	Successful early test of running transformers in a quantum computer
	06	Laser light to control individual qubits
	07	Laser-equipped satellites for secure quantum communications
Biotechnologies	**08**	Possibilities of microgravity bioreactors and 3D bioprinting for regenerative medicine
	09	Programmable DNA machines offer general-purpose computing
	10	Using AlphaFold AI to engineer bacterial nanosyringes for precise protein delivery
	11	Enhanced minimally-invasive patient monitoring with a new peripheral nerve interface technology
	12	Inverse vaccines flags 'off switch' in livers to combat autoimmune diseases
	13	Potential use of gut bacteria to enhance cancer immunotherapy's effectiveness

[13] The AI-generated images accompanying each signal are conceptual illustrations, intended to provide an abstract visualisation of the technologies and ideas they represent. These images are in no way intended to depict precise or factual representations.

Critical Tech Area (main)	Signal number and title	
Advanced connectivity, navigation and digital technologies	**14**	UK trials jam-resistant quantum positioning, navigation & timing
	15	First universal metasurface antenna for more advanced, secure sensing and 6G communications
	16	Lego-like photonic chip that boosts advanced sovereign manufacturing, bandwidth control for radars, 6G
Advanced sensing technologies	**17**	New wearable plants sensors use established microfabrication techniques and ML for more accurate data interpretation
	18	Highly energy efficient sensors using microcombs
Space & propulsion technologies	**19**	Self-consuming rockets to reduce space debris and improve efficiency
	20	Novel hyperspectral technology to detect space debris under any illumination conditions
Energy technologies	**21**	Capturing osmotic energy using off-the-shelf nanotechnology materials and processes
	22	Renewable energy using modular, adaptable wave-riding generators
	23	New water and underwater battery for offshore wind generation
	24	First demonstration of miscibility gaps alloy, a novel thermal storage technology
	25	Potential to capture wasted 'reflected' energy from PV systems
Robotics and autonomous systems	**26**	Splittable six-in-one drone for higher efficiency and multi-use missions
	27	LLM-powered robots for faster learning, complex task completion
Advanced materials, manufacturing and recycling technologies	**28**	Mushroom skin could make IoT sensors easier to recycle
	29	Preparation–free, adhesive skin patches to help people control robotic exoskeletons
	30	A biodegradable "living plastic" with embedded bacterial spores break down plastic

Source: Authors.

3.1 Advanced semiconductors technologies

3.1.1 Introduction

Today's rapid adoption of AI technologies has raised concerns about their intense energy usage and long-term sustainability. The selected semiconductor signals highlight ongoing research to develop alternative chip architectures and approaches optimised for AI-related processing and decreasing energy usage.

IBM Research's latest chip, dubbed NorthPole, uses a new architecture inspired by neuromorphic computing that could offer substantial improvements in energy, space, and time efficiencies. The chip is reportedly 25 times more energy efficient than common Graphics Processing Units (GPUs) and Central Processing Units (CPUs), and potentially 35 times more efficient for specific tasks like image classification or audio transcription.

Researchers at Tsinghua University in China have developed a light-based AI-focused photonic chiplet (see Box 1) that presents an alternative approach to energy-efficient chip design. By using light instead of electricity, researchers claim the chiplet significantly reduces energy consumption while increasing processing speed by 2-3 orders of magnitude over current AI chips.

Box 1. What is a chiplet?

Chiplets are an area where innovation is rapidly emerging and transforming the semiconductor industry. A chiplet is a small integrated circuit (IC) designed to perform a specific function and is intended to be combined with other chiplets to create a more complex chip or system. This modular approach to chip design offers several advantages, including increased flexibility, improved manufacturing yields, cost efficiency, and the ability to mix and match different types of chiplets to meet specific needs.

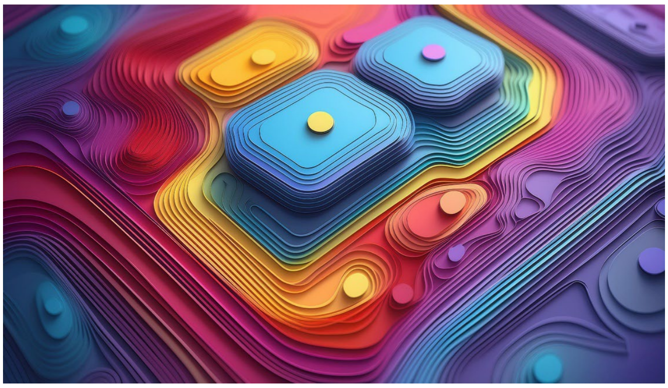
Chiplets are typically mounted on a single substrate or interposer, which connects them and facilitates communication between them. This allows for heterogeneous integration, meaning different technologies and manufacturing processes can be used for different chiplets, optimising performance and cost. For instance, a processor core, memory block, and I/O driver can each be separate chiplets combined into a single package.

This design approach contrasts with traditional monolithic chip designs where all functionality is integrated into a single large piece of silicon. By using chiplets, manufacturers can reduce development timelines and costs, improve performance by employing specialised processing elements, and reduce power consumption by situating chiplets closer to the processing unit.

Sources: (ARM, 2024; Cadence, 2024; Brookes, 2021; Semiconductor Engineering, 2024)

01

New-hybrid chip architecture for highly efficient AI chip



Borrowing from neuromorphic computing concepts, IBM's NorthPole is a breakthrough in chip architecture that promises massive improvements in energy, space, and time efficiencies. Neuromorphic computing is an approach to computer engineering inspired by biological neural networks, aiming to mimic the brain's efficiency and adaptability in processing information.

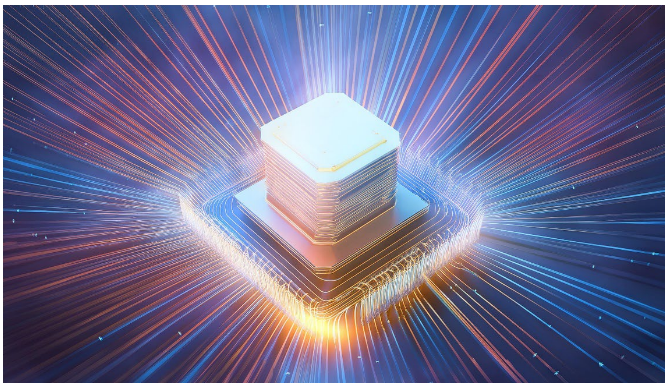
Researchers claim that the 12nm chip is 25 times more energy efficient, when it comes to the number of frames interpreted per joule of power required, compared to common 12-nm GPUs and 14-nm CPUs, including those from NVIDIA, the most popular maker of GPUs for AI computing. For specific tasks like image classification or audio transcription, the chip can be up to 35 times more efficient than relying on a GPU.

The NorthPole chips was fabricated using a 12 nm process, while current state of the art chips like the M4 by Apple, uses 3 nm, which suggests that opportunities for further development are readily available.

Sources	(Timmer, 2023; Ottati, 2023)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Advanced Semiconductors Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Responsible and Sustainable Electronics	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Semiconductors & Integrated Circuits / Artificial Intelligence / Energy Efficiency
	Technologies/Applications (Tertiary)	Neural Networks / Machine & Deep Learning / Natural Language Processing (NLP) & Foundation Models
	Verticals	n/a

02

High-energy efficiency, light-based chiplet



To overcome China's challenges in accessing the latest chip manufacturing technologies, researchers at Tsinghua University have developed an AI-focused photonic chiplet that uses light instead of electricity to process information. This significantly reduces energy consumption and increases processing speed.

In a paper published in *Science*, the researchers state that the chiplet integrates optical diffraction and interference techniques to manipulate light efficiently, allowing it to perform complex calculations with high energy efficiency. The researchers claim the chiplet design performs at 160-TOPS/W energy efficiency with up to 2-3 orders of magnitude improvement in efficiency compared to current AI chips.

While US and European researchers are also developing photonic chiplet designs, this particular development represents an achievement by Chinese-based researchers in their ability to advance chipmaking designs in critical areas related to artificial intelligence and energy-efficient chip design, despite growing technology restrictions.

Sources	(Xu, et al., 2024; Fan, 2024; Afifi-Sabet, 2024)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Advanced Semiconductors Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Responsible and Sustainable Electronics	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Photonics & Optoelectronics / Semiconductors & Integrated Circuits / Energy Efficiency
	Technologies/Applications (Tertiary)	Machine & Deep Learning / Natural Language Processing (NLP) & Foundation Models / System-on-Chip (SoC) Solutions
	Verticals	n/a

3.2 Artificial intelligence technologies

3.2.1 Introduction

In a push to find alternative approaches to reducing the significant energy cost of current AI processing approaches (specifically LLMs), the selected signals illustrate how researchers are taking inspiration in two different ways from the human brain's architecture as potential pathways to more efficient AI processing.

Researchers at the University of California, Santa Cruz, have developed SpikeGPT, which uses Spiking Neural Networks (SNNs) (see Box 2), a machine learning approach inspired by natural neural networks, to achieve competitive performance with 20 times fewer operations and energy consumption compared to models like OpenAI's ChatGPT-3. Although SpikeGPT's current capabilities are limited, it marks an early step toward learning from the human brain to develop more efficient AI processing.

Similarly, Sandia Labs (a US government research lab) and Intel have co-developed Hala Point, a neuromorphic chip that emulates the brain's architecture that achieves up to 15 trillion operations per second per watt (TOPS/W). Researchers claim that the system outperforms traditional GPU and CPU architectures, solving problems with 100 times less energy and 50 times faster speeds.

Box 2. What are spiking neural networks (SNNs)?

Spiking Neural Networks (SNNs) are a form of artificial neural network designed to emulate the way biological neurons communicate through discrete spikes or action potentials. Unlike traditional neural networks that use continuous values, SNNs rely on the precise timing of spikes to encode and process information.

This approach allows SNNs to handle temporal data effectively and perform real-time processing tasks. Learning in SNNs often uses Spike-Timing-Dependent Plasticity (STDP), where the timing difference between pre- and post-synaptic spikes strengthens or weakens synaptic connections.

This makes SNNs particularly suitable for applications requiring temporal pattern recognition, such as sensory processing, robotics, and neuromorphic engineering. Additionally, their event-driven nature can lead to more energy-efficient computations, as neurons only process information when spikes occur.

Sources: (Yamazaki, 2022; Taherkhani, et al., 2020; Vreeken, 2003)

03

More energy-efficient LLM using spike neural networks

As the size of large language models (LLM) continues to scale, their increasing energy demands have become a concern, as have the challenges of scaling up energy production to support wider development and usages of LLMs.

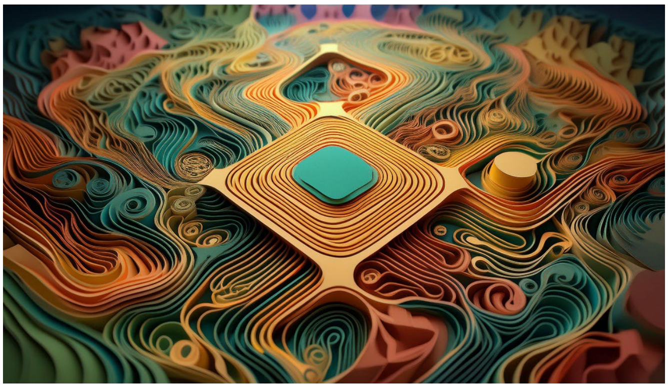
As a potential solution, researchers at the University of California, Santa Cruz have developed SpikeGPT, which uses spiking neural networks (SNNs) in a way that is compatible with the contemporary AI methods used in large language models (LLMs). SpikeGPT is said to be competitive with non-spiking models but with 20x fewer operations and a corresponding 20x reduction in power consumption. The potential for a 20x reduction in electricity needs is critical in light of concerning projections published in *Joule* last year, that by 2027, AI may consume as much as 85 to 134 terawatt hours each year, roughly equivalent to the annual energy usage of the Netherlands.

Currently, SpikeGPT uses only 216M parameters in its model, compared to the 175 billion parameters used in OpenAI's Chat GPT-3. While still in its early stages, the development of SpikeGPT demonstrates an alternative to the more common but energy-intensive approach of using transformers, as used by OpenAI, Mistral, and others.

Sources	(Ward-Foxton, 2023; Zhu, Zhao, Li, & Eshraghian, 2024; Cerf, 2023; Vries, 2023)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Artificial Intelligence Technologies / Advanced Semiconductors Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Responsible and Sustainable Electronics	
EIC taxonomy	**Sector (Primary)**	AI, Data & ICT
	Sub-sector (Secondary)	Artificial Intelligence / Energy Efficiency
	Technologies/Applications (Tertiary)	Natural Language Processing (NLP) & Foundation Models / Neural Networks / Computing & Logic Systems
	Verticals	n/a

04

Neuromorphic chip optimised for energy efficient AI workloads



Intel has developed Hala Point, a neuromorphic computing system designed to mimic the human brain's architecture and functionality. This system can achieve efficiencies of up to 15 trillion operations per second per watt (TOPS/W), far surpassing the capabilities of conventional architectures.

Intel claims Hala Point can solve optimisation problems using 100 times less energy and at speeds that are 50 times faster than traditional GPU and CPU architectures. For comparison, the EU-funded Human Brain Project ran a billion artificial neurons using 100 Kilowatts (kW) of power, while the Hala Point system has 1.15 billion artificial neurons but uses only 2.6 kW watts of power. This represents a nearly 40x reduction in power usage.

Hala Point leverages brain-inspired principles such as event-based spiking neural networks (SNNs) and integrates memory and computing directly into its architecture, reducing the need for data movement and significantly enhancing energy efficiency. One of the critical aspects of Hala Point's novelty lies in its scalability and adaptability, which has been a challenge for neuromorphic computers compared to traditional computers. It can support up to 20 quadrillion operations per second, making it suitable for a wide range of AI applications. If successful, the Hala Point computer would be a major development in computational efficiency and pave the way for more sustainable AI technologies.

Sources	(Ward-Foxton, 2023; Morgan, 2024; Tomic, 2024; Tripathi, 2024; Cutress, 2021)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Artificial Intelligence Technologies / Advanced Semiconductors Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Responsible and Sustainable Electronics	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Semiconductors & Integrated Circuits / Artificial Intelligence / Energy Efficiency
	Technologies/Applications (Tertiary)	Neural Networks / Machine & Deep Learning / Natural Language Processing (NLP) & Foundation Models
	Verticals	n/a

3.3 Quantum technologies

3.3.1 Introduction

The selected signals in quantum technologies illustrate a field still maturing in both foundational technologies and demonstrating immediate applications. This includes areas such as adapting current AI approaches (e.g. LLMs similar to those used by ChatGPT) into quantum computers, improving how quantum computers control data, and developing ways to improve the security of quantum-based satellite communication. Integrating quantum computing with AI, researchers have successfully tested quantum transformers, achieving significant accuracy in medical image analysis. This suggests quantum-AI hybrids could outperform classical systems by leveraging quantum properties such as superposition and entanglement.

Precision control of qubits (see Box 3) has improved through laser light methods, allowing researchers to manipulate individual barium ion qubits with high precision and minimal error, avoiding interference with neighbouring qubits. This potential advancement is crucial for scaling quantum computers and performing complex algorithms, marking a significant step towards more reliable and advanced quantum computing systems.

In quantum communication, the QUICK^3 project aims to address long-distance transmission issues using satellite-based quantum cryptography. By encoding information into individual light particles, the method ensures secure data transmission, immediately detectable upon interception. With satellite component testing underway and a planned launch in 2025, this project marks significant progress towards secure global quantum communication networks.

Box 3. What is a qubit?

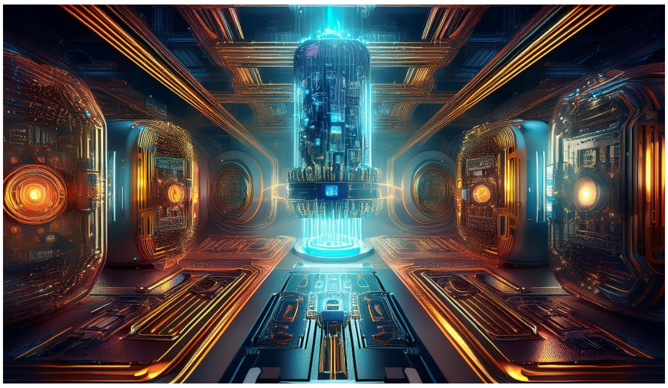
A qubit, or quantum bit, is the fundamental unit of information in quantum computing. Unlike a classical bit, which can be either 0 or 1, a qubit can exist in a superposition of both states simultaneously due to the principles of quantum mechanics. This property allows qubits to perform complex calculations more efficiently than classical bits.

Additionally, qubits can be entangled with one another, creating correlations that classical bits cannot achieve. This entanglement enables quantum computers to solve certain problems much faster than classical computers. Qubits are typically implemented using quantum physical systems such as atoms, ions, photons, or superconducting circuits.

Sources: (IBM, 2024; Kwiat & James, 2005; Fano & Blinder, 2019)

05

Successful early test of running transformers in a quantum computer



A new study published recently used simple hardware to show that rudimentary quantum transformers could indeed work, hinting that more developed quantum-AI combinations might solve crucial problems in areas including encryption and chemistry. As shown through generative AI tools like ChatGPT, traditional transformers have proven quite powerful using classical computing hardware. Quantum computers, however, can process multiple possibilities simultaneously due to superposition and entanglement.

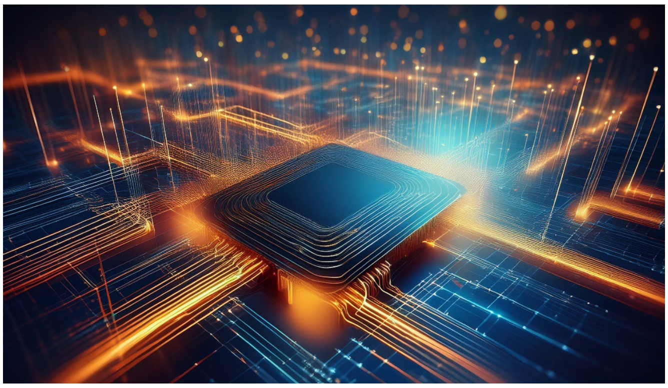
In the paper, researchers adapted a transformer designed for medical analysis into a quantum computing-adapted model. From a database of images of 1,600 people's retinas, some in healthy eyes and some in people with diabetes-induced blindness, the quantum model sorted each image into one of five levels from no damage to the most severe. The quantum transformer performed with between 45 and 55 percent accuracy which is greater than the 20 percent accuracy achieved when randomly sorting retinas into one of five categories.

While the research is still early, by combining the deep learning capabilities of transformers with the powerful processing potential of quantum computers, quantum transformers could vastly outperform their classical counterparts, providing unprecedented computational power and efficiency.

Sources	(Rao, 2024; Cherrat, et al., 2024)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Quantum Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation	
EIC portfolios	Quantum Technologies	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Quantum Technologies / Medical Imaging
	Technologies/Applications (Tertiary)	Computing & Logic Systems / Machine & Deep Learning / Cryptography
	Verticals	**n/a**

06

Laser light to control individual qubits



Researchers at the University of Waterloo's Institute for Quantum Computing (IQC) have developed a robust method to control individual qubits using laser light. The precision and control achieved with this setup surpass previous efforts to control qubits, a critical hurdle in quantum computing.

In this specific research, the qubits stored in individual barium ions can be manipulated using light. Qubits need to be manipulated with high precision and minimal error to perform complex quantum algorithms effectively.

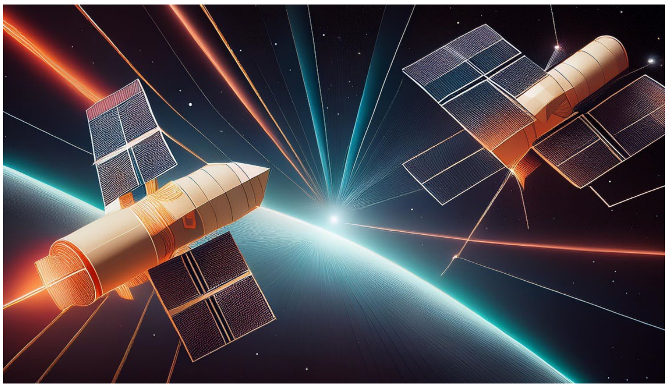
Unlike earlier techniques, the laser light allows precise control over each barium ion without impacting its neighbours. The method employs a small glass waveguide to separate laser beams and focus them four microns apart, about four-hundredths the width of a human hair.

By potentially providing a reliable method to control qubits with high precision, the research paves the way for more advanced and scalable quantum computers.

Sources	(University of Waterloo, 2023; Future Today Institute, 2024; Binai-Motlagh, et al., 2023)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Quantum Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation	
EIC portfolios	Quantum Technologies	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Quantum Technologies / Photonics & Optoelectronics
	Technologies/Applications (Tertiary)	Computing & Logic Systems
	Verticals	n/a

07

Laser-equipped satellites for secure quantum communications



Researchers at the Technical University of Munich, as part of the QUICK^3 project, are aiming to develop new encryption methods for quantum cryptography that use physical laws to prevent message interception over long distances.

The main challenge in quantum cryptography is long-distance data transmission, as light signals in quantum cryptography cannot be repeatedly amplified like in traditional digital communication through fibre optics. This limits the transmission distance to only a few hundred kilometres.

The QUICK^3 mission will use satellites to encode information into individual light particles for transmission. Physical laws ensure that any interception of the data will be immediately detected, regardless of technological advancements.

The team has tested each satellite component. The next step involves testing the entire system in space to see if the technology can withstand outer space conditions and how the system components interact. The satellite launch is planned for 2025.

Sources	(Technical University of Munich, 2024; Ahmadi, et al., 2024)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Quantum Technologies / Space & Propulsion Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation	
EIC portfolios	Quantum Technologies / Space	
EIC taxonomy	**Sector (Primary)**	Space
	Sub-sector (Secondary)	Satellite Communications & Space-based Connectivity / Quantum Technologies
	Technologies/Applications (Tertiary)	Space Missions, Operations & Ground Segment / Secure Protocols & Networks
	Verticals	n/a

3.4 Biotechnologies

3.4.1 Introduction

The selected signals illustrate the breadth of potential applications and research areas available in biotechnologies, which span from spaced-based regenerative medicine to programmable DNA computers.

Using AI-powered tools like AlphaFold, researchers have redesigned bacterial injection systems to target specific human cells. This approach has shown potential in targeting cancer cells and could be adapted for treatments for oncology and genetic disorders.

In immunology, inverse vaccines are being investigated as a possible treatment for autoimmune diseases. Unlike traditional vaccines, these aim to erase the immune system's memory of specific molecules, potentially halting attacks on healthy tissues without compromising overall immune function. Preclinical work and early safety trials have begun for conditions such as coeliac disease and multiple sclerosis.

Microgravity bioreactors (see Box 4) and 3D bioprinting in space environments are being explored as possible methods to create complex tissue structures without gravity-induced limitations. These technologies may offer new avenues for personalised organ constructs and could possibly reduce transplant rejection risks.

The other selected signals include research on using DNA as the building blocks for a programmable 'computer' as a diagnostic tool, potential use of gut bacteria to enhance cancer immunotherapy's effectiveness, and novel approaches to minimal-evasive neural implants.

Box 4. What is a bioreactor?

A bioreactor is a device that employs mechanical methods to influence biological processes. In tissue engineering, bioreactors aid in the in vitro development of new tissues by providing biochemical and physical signals to cells, promoting their differentiation and the production of extracellular matrix before in vivo implantation.

Many mammalian cells and tissues require a surface or structural support to grow, and agitated environments can be harmful. Additionally, higher organisms need highly specialised growth media, posing a challenge for culturing large quantities of cells for therapeutic purposes.

Unlike industrial bioreactors for yeast and bacteria, bioreactors for mammalian cells must be uniquely designed. Research groups have developed novel bioreactors to grow specialised tissues on structural scaffolds, aiming to recreate organ-like structures in vitro, including heart tissue, skeletal muscle, ligaments, and cancer tissue models. However, scaling these bioreactors for industrial use remains challenging and is a key area of ongoing research.

Sources: (Rosser & Thomas, 2018; Zhong, 2011; Afzali, Kheradmand, & Naghi, 2024)

08

Possibilities of microgravity bioreactors and 3D bioprinting for regenerative medicine

Microgravity bioreactors and 3D bioprinting are two promising emerging fields that may impact the future of regenerative medicine. These technologies leverage the use of space's microgravity environments to better mimic the natural environment in which cells develop. In particular, 3D bioprinting in microgravity enables the creation of complex tissue structures without gravity-induced collapse.

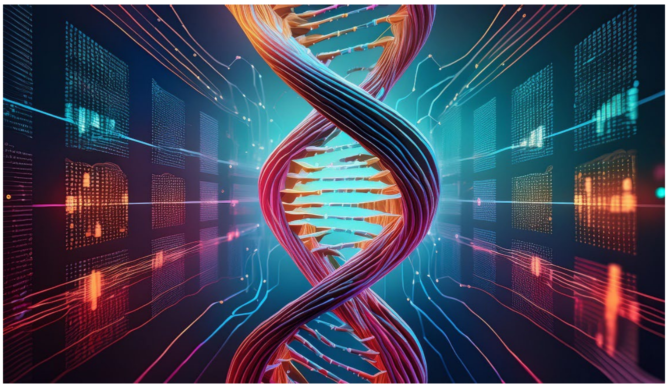
These technologies may open the door to enhancing biomedical research and improving treatments. Microgravity 3D bioprinting, in particular, may offer personalised organ constructs, potentially reducing transplant rejection and enhancing recovery. If successful, the fields also represent an enabler for viable and profitable in-space economic activities.

In 2023, the US government awarded the Wake Forest Institute for Regenerative Medicine the use of the International Space Station (ISS) to study various 3D bio-printed designs of liver tissue constructs in microgravity and biomanufacturer optimal constructs for potential use in human clinical trials. In 2024, a German consortium launched Eva, an end-to-end special service for microgravity life science research that provides space cargo, modular microgravity bioreactors, and space launch services, as an alternative to the ISS laboratory.

Sources	(Geraud, 2024; Geospatial World, 2023; NASA, 2023)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Biotechnologies / Space & Propulsion Technologies	
STEP categories	Biotechnologies	
EIC portfolios	Health and Biotechnology / Space	
EIC taxonomy	**Sector (Primary)**	Health Biotechnology
	Sub-sector (Secondary)	Cell, tissue and other regenerative therapies / Industrial Biotech & Biomanufacturing
	Technologies/Applications (Tertiary)	Tissue Engineering / 3D Printing & Additive Manufacturing / Microgravity and exploration orbital systems
	Verticals	Biomass & Bio-based Materials, incl. Engineered Living Materials

09

Programmable DNA machines offer general-purpose computing



A team of researchers from China’s Shanghai Jiao Tong University have created what may be the world’s first programmable DNA computer. In a paper published in *Nature*, researchers explained how they created DNA-based programmable gate arrays or “DPGAs” that can support more than 100 billion distinct computational circuits.

Previous successes in designing DNA computers were limited to performing a singular task only. The researchers found a potential way to develop “programmable arrays of logic gate” – a major requirement for programmable computing as found in silicon-based microchips. Researchers claim they say they can program a single DNA-based array to implement more than 100 billion distinct circuits.

In their experiments, the researchers used a DNA computer made up of 30 logic gates with about 500 DNA strands to accurately find square roots. They also used it to identify three genetic molecules related to kidney cancer. The researchers suggest that DNA computers may find use in programming cells to respond to pollutants for environmental monitoring, or to cancer-related molecules for disease treatment.

Sources	(Choi, 2023; Future Today Institute, 2024; Lv, et al., 2023)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Biotechnologies	
STEP categories	Biotechnologies / Digital Technologies and Deep-Tech Innovation	
EIC portfolios	n/a	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Hybrid & High Performance Computing / Industrial Biotech & Biomanufacturing
	Technologies/Applications (Tertiary)	Computing & Logic Systems / Printed, Flexible & Organic Electronics
	Verticals	n/a

10

Using Alphafold AI to engineer bacterial nanosyringes for precise protein delivery

In an emerging advancement bridging microbiology and medicine, researchers are transforming bacteria into nanosyringes capable of targeting human cells for precise protein delivery. This system, known as the extra-cellular contractile injection system (eCIS), leverages a natural syringe-like mechanism from bacteria to achieve its task.

Structurally, the eCIS consists of a rigid tube encased in a sheath that contracts, driving a spike at the tube's end through the cell membrane to inject the protein cargo. Tail fibres on the eCIS recognise and bind to specific receptors on the cell surface, ensuring targeted delivery.

Using AlphaFold, an AI-powered protein prediction tool from Alphabet's DeepMind, the researchers redesigned tail fibres of an eCIS produced by Photorhabdus bacteria to bind to human cells. The researchers made eCIS that targeted cancer cells and showed that they killed almost 100 percent of the cells but did not affect other cells.

Researchers have also used it to deliver a range of cargoes, including proteins that make single-letter changes to DNA, proteins toxic to cancer cells, and DNA-cutting enzymes. Researchers are looking to engineer eCIS to deliver other cargo and better understand the function of these systems in nature.

Sources	(DiCorato, 2023; Future Today Institute, 2024; Kreitz, et al., 2023)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Biotechnologies / Artificial Intelligence Technologies	
STEP categories	Biotechnologies / Digital Technologies and Deep-Tech Innovation	
EIC portfolios	Health and Biotechnology / Medical Technologies and Medical Devices	
EIC taxonomy	**Sector (Primary)**	Health Biotechnology
	Sub-sector (Secondary)	Drugs & Biologics / Artificial Intelligence
	Technologies/Applications (Tertiary)	Drug Delivery / Precision Medicine
	Verticals	Cancer & Neoplasms

11

Enhanced minimally-invasive patient monitoring with a new peripheral nerve interface technology

Researchers from the University of Cambridge combined flexible electronics and soft robotics techniques to develop the devices. They could be used to diagnose and treat a range of disorders, including epilepsy and chronic pain, or to control prosthetic limbs.

Current tools for interfacing with the peripheral nerves – the 43 pairs of motor and sensory nerves that connect the brain and the spinal cord – are outdated, bulky, and carry a high risk of nerve injury. The robotic nerve 'cuffs' developed by the Cambridge team are sensitive enough to grasp or wrap around delicate nerve fibres without causing any damage.

The researchers say the combination of soft electrical actuators with neurotechnology could be an answer to minimally invasive monitoring and treatment for a range of neurological conditions.

Sources	(University of Cambridge, 2024; Dong, et al., 2024)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Biotechnologies	
STEP categories	Biotechnologies	
EIC portfolios	Health and Biotechnology / Medical Technologies and Medical Devices / Medical Imaging and AI	
EIC taxonomy	**Sector (Primary)**	Health Biotechnology
	Sub-sector (Secondary)	Cell, tissue and other regenerative therapies / Internet-of-Things & Wearables
	Technologies/Applications (Tertiary)	Nervous System / Implants and Prosthetics / Tissue Engineering
	Verticals	Mental & Neurodevelopmental Disorders

12

Inverse vaccine flags 'off switch' in livers to combat autoimmune diseases

The University of Chicago's Pritzker School of Molecular Engineering (PME) has been conducting research on an inverse vaccine, which represents a significant advancement in immunology. The inverse vaccine (or reverse vaccine) in development aims to treat autoimmune diseases such as multiple sclerosis (MS) and type 1 diabetes.

Unlike traditional vaccines, which stimulate the immune system to recognise and attack pathogens, the inverse vaccine works by erasing the immune system's memory of a specific molecule. This process halts the immune system's attack on healthy tissues without compromising its overall function.

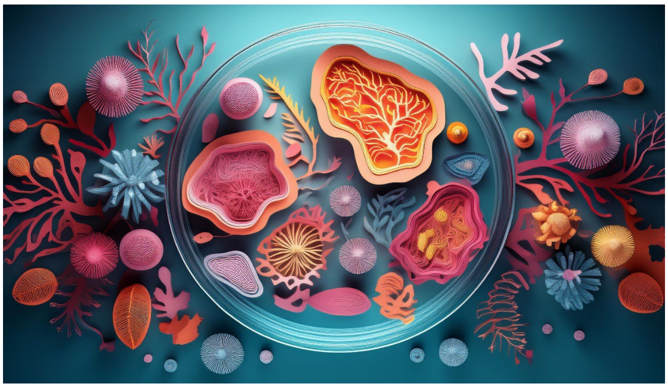
Autoimmune disorders are a significant health issue. A 2023 study in the *Lancet* found that they may affect about one in ten individuals. The possibility of an inverse vaccine may bring tremendous benefits to those impacted by autoimmune disorders.

In 2023, the university researchers carried out preclinical work in people with coeliac disease and also began phase 1 safety trials for people with MS.

Sources	(Willyard, 2023; Tremain, A.C. et al., 2023; University of Oxford, 2023; Williams S. , 2023)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Biotechnologies	
STEP categories	Biotechnologies	
EIC portfolios	Health and Biotechnology	
EIC taxonomy	**Sector (Primary)**	Health Biotechnology
	Sub-sector (Secondary)	Drugs & Biologics
	Technologies/Applications (Tertiary)	Vaccines / Antibodies & Immunotherapy
	Verticals	Immune System

13

Potential use of gut bacteria to enhance cancer immunotherapy's effectiveness



Recent studies have uncovered a fascinating connection between gut bacteria and the enhancement of cancer immunotherapy. Researchers from institutions like Washington University School of Medicine and Harvard Medical School have found that specific gut microbes can significantly boost the immune system's ability to fight cancer, potentially transforming cancer treatment outcomes. These findings provide a novel approach to rethinking current cancer immunotherapies. By understanding how specific gut bacteria influence immune responses, researchers can develop new strategies to enhance the effectiveness of treatments.

This finding potentially leads to the use of next-generation probiotics or small-molecule drugs derived from microbial metabolites, which could be cheaper and easier to administer than current antibody-based therapies. Instead of administrating intravenously-infused antibodies, small-molecule medicines are generally given as pills.

Additionally, this research underscores the broader significance of the gut microbiome in health and disease. The gut microbiome's ability to modulate the immune system opens new avenues for therapeutic interventions in cancer and immune-related conditions. This holistic view of health, considering the interplay between microbiota and immune function, represents a shift in how we approach treatment and disease prevention.

Sources	(Wegorzewska, 2024; Pesheva, 2023; Choudhury, 2024; Genetic Engineering & Biotechnology News, 2023; Wardill & Gibson, 2017)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Biotechnologies	
STEP categories	Biotechnologies	
EIC portfolios	Health and Biotechnology	
EIC taxonomy	**Sector (Primary)**	Health Biotechnology
	Sub-sector (Secondary)	Drugs & Biologics / Clinical Pathology
	Technologies/Applications (Tertiary)	Antibodies & Immunotherapy / Drug Discovery / Drug Delivery
	Verticals	Cancer & Neoplasms

3.5 Advanced connectivity, navigation and digital technologies

3.5.1 Introduction

The selected signals in advanced connectivity and navigation technologies highlight the emphasis on security and sovereignty in the digital space. The signals showcase developments in chip manufacturing, resilient positioning, navigation, & timing systems (PNT), and advancements in 6G technologies. Many of these advances are enabled by other emerging critical technologies in Quantum Computing and Advanced Semiconductors Technologies.

Related to chip design and manufacturing, researchers in Australia have developed a Lego-like chiplet (see Box 1) that integrates traditional electronics with photonic, or light, components in a way that significantly expands radio-frequency (RF) bandwidth, useful for 6G and other communications. This new approach enables the manufacture of chiplets using foreign and local circuits, which can help boost domestic manufacturing.

There is also a push to develop new navigation technology to address GPS vulnerabilities. A consortium of UK companies demonstrated a quantum-based navigation system with the potential for resilient navigation methods independent of satellite input, offering greater accuracy and jam-resistance.

In the area of mobile connectivity, researchers in Hong Kong have developed a universal metasurface (see Box 5) antenna for 6G systems that manipulates all five fundamental properties of electromagnetic waves independently, enabling advanced waveform manipulation for secure and efficient information transmission.

Box 5. What is a metasurface?

Metasurfaces are very thin materials made of tiny, carefully arranged structures that can control electromagnetic (EM) waves. Unlike traditional bulky metamaterials, metasurfaces are flat and offer new possibilities for applications across different frequencies, including microwave, terahertz (THz), and optical.

They are especially useful for creating small, efficient EM devices for future optical technologies. Due to their excellent ability to manage EM waves, metasurfaces have also potential in wireless communication.

Metamaterials, in general, are made from repeated small metal or dielectric structures that interact with EM fields in unique ways, showing properties not found in nature. Despite their promise, practical use of metamaterials has been limited by challenges like high energy loss, complex fabrication, and the need for very precise small-scale structures.

Sources: (Kar, 2023; Chen, Taylor, & Yu, 2016; Cheng, et al., 2024; Sun, He, Hao, Xiao, & Zhou, 2019)

14

UK trials jam-resistant quantum positioning, navigation & timing

Recent geopolitical tensions have demonstrated the vulnerability of commercial flights to Global Navigation Satellite Systems (GNSS) jamming, which has disrupted air travel over parts of the Baltic states and Scandinavia. Such events have underlined the fragility of and dependence on GNSS and the need for alternatives.

In a series of test flights, a team led by a British consortium has demonstrated two ground-breaking quantum technologies to protect aircraft from GNSS jamming by providing a navigation system that works independently of any external input from satellites.

The navigation system, technically called a Positioning, Navigation and Timing (PNT) system, uses an ultra-cold-atom-based quantum compass, which calculates its position and motion based on measurements of inertial forces acting on atoms held in quantum superposition states.

The technology tested is the first known live in-flight demonstration of quantum inertial navigation, which offers greater accuracy and resilience, independent of traditional satellite navigation using GNSS. The project is part of a larger, longer-term initiative by the UK government to develop and deploy alternatives to the GNSS for location, navigation and timing data by 2030.

Sources	(Ahlgren, 2024; Saran, 2024; Weaver, 2024; Advanced Navigation, 2024)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Advanced Connectivity, Navigation and Digital Technologies / Quantum Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation	
EIC portfolios	Quantum Technologies	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Quantum Technologies / Aviation & Airports
	Technologies/Applications (Tertiary)	Positioning & Navigation Systems
	Verticals	n/a

15

First universal metasurface antenna for more advanced, secure sensing and 6G communications

City University of Hong Kong (CityU) has developed the world's first universal metasurface antenna (UMA), a significant advancement for 6G communication systems. This antenna is capable of independently and simultaneously manipulating all five fundamental properties of electromagnetic waves.

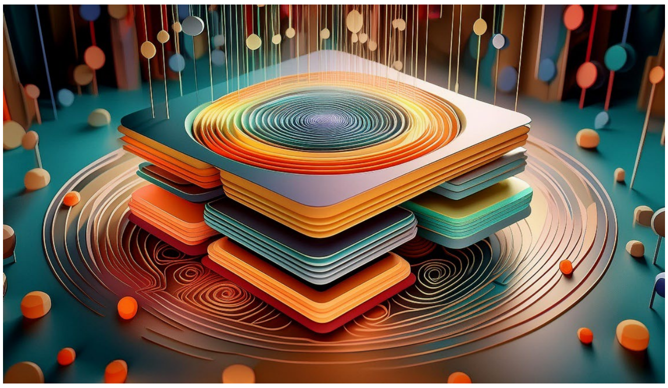
This functionality allows for advanced waveform manipulation, essential for high-security, high-capacity information transmission, real-time imaging, and wireless power transfer. Unlike traditional antennas that can only control one or two properties of electromagnetic waves, the metasurface antenna developed by CityU can manipulate all five properties (amplitude, phase, frequency, polarisation, and direction) independently. This multi-dimensional control enables the generation of complex waveforms that can enhance communication security and efficiency.

By controlling multiple properties of electromagnetic waves, the metasurface antenna can create highly secure communication channels that are resistant to eavesdropping. Additionally, the ability to manipulate the direction and polarisation of electromagnetic waves allows for more efficient use of the radio spectrum. This can lead to better performance in dense urban environments where the radio spectrum is heavily utilised. The metasurface antenna can dynamically adjust its parameters to avoid interference and optimise signal quality, resulting in more reliable and higher quality communications.

Sources	(Wu, et al., 2023; City University of Hong Kong, 2023; Hertz, 2024)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Advanced Connectivity, Navigation and Digital Technologies / Advanced Materials, Manufacturing and Recycling Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Advanced Materials	
EIC taxonomy	**Sector (Primary)**	AI, Data & ICT
	Sub-sector (Secondary)	Telecommunications / Advanced Materials
	Technologies/Applications (Tertiary)	Mobile Connectivity & Devices
	Verticals	Nanomaterials

16

Lego-like photonic chip that boosts advanced sovereign manufacturing, bandwidth control for radars and 6G



Researchers in Sydney have developed a Lego-like photonic chip, which allows a single photonic chip to be composed of separately manufactured circuits. The design presents potential opportunities for local semiconductor manufacturing industries, where overseas foundries create the wafer and it is further adapted locally using its Lego-like architecture.

In the long term, this process could encourage and support the domestic production of advanced photonic chiplets, reducing reliance on international supply chains and fostering technological sovereignty. In addition, this design allows for easy customisation and scalability of the chip, enabling the addition or replacement of components without redesigning the entire system.

The photonic chip significantly expands radio-frequency (RF) bandwidth, which means more information can flow through the chip and the inclusion of photonics allows for advanced filter control for application in advanced radar, satellite systems, wireless networks and the roll-out of 6G and 7G telecommunications.

Sources	(Garrett, et al., 2023; The University of Sidney, 2023)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Advanced Connectivity, Navigation and Digital Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation	
EIC portfolios	Responsible and Sustainable Electronics	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Photonics & Optoelectronics / Telecommunications
	Technologies/Applications (Tertiary)	Mobile Connectivity & Devices / Radar Technologies / Advanced Packaging / System-on-Chip (SoC) Solutions
	Verticals	n/a

3.6 Advanced sensing technologies

3.6.1 Introduction

In advanced sensing technologies, the selected signals showcase the diverse array of research areas and applications within the field. Like many signals in other categories, these advancements look at increasing energy efficiency and may contribute to sustainability goals.

In one area, researchers have developed new plant sensors designed to be flexible and wireless, which may offer improved monitoring of plant water stress and other environmental factors. When compared with previous solutions, these sensors appear to adhere better to plant surfaces and could provide more reliable long-term data, which may be crucial for precision agriculture.

At the other end of the spectrum, the United State's (US) National Institute of Standards and Technology (NIST) researchers have developed a new type of on-chip frequency comb, a device that can rapidly measure different wavelengths of light, such as those absorbed by atoms and molecules, critical in fields such as quantum sensing (see Box 6). The new design requires as little as one ten-millionth of the power required by previous designs and fewer components leading to easier fabrication and integration with other chips.

Box 6. What is quantum sensing?

Quantum sensing is one of the most advanced areas within quantum technologies, a broad field that also includes quantum computation and communication.

It uses quantum systems, properties, or phenomena to measure physical quantities with high sensitivity and precision. Traditional examples include magnetometers based on superconducting quantum interference devices and atomic clocks.

Quantum sensing has emerged as a rapidly growing field focusing on platforms like spin qubits, trapped ions, and flux qubits. This field promises new opportunities in applied physics and other sciences, offering unmatched sensitivity and spatial resolution for various tasks, such as characterising dynamic biological processes and detecting phenomena in condensed matter.

This avenue of research promises to revolutionise biomedical research by operating at various scales. Nitrogen-vacancy (NV) centres in diamonds are ideal for analysing single molecules. At the cellular level, they can study metabolism and neuron activity. Integrated into nanodiamonds, they serve as nanoscale temperature sensors in living organisms. Additionally, quantum sensors like optically pumped magnetometers (OPMs) can detect biomagnetic signals from animals and humans due to their high sensitivity to magnetic fields.

Sources: (Degen, Reinhard, & Cappellaro, 2017; Pirandola, Bardhan, Gehring, Weedbrook, & Lloyd, 2018; Yu, von Kugelgen, Laorenza, & Freedman, 2021; Aslam, et al., 2023)

17

New wearable plants sensors use established microfabrication techniques and ML for more accurate data interpretation

Researchers have introduced a novel wearable technology designed for plants. This technology consists of flexible sensors that are capable of wirelessly transmitting data regarding the plant's water loss to a smartphone app, enabling real-time monitoring and management of drought stress.

Wearable technologies for plants can help detect water stress early, enabling farmers to implement timely irrigation strategies, conserving water resources, and improving crop yields. This proactive approach to plant care can also reduce the risk of crop failure due to unforeseen drought conditions.

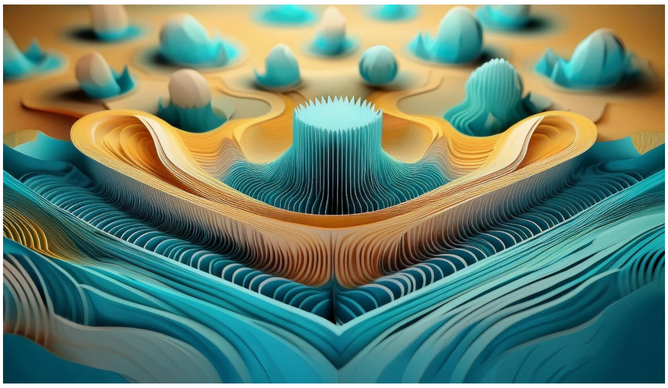
Traditional sensors faced challenges with long-term attachment and accurate data collection. The new sensors, however, adhere more effectively to plant surfaces and provide reliable data over extended periods, making them practical for continuous monitoring. A machine-learning model translated the sensing responses into percent of water content lost.

In addition to drought stress detection, these sensors can also help identify other environmental stressors such as pest infestations and exposure to toxins. This multifunctional capability further broadens the scope of plant monitoring and care, which are critical in the growing field of precision agriculture.

Sources	(World Economic Forum, 2023; American Chemical Society, 2022; Barbosa, et al., 2022)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Advanced Sensing Technologies / Advanced Semiconductors Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Agriculture and Food	
EIC taxonomy	**Sector (Primary)**	Agriculture & Food
	Sub-sector (Secondary)	Agrifood Biotechnology / Internet-of-Things & Wearables
	Technologies/Applications (Tertiary)	Precision & Smart Farming / Sensors, Actuators & MEMS
	Verticals	n/a

18

Highly energy efficient sensors using microcombs



U.S.'s National Institute of Standards and Technology (NIST) researchers have developed on-chip frequency combs that can integrate with sensors for temperature and acceleration. Frequency combs enable rapid measurements of different light wavelengths absorbed by atoms and molecules, allowing real-time analysis of atomic and molecular systems.

Combining these on-chip frequency combs with other integrated sensors has significant potential in quantum sensing, which detects changes in physical properties at the atomic level.

While chip-scale frequency combs have been created before, this new design operates with as little as one ten-millionth of the power required by previous versions. Traditional designs relied on acousto-optic and electro-optic modulators, which are often incompatible with chip-based fabrication methods.

The new approach eliminates the need for acousto-optic modulators, simplifying the integration process and enhancing the feasibility of chip-based devices. This innovation represents a significant advancement in sensor technology and its applications.

Sources	(NIST, 2024; Han, et al., 2024)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Advanced Sensing Technologies / Advanced Semiconductors Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Responsible and Sustainable Electronics	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Semiconductors & Integrated Circuits / Energy Efficiency
	Technologies/Applications (Tertiary)	Sensors, Actuators & MEMS / Micro and Nano-systems engineering / Advanced Packaging / System-on-Chip (SoC) Solutions
	Verticals	n/a

3.7 Space & propulsion technologies

3.7.1 Introduction

According to the European Space Agency's "Space Environment Report 2023", the number of objects launched into orbit has significantly increased in recent years, with more satellites launched in 2022 than in any year before (see Box 7). This increase in objects has raised concerns about 'congestion' in space and the growing number of debris caused by obsolete satellites and rocket debris. Collisions with debris can damage or destroy satellites, leading to loss of crucial services such as communications, weather monitoring, and navigation. The two selected signals illustrate different technological approaches to addressing this issue: reducing space debris at its source and improving space debris tracking.

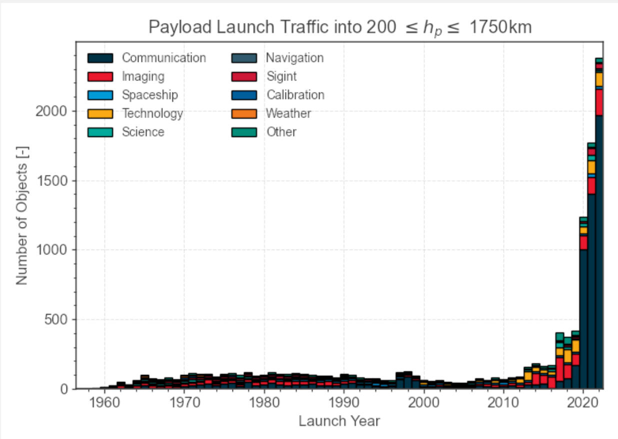
The University of Glasgow is researching an 'autophage' rocket engine, dubbed Ouroboros-3, that consumes parts of its own body for fuel, potentially lowering space debris. This engine uses waste heat to melt its plastic fuselage, feeding the molten plastic into the combustion chamber.

University of Strathclyde researchers are developing hyperspectral imaging technology, paired with machine learning, that would enable continuous tracking of space objects under any illumination conditions. Unlike traditional methods that rely on visible light, this technology would ensure reliable tracking even in darkness. This technology could enhance safety by providing accurate debris tracking, crucial for protecting satellites.

Box 7. What is space debris mitigation?

Earth's orbital environment is a limited resource increasingly congested by satellites, with a record number launched in 2022. Commercial satellite constellations in valuable low-Earth orbits are growing, but many satellites do not vacate these orbits at the end of their lives, risking fragmentation into debris. This increases the need to perform collision avoidance manoeuvres for active satellites.

Beyond collision avoidance, space debris mitigation includes other measures and strategies aimed at reducing the generation and impact of space debris that pose risks to active satellites and spacecraft. Although it is improving, the rising number of new satellites and existing debris makes current efforts insufficient, leading to concerns about the long-term sustainability of space activities.



Source: (European Space Agency, 2023)

19

Self-consuming rockets to reduce space debris and improve efficiency

Engineers at the University of Glasgow have built and fired Ouroboros-3, the first unsupported 'autophage' rocket engine which consumes parts of its own body for fuel. An autophage vehicle would require less propellant in onboard tanks, allowing more mass allocated for payload instead, and would at the same time reduce space debris.

The explosion of low-cost satellites in recent years has led to warnings of orbital congestion caused by both new satellites in orbit and increased space debris from obsolete or failed satellites. SpaceX alone has over 4000 satellites in orbit.

The engine works by using waste heat from combustion to sequentially melt its own plastic fuselage as it fires. The molten plastic is fed into the engine's combustion chamber as additional fuel to burn alongside its regular liquid propellants.

The engineers have successfully test-fired the Ouroboros-3, producing 100 newtons of thrust. They have also demonstrated their ability to be throttled, restarted, and pulsed in an on/off pattern. These are key steps towards developing a viable flight concept.

Sources	(Williams A. , 2023; University of Glasgow, 2024; UK Space Agency, 2023)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Space & Propulsion Technologies	
STEP categories	Clean and Resource Efficient Technologies / Digital Technologies and Deep-Tech Innovation	
EIC portfolios	Space	
EIC taxonomy	**Sector (Primary)**	Space
	Sub-sector (Secondary)	Launch vehicles / Circular Economy & Recycling
	Technologies/Applications (Tertiary)	Spacecraft Propulsion Technologies / Resource Management & Valorisation
	Verticals	n/a

20

Novel hyperspectral technology to detect space debris under any illumination conditions

HyperNav combines hyperspectral imaging technology with advanced machine learning algorithms to track the motion of space objects. Traditional tracking methods often rely on visible light, which limits their effectiveness during periods of darkness or in shadowed regions of space. HyperNav's hyperspectral capabilities allow it to gather data in various lighting conditions, ensuring continuous and reliable tracking.

The rapid increase in space debris poses significant risks to operational satellites and future space missions. Collisions with debris can damage or destroy satellites, leading to loss of crucial services such as communications, weather monitoring, and navigation. Improving the ability to track debris accurately is essential for enhancing the safety and sustainability of space operations.

If successful, HyperNav could also support the long-term development of in-orbit servicing missions. These missions involve activities such as satellite repair, refuelling, or upgrading, which are crucial for extending the operational lifespan of satellites and reducing space waste. By providing precise tracking data, HyperNav could enable these missions to be conducted more safely and efficiently.

Sources	(University of Strathclyde Glasgow, 2023; UK Space Agency, 2023)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Space & Propulsion Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Space	
EIC taxonomy	**Sector (Primary)**	Space
	Sub-sector (Secondary)	In-Space Servicing, Assembly, and Manufacturing / Artificial Intelligence
	Technologies/Applications (Tertiary)	Space Debris Tracking & Management / Machine & Deep Learning / Sensors, Actuators & MEMS
	Verticals	n/a

3.8 Energy technologies

3.8.1 Introduction

The push to advance renewable energy and storage capabilities is reflected in a several of the selected signals in the Energy Technologies field. These signals range from developing new sources of renewable energies to advancing current energy generation systems. Two of the selected signals connect with the Advanced Materials category, where new alloys and nanoparticles are used for energy storage and osmotic power, respectively.

While still early in development, Caltech researchers have potentially found a way to circumvent Kirchhoff's thermal law, which could lead to higher energy-conversion efficiencies in photovoltaic systems. This innovation may allow solar panels to redirect reflected energy that would typically be lost, possibly increasing overall system performance.

In the realm of energy storage, MGA Thermal in Australia is exploring a novel thermal energy storage (TES) system using miscibility gaps alloy (MGA) (see Box 8). This technology potentially offers advantages over existing thermal storage methods, including higher energy density and reduced material degradation. A demonstration unit deployed in Australia showcased the system's ability to store enough energy to power numerous homes over an extended period.

The other selected signals include using nanotechnology material to develop more efficient approaches to osmotic power, scalable underwater battery storage, and the recent piloting of an adaptable wave-riding generator.

Box 8. What is a miscibility gap alloy?

In a miscibility gap alloy (MGA) the metals don't completely mix, forming separate regions instead of a single, uniform material. This occurs because the metals have limited solubility in each other due to differences in their atomic structures.

Imagine mixing oil and water—they don’t mix well and separate into layers. Similarly, in some metal alloys, components separate into distinct phases, each with different properties.

In the energy domain, MGAs can be used to store heat using materials with high thermal conductivity. They are composed of two components: one that melts and stores energy, and another that remains solid, maintaining the block's shape and distributing heat. This allows MGAs to repeatedly absorb, store, and release energy. MGA blocks can also heat water to produce steam for turbines and generators, similar to traditional power stations. This process can utilize various heat sources, including solar, renewable energy, and industrial waste heat.

Sources: (The University of NewCastle Australia, 2020)

21

Capturing osmotic energy using off-the-shelf nanotechnology materials and processes

Pressure Retarded Osmosis (PRO) is a proposed method of harnessing the osmotic pressure difference between water of different salinity levels. Current approaches are not economically viable due to low power density and are also limited in their location as they require freshwater and saltwater as inputs in the process.

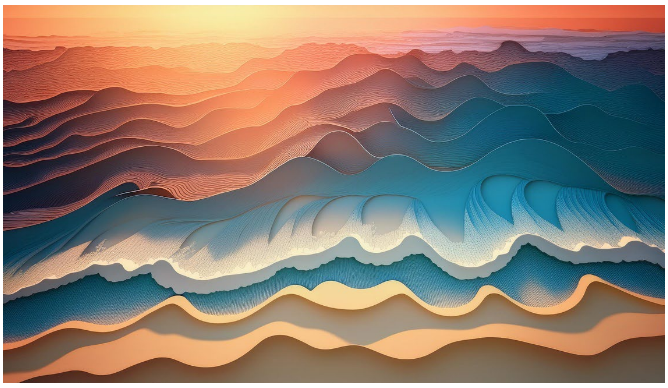
Grenoble-Alpes University is currently researching an approach that allows for the use of off-the-shelf processes and materials to create a PRO energy system that would not need fresh water to operate. The approach includes using hydrophobic nanoporous powder, a commercially available nanomaterial currently used in hospitals, and existing processes based on nanotechnology, specifically nanofluidics.

Currently, this approach is at the exploratory level and presents new opportunities for the application of nanomaterials and nanofluidics. The university is planning a pilot project along the Rhône River in France to validate the technology in real-world conditions, especially looking to demonstrate higher energy densities and better cost efficiencies.

Sources	(Triou, 2023; Planchenault, 2022; ENGIE, 2024)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Energy Technologies / Advanced Materials, Manufacturing and Recycling Technologies	
STEP categories	Clean and Resource Efficient Technologies	
EIC portfolios	Energy Systems / Advanced Materials	
EIC taxonomy	**Sector (Primary)**	Energy
	Sub-sector (Secondary)	Energy Generation & Conversion / Advanced Materials
	Technologies/Applications (Tertiary)	Electricity
	Verticals	Ocean & Salinity Gradient / Nanomaterials

22

Renewable energy using modular, adaptable wave-riding generators



The push for renewable energy sources has led to investments in novel forms of harnessing tidal and wave energy from the ocean. A UK-based company has been developing a wave energy converter called the 'Waveline Magnet.' It is composed of an array of flexible segments connected by a spine power system. Waves pass through the system and generate electricity as they rise and fall.

One of the key advantages of the 'Waveline Magnet' is its adaptability. This wave energy device can operate effectively regardless of the wave profile or prevailing weather conditions. Furthermore, it occupies only a few centimetres of the water column, making it a versatile and efficient solution for wave energy conversion.

The company has launched pilot tests in Cyprus to evaluate its performance in real-world conditions. There are outstanding concerns about its energy density and levelised cost of energy in real-world conditions. If these pilot tests are successful, the next step is commercialisation of a two hundred-kilowatt converter—mostly suited for providing power to small islands for desalination and other applications.

Sources	(Garanovic, 2021; Mereu, 2023; Blain, 2022; ENGIE, 2024)	
Technology maturity	Close to market (TRL 7-9)	
10 Critical Tech Areas	Energy Technologies	
STEP categories	Clean and Resource Efficient Technologies	
EIC portfolios	Energy Systems	
EIC taxonomy	**Sector (Primary)**	Energy
	Sub-sector (Secondary)	Energy Generation & Conversion
	Technologies/Applications (Tertiary)	Electricity
	Verticals	Other Sources

23

New water- and underwater-battery for offshore wind generation

Ocean Grazer is developing an underwater battery to store electricity from offshore wind turbines. The battery promises minimal environmental impact and can be deployed widely, relying on existing technologies and approaches.

Similar to other hydro-storage batteries, excess electricity from renewable sources can be used to pump water from the reservoir into the bladder. When energy is needed, water from the bladder is released back down to the reservoir, spinning hydro turbines that feed electricity back to the grid.

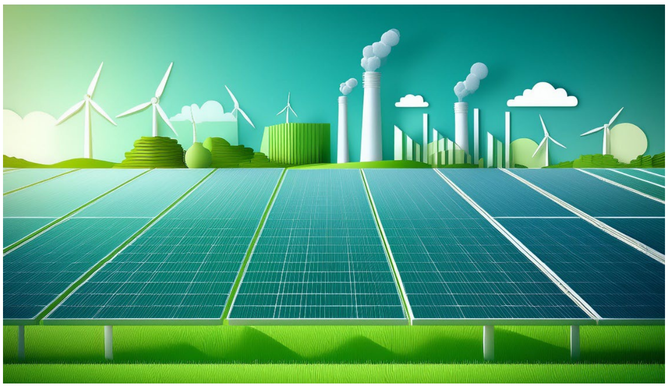
The battery promises to be rapid, deployable, and scalable near wind farms, with low maintenance needs, taking potentially over a million cycles.

Ocean Grazer is currently preparing a 3 Megawatt (MW) capacity demo plant in the Netherlands. It will be deployed at the bottom of a flooded quarry to simulate the conditions of an actual seabed. If successful, the company plans to pilot the battery on the seabed by 2025.

Sources	(Vels, 2024; ENGIE, 2024)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Energy Technologies	
STEP categories	Clean and Resource Efficient Technologies	
EIC portfolios	Energy Systems	
EIC taxonomy	**Sector (Primary)**	Energy
	Sub-sector (Secondary)	Energy Storage
	Technologies/Applications (Tertiary)	Batteries & Supercapacitors
	Verticals	Wind

24

First demonstration of miscibility gaps alloy, a novel thermal storage technology



MGA Thermal in Australia is developing a new thermal energy storage (TES) system using a novel miscibility gaps alloy (MGA), a new type of phase-change thermal storage material with high thermal conductivity. Thermal energy storage enables the capture and storage of energy from solar thermal plants and the heat from industrial processes.

Energy is stored as heat in GMA-alloy and graphite-mixed blocks, which are enclosed within a fully insulated system. When electricity is needed, the heat is used to drive a steam turbine generator.

Last year, the company deployed a shipping container-sized demonstration unit in Australia that can store enough energy to power more than 135 homes for 24 hours.

The unique properties of the alloy allow heat to be added or extracted without affecting the material's temperature, giving it an advantage over sensible heat storage (SHS) technologies. The use of miscibility gaps alloy promises higher energy density, reduced material degradation, and greater overall cost-effectiveness over existing technologies and approaches used in TES systems.

Sources	(UNICEF, 2024; Hill, 2023; Nichols, 2024; MGA Thermal, 2024; Arena Wire, 2022; Thomsen, 2024; Foley, 2024)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Energy Technologies / Advanced Materials, Manufacturing and Recycling Technologies	
STEP categories	Clean and Resource Efficient Technologies	
EIC portfolios	Energy Systems / Advanced Materials	
EIC taxonomy	**Sector (Primary)**	Energy
	Sub-sector (Secondary)	Energy Storage / Advanced Materials
	Technologies/Applications (Tertiary)	Batteries & Supercapacitors
	Verticals	Metals & Alloys

25

Potential to capture wasted 'reflected' energy from PV Systems

The California Institute of Technology (Caltech) has devised a device that uses a magnetic field to break Kirchhoff's law of thermal radiation, which could have important implications for sustainable energy-harvesting systems.

Kirchhoff's thermal law states that an energy-harvesting object such as a photovoltaic (PV) panel will re-emit some of its absorbed energy back toward the energy source (the Sun) as heat. A common way to experience this effect is feeling heat radiating from a paved road during a sunny afternoon.

Caltech's work shows it is possible to break this law using a device placed in a magnetic field, allowing re-emitted energy to bend in other directions. The device itself combines a material that has a strong magnetic-field response and another material which enhances absorption and emission in infrared wavelengths.

The implication of this work is that it might be theoretically possible to place a PV device in a magnetic field that bends the re-emitted energy toward another energy-harvesting object to create higher energy-conversion efficiencies.

Sources	(Schweber, 2023; Shayegan, Biswas, Zhao, Fan, & Atwater, 2023; California Institute of Technology, 2023)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Energy Technologies	
STEP categories	Clean and Resource Efficient Technologies	
EIC portfolios	Energy Systems	
EIC taxonomy	**Sector (Primary)**	Energy
	Sub-sector (Secondary)	Energy Generation & Conversion
	Technologies/Applications (Tertiary)	Electricity
	Verticals	Solar

3.9 Robotics and autonomous systems

3.9.1 Introduction

The selected signals for robotics and autonomous systems interact with large dominant trends around the integration of generative AI, specifically large language models (MLLs) into drone/robot technologies.

The first involves a novel drone design from Nanjing University of Aeronautics and Astronautics, inspired by maple seeds. This drone can split into six independent sub-drones, each potentially carrying different mission-specific payloads. This design may offer improved flight efficiency and extended range compared to traditional multirotor drones, thereby enabling more complex and versatile missions.

The second advancement comes from the University of Michigan, where researchers have developed a 3D visual grounding technique (see Box 9) integrating LLMs into robotic systems. Integrating LLMs into physical robots enhances their ability to understand and navigate 3D environments, potentially leading to more intuitive human-robot interactions. In practical areas, LLM-enabled robots can interpret natural language commands more effectively, make more informed decisions, and possibly adapt better to new tasks and environments.

Box 9. What is 3D visual grounding?

3D visual grounding is a process of identifying objects in a 3D scene using text descriptions. For example, if we have a 3D model of a living room, the system would be able to recognise and pinpoint a specific piece of furniture when prompted by the user.

This task is performed through the combination of visual information from the scene (shapes, colours and positions of objects) with linguistic information from the user's text. Its applications range from augmented and virtual reality to emerging fields such as robotics.

Current techniques often simplify the scene by reducing its resolution, leading to potential mismatches. New methods involve gathering additional object-related points to provide more contextual information, overcoming these limitations.

Sources: (Guo, Zhu, Ye, Li, & Chen, 2024)

26

Splittable six-in-one drone for higher efficiency and multi-use missions

Inspired by the structure of maple seeds, Nanjing University of Aeronautics and Astronautics has developed a drone that can split into six separate sub-drones.

Each sub-drone can fly around independently and communicate with the others to carry out complex missions, where each sub-drone can have mission-specific capabilities. The sub-drones fly as a single unit but then fly with one blade when divided.

Progress in this technology has been slow because flight efficiency is significantly decreased when traditional drones are combined. The scientists' work includes addressing this challenge. expect to have overcome this challenge.

Despite their unusual shape, they claim a flight efficiency nearly twice that of a similar-sized multirotor drone and that it can fly further as a single unit than each sub-drone could alone.

Sources	(Chen S. , 2024; McFadden, 2024; Saballa, 2024)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Robotics and Autonomous Systems	
STEP categories	Digital Technologies and Deep-Tech Innovation	
EIC portfolios	n/a	
EIC taxonomy	**Sector (Primary)**	Mobility
	Sub-sector (Secondary)	Aviation & Airports
	Technologies/Applications (Tertiary)	Autonomous Vehicles & Drones
	Verticals	n/a

27

LLM-powered robots for faster learning, complex task completion

Researchers at the University of Michigan have invented an innovative 3D visual grounding technique that integrates LLMs to enable household robots and AI agents to better understand and navigate 3D environments. Although modern AI household tools like Siri and Alexa may appear quite advanced, they are not designed to understand the physical world or assist with tasks in real-life scenarios.

Additionally, despite progress in developing 3D visual grounding tools, these technologies often lack precision. With LLM-powered enhanced natural language interaction, such robots would be able to understand and respond to non-expert user requests, translating them into specific actions without needing programming knowledge or traditional controls. Improved decision-making and intelligence are evident, as robots leverage LLMs' vast information and reasoning capabilities to make informed decisions.

For instance, a robot can interpret "I'm hungry, what's to eat?" as a command to locate, identify, and retrieve nearby food, potentially even preparing it. With further development, LLMs might be able to help provide robots with flexible and adaptive learning, enabling them to learn from interactions and adapt to new tasks or environmental changes, ensuring effective functioning in diverse and dynamic conditions.

Sources	(University of Michigan, 2023; Zeng, Gan, Wang, Liu, & Yu, 2023; Zhang, Chen, Li, Peng, & Mao, 2023; Jiang, et al., 2023)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Robotics and Autonomous Systems / Artificial Intelligence Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation	
EIC portfolios	n/a	
EIC taxonomy	**Sector (Primary)**	AI, Data & ICT
	Sub-sector (Secondary)	Artificial Intelligence
	Technologies/Applications (Tertiary)	Natural Language Processing (NLP) & Foundation Models / Robotics & Cyber-physical Systems
	Verticals	n/a

3.10 Advanced materials, manufacturing, and recycling technologies

3.10.1 Introduction

In the area of advanced materials, the selected signals illustrate the role of advanced materials in supporting sustainability. They also point to intersections with the Biotechnologies category. The selected signals describe advanced biodegradable spores-embedded plastics, adapting mushroom skin for electronic circuits, and novel approaches to electrophysiological sensing using precision manufacturing.

At the University of California San Diego, researchers have developed a biodegradable thermoplastic polyurethane (TPU) with Bacillus Subtilis spores that decompose the plastic in compost. This innovation showcases hybrid engineered living materials (ELMs) and how they can manage plastic waste through biological processes.

In wearable technology, CU Boulder and KAIST engineers have created the Stretchable Nanowire-Array Patch (SNAP), a skin-adhering patch with silicon-gold needles which detect muscle electrical signals. SNAP enhances control of robotic exoskeletons and assists in diagnosing neurological conditions, benefiting people with disabilities, and marking a significant leap in flexible electronics (see Box 10).

Johannes Kepler University researchers have prototyped a mushroom-based substrate for Internet-of-Things (IoT) sensors, offering an eco-friendly alternative to plastic substrates. This durable, flexible substrate decomposes quickly in soil, addressing e-waste challenges and promoting environmental sustainability in electronics.

Box. 10 What are flexible electronics?

Flexible and stretchable electronics are advancing electronic devices toward more flexible, convenient, and human-friendly designs, with significant potential in wearable technology, electronic skin, and medical health monitoring.

These devices maintain multiple functionalities during deformation, making them promising for applications ranging from sensors to circuits. Recently, flexible conductive materials have gained considerable attention for their use in energy storage devices, touch panels, sensors, and memristors.

Hydrogels, in particular, are ideal conductive materials for flexible electronics due to their outstanding flexibility, electrical conductivity, and tunable mechanical properties.

This combination of attributes positions flexible and stretchable electronics as a key technology for future innovations in various fields.

Sources: (He, Shi, Tian, Zhu, & Wu, 2024; Lin, Li, Yang, Ji, & Wang, 2024; Dutta, et al., 2024)

28

Mushroom skin could make IOT sensors easier to recycle

As digitalisation advances, so will e-waste from IoT and other electronic devices. While many parts of electronics can be recycled, the substrate—which connects different chips—is the most difficult to recycle. Compounding the difficulties, the plastic substrate is the largest component in electronics yet also the cheapest, making recycling incentives challenging.

Researchers at Johannes Kepler University have prototyped a mushroom-based substrate that connects microchips and standard plastic polymers. They further demonstrate that the mushroom-based material could be used in a basic battery for low-power devices like Bluetooth sensors.

The mushroom-based substrate remains effective even after being bent more than 2000 times. It should have long-lasting durability yet be able to decompose in soil in only two weeks.

The researchers hope further research can allow the mushroom substrate to work in current industrial electronic processes, and eventually be used in electronics that are not designed to last for a long time, such as IoT devices, wearable sensors, or radio tags.

Sources	(Wilkins, 2022; Danninger, Pruckner, Holzinger, Koeppe, & Kaltenbrunner, 2022)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Advanced Materials, Manufacturing and Recycling Technologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Clean and Resource Efficient Technologies	
EIC portfolios	Advanced Materials / Responsible and Sustainable Electronics	
EIC taxonomy	**Sector (Primary)**	Quantum, Advanced Computing & Semiconductors
	Sub-sector (Secondary)	Internet-of-Things & Wearables / Industrial Biotech & Biomanufacturing
	Technologies/Applications (Tertiary)	Sensors, Actuators & MEMS / Printed, Flexible & Organic Electronics / Alternatives to Critical Raw Materials (CRM)
	Verticals	Biomass & Bio-based Materials, incl. Engineered Living Materials

29

Preparation–free, adhesive skin patches to help people control robotic exoskeletons

Engineers at CU Boulder and KAIST have developed a Stretchable Nanowire-Array Patch (SNAP) that enhances control of robotic exoskeletons by detecting muscle electrical signals through tiny silicon-gold needles. They created a stretchable and adhesive microneedle sensor by integrating microneedles into a soft silicon polymer substrate.

This patch, about the size of a plaster, adheres to the skin and accurately measures muscle activity even during vigorous movement, making it a significant advancement in human-machine interaction.

By reducing the muscle effort required to perform tasks, SNAP could enhance movement for people with disabilities and assist in diagnosing neurological conditions. This innovative integration of flexible EMG sensors into the skin marks a novel breakthrough in wearable technology.

Sources	(Strain, 2024; Kim, et al., 2024)	
Technology maturity	Emerging (TRL 4-6)	
10 Critical Tech Areas	Advanced Materials, Manufacturing and Recycling Technologies / Biotechnologies	
STEP categories	Digital Technologies and Deep-Tech Innovation / Biotechnologies	
EIC portfolios	Health and Biotechnology / Medical Technologies and Medical Devices	
EIC taxonomy	**Sector (Primary)**	Health Biotechnology
	Sub-sector (Secondary)	Cell, tissue and other regenerative therapies / Internet-of-Things & Wearables
	Technologies/Applications (Tertiary)	Implants and Prosthetics / Robotics & Cyber-physical System:
	Verticals	Musculoskeletal & Connective Tissue

ADVANCED MATERIALS, MANUFACTURING AND RECYCLING TECHNOLOGIES

30

A biodegradable "living plastic" with embedded bacterial spores breaks down plastic

Researchers at the University of California San Diego have developed a biodegradable form of thermoplastic polyurethane (TPU) filled with bacterial spores that, when exposed to nutrients present in compost, germinate and break down the material at the end of its life cycle.

(TPU is a commonly-used plastic found in products from footwear to memory foam, making it a staple in various industries. The biodegradable TPU is made with bacterial spores from a strain of Bacillus subtilis that have the ability to break down plastic polymer materials.

This research connects to the larger work being done in hybrid ELMs, a burgeoning field in which living and synthetic matter are combined to provide composite materials with augmented and complex functions.

More research is needed to understand the scalability of the process and the feasibility of incorporating similar spores into other plastics.

Sources	(Labios, 2024; Allemann, et al., 2024; Irving, 2024)	
Technology maturity	Novel (TRL 1-3)	
10 Critical Tech Areas	Advanced Materials, Manufacturing and Recycling Technologies / Biotechnologies	
STEP categories	Biotechnologies	
EIC portfolios	Advanced Materials	
EIC taxonomy	**Sector (Primary)**	Advanced Manufacturing & Advanced Materials
	Sub-sector (Secondary)	Industrial Biotech & Biomanufacturing / Advanced Materials
	Technologies/Applications (Tertiary)	Process & Packaging Technologies
	Verticals	Biomass & Bio-based Materials, incl. Engineered Living Materials

4 Analysis and final notes

4.1 Signal distribution

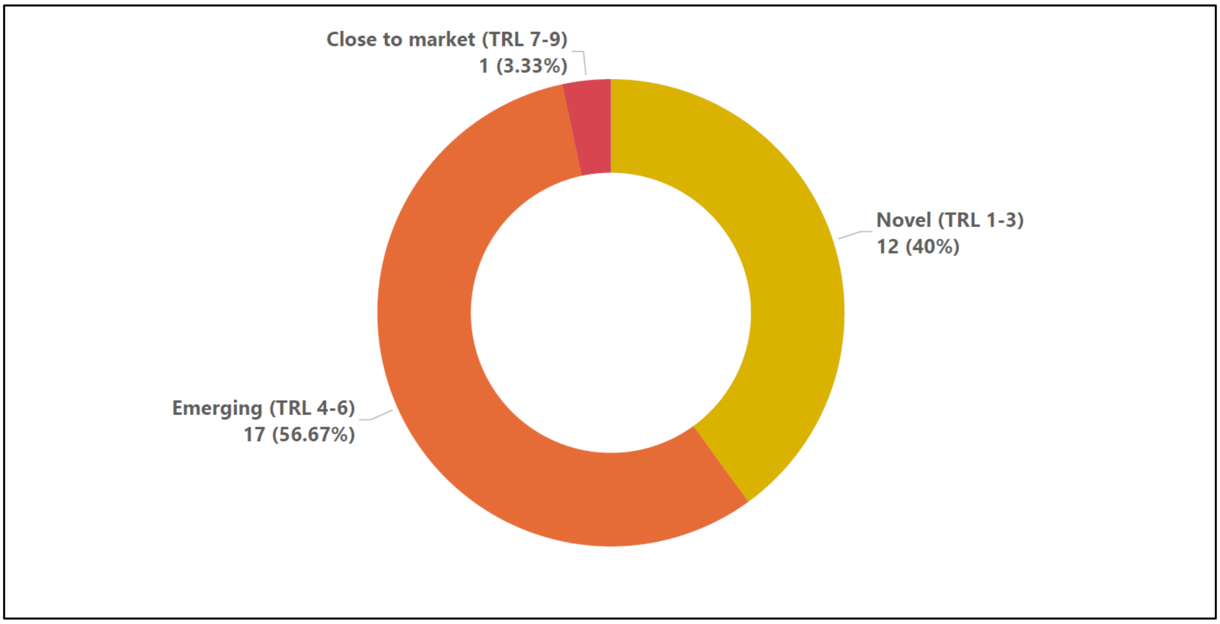
The following analysis is based on a relatively small sample size of 30 signals never intended to induce broad conclusions. Nevertheless, it is still possible to identify some innovation hotspots and to highlight areas and technologies that are of particular interest for the EIC's strategic intelligence. To achieve this, the authors used several frameworks: the EIC's own taxonomy and portfolio domains, the European Commission's 10 critical technology areas and its STEP initiative.

4.1.1 Maturity

It is the authors' understanding that novelty in the context of technology foresight can emerge at all technology readiness levels. For the EIC, considering their broad range of financing mechanisms, capturing a wide scope of signals is of strategic interest. The program supports initiatives from the earliest stages of scientific, technological, or deep-tech R&D to more mature innovative, game changing products, services, or business models that could create new markets or disrupt existing ones. Additionally, and regardless of the maturity level of the technology behind them, both disruptive and incremental innovations (Christensen, 1997) are of relevance.

However, in this Volume 2 and as the result of the application of the decision tree and the signal selection criteria (see Annex 4), there were significantly fewer signals selected that were in TRL 7 to 9 (see Figure 2), with a balance distribution of signals between the other two levels. This is because some of these close to market innovations are already well-known to the target public, and therefore fall outside of the objectives of this report.

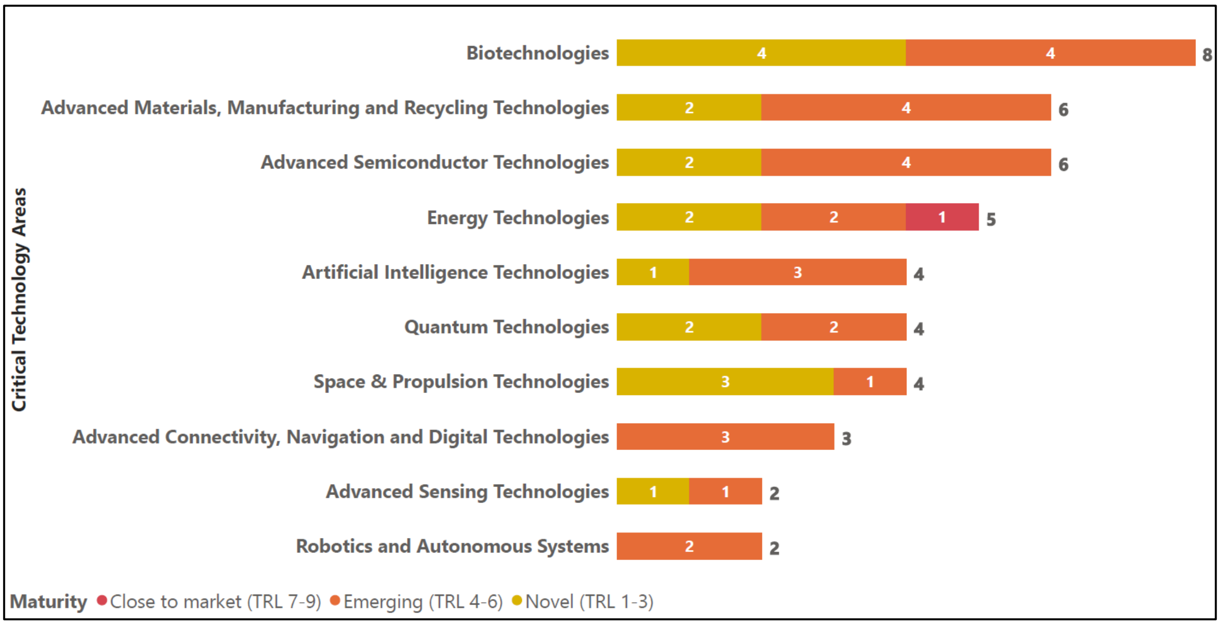
Figure 2. Distribution of the 30 selected signals according to their maturity.



Source: Authors.

The distribution within each critical technology area also varies, with some areas encompassing more early-stage technologies (see Figure 3). Nevertheless, the small number of signals does not allow for definitive conclusions from this, other than highlighting the need to continuously monitor developments that are still at the concept or lab stage, as well as innovations already being tested in pilot projects.

Figure 3. Distribution of the 30 selected signals according to their critical technology area and maturity.



Source: Authors.

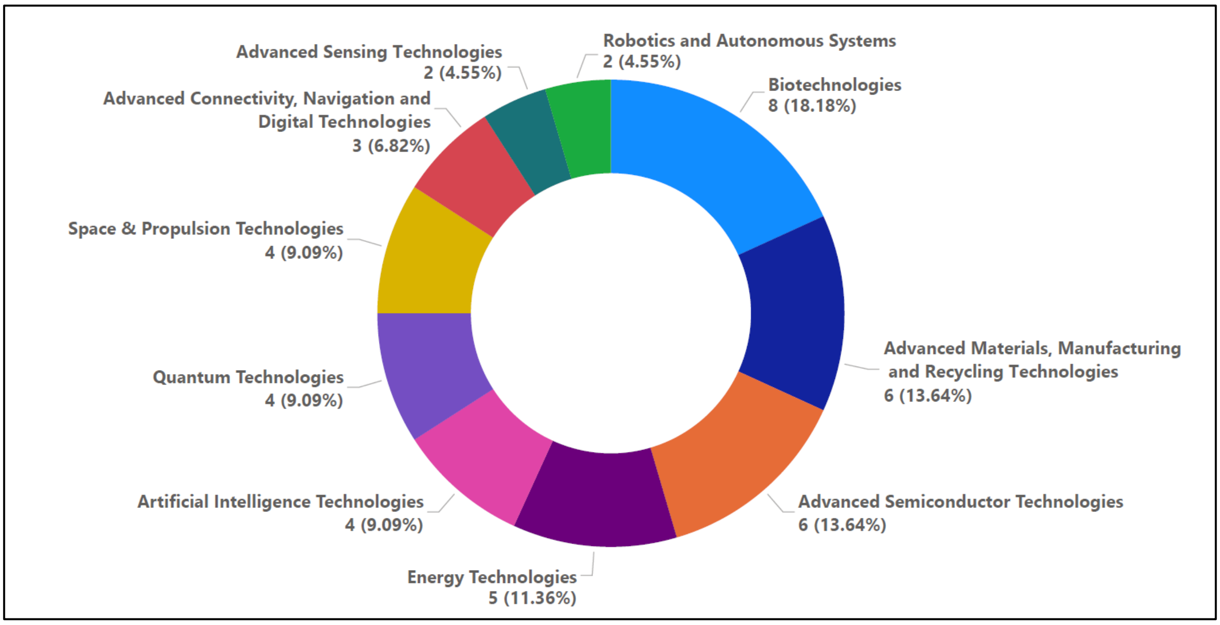
4.1.2 Critical Technology Areas

The 10 critical technology areas (European Commission, 2023) differ in scale and granularity. Some encompass broad, enabling technologies with applications across various fields, such as AI, while others focus on more specific technological capabilities like sensing or economic domains, like energy or space (see Annex 2 for non-exhaustive examples).

One important element of the Commission Recommendation is that it highlights 4 of these 10 areas as having the highest likelihood of presenting sensitive and immediate risks to technology security and technology leakage. These are: Advanced semiconductors technologies; Artificial intelligence technologies; Quantum technologies; and Biotechnologies. This type of risk analysis is outside of the scope of this report. One reason for this is that the selected signals refer to technologies and innovations developed across multiple geographies. However, it is worth noting that among the top five areas with the most selected signals in this review, we find these four priorities.

As mentioned in Section 3, for this categorisation the authors considered one main area for each signal and, when applicable, a secondary area. The editorial criteria for this volume required the final selection to include at least two signals for each area. Nevertheless, the process of evaluating and ranking signals according to their impact and novelty resulted in an uneven distribution across the 10 critical technology areas (see Figure 4). In that sense certain areas exhibit a more substantial number of innovation signals. Leading this chart are Biotechnologies, followed by Advanced Materials, Manufacturing and Recycling Technologies, Advanced Semiconductors, and Energy.

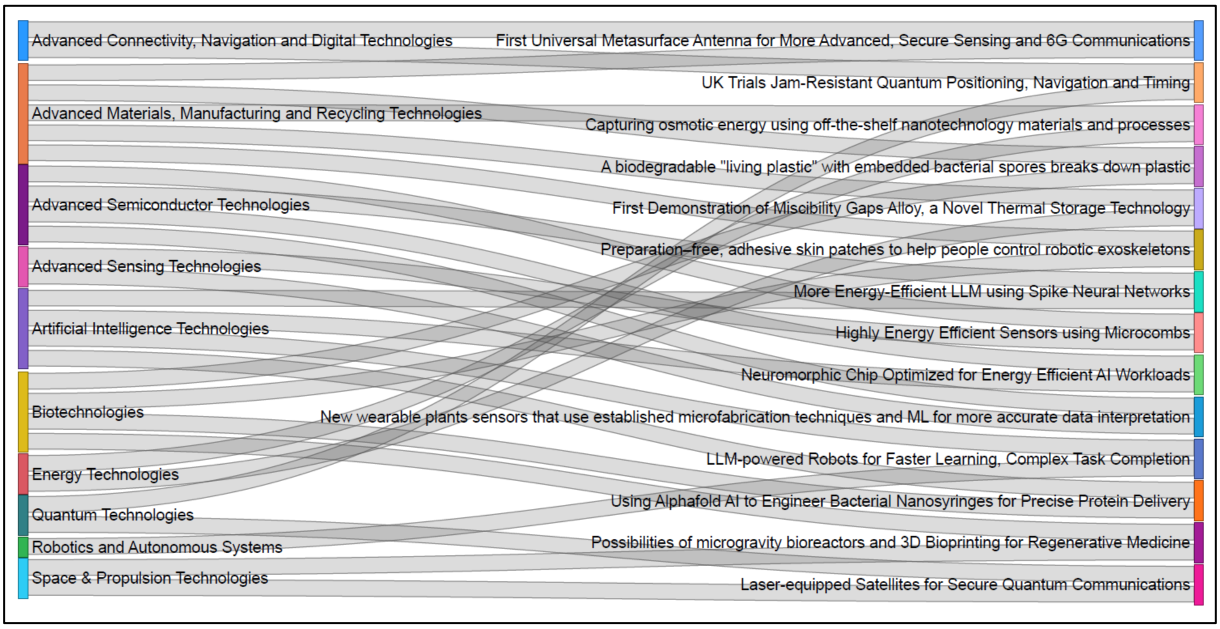
Figure 4. Distribution of the 30 selected signals across the 10 critical technology areas.



Source: Authors.

Additional insights can be extracted by analysing signals that are connected with more than one Critical Technology Area (14 out of 30), as this uncovers synergies worth exploring. Figure 5 shows that for these signals, the fields of Advanced Materials, Manufacturing and Recycling, AI, Biotechnologies and Advanced Semiconductors appear as the most interconnected. This is not surprising, as these are fields where a significant number of enabling technologies can be found.

Figure 5. Signals (titles on the right) that connect with more than one Critical Technology Area (on the left).



Source: Authors.

4.1.3 STEP

The Strategic Technologies for Europe Platform (STEP) (European Parliament and European Council, 2024) was established by the European Union with the objective of bolstering European industry and enhancing investment in critical technologies across the continent. To achieve this, STEP is designed to mobilise and direct funding from 11 different EU programs toward three target investment areas: Digital Technologies and Deep-Tech Innovation; Clean and Resource-Efficient Technologies; and Biotechnologies.

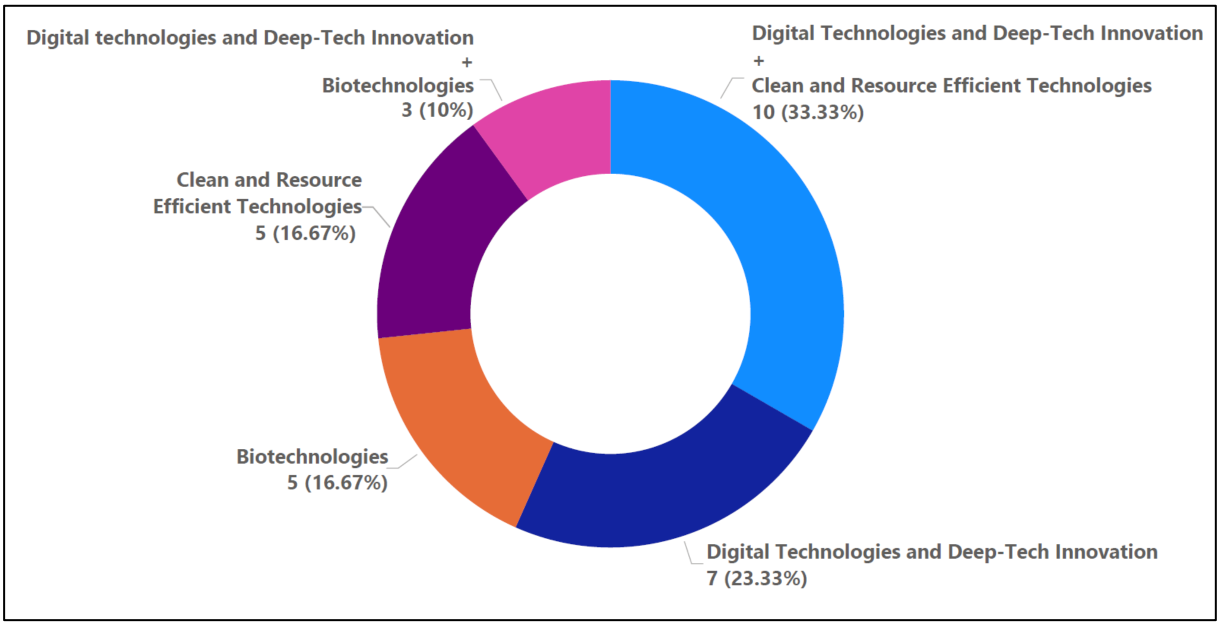
In addition to funding, STEP also plays a pivotal role in supporting projects that foster the development of essential skills necessary for advancing these critical technologies. By focusing on skill development, STEP ensures that the workforce is adequately prepared to meet the demands of rapidly evolving technological landscapes.

Within the target investment areas, STEP is also strategically aligned with several other significant EU initiatives, including the Advanced Materials for Industrial Leadership initiative, the Net-Zero Industry Act, the Critical Raw Materials Act, the European Chips Act, the Circular Economy Action Plan, and the EU Secure Connectivity programme. These initiatives are critical for creating a cohesive framework that supports innovation, sustainability, and security within the European Union.

While STEP's focus on just three domains provides clear direction for the EU's investment, it also creates some limitations for a quantitative assessment of signals in the context of this report. Similar to what was observed with the 10 critical technology areas, the STEP framework reveals some granularity imbalances. For instance, Biotechnologies is a very specific field while potentially covering a wide range of application areas, from health and pollution control to agriculture and food production. In contrast, the other two domains are broader, encompassing a multitude of technology groups and application areas (see Annex 3 for non-exhaustive examples).

Despite these limitations, the signal distribution under this framework offers some insights (see Figure 6). There is a pronounced emphasis on Digital Technologies and Deep-Tech Innovations, reflecting their central role both as enabling technologies and in driving Europe's technological future. Additionally, the growing significance of Biotechnologies is evident, underscoring their potential as already stated through this report.

Figure 6. Distribution of the 30 selected signals across the 3 target investment areas of the STEP, including the situations where more than 1 area is associated.



Source: Authors.

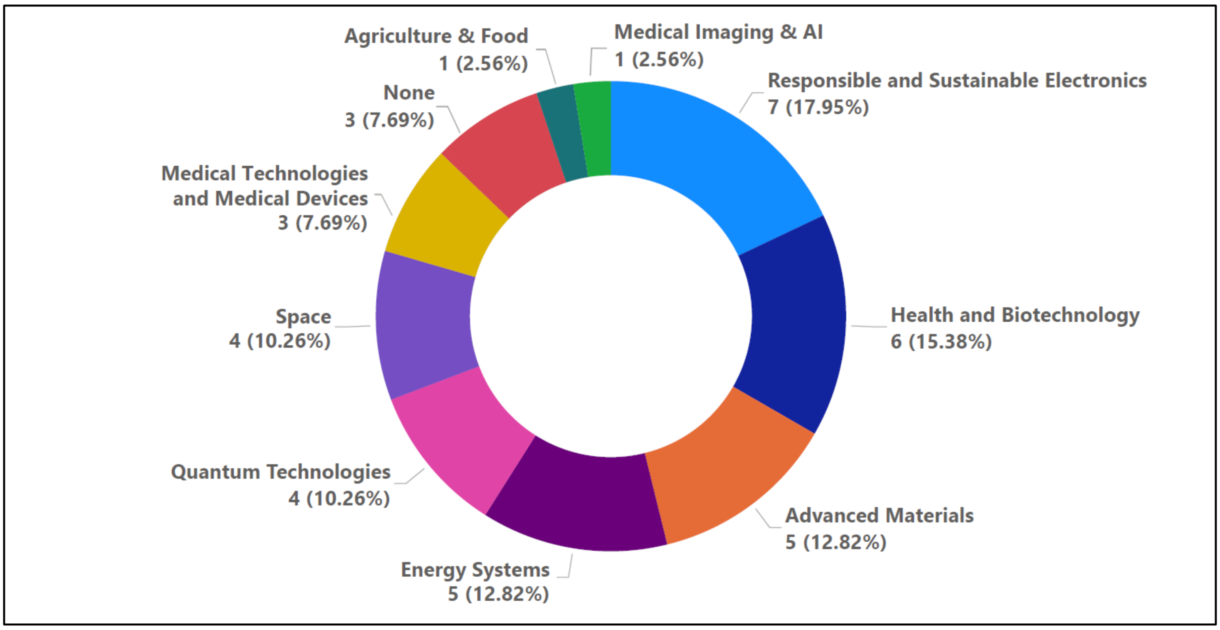
Clean and Resource-Efficient Technologies are frequently coupled with digital and deep-tech innovations, underlining the recurring importance of innovations that enhance digital's energy efficiency and showing examples of synergies that result from coupling digital and green transition efforts, instead of addressing them separately.

4.1.4 EIC Portfolios

Since the first literature review developed by the JRC to support EIC with anticipatory strategic intelligence (Farinha, Vesnic-Alujevic, & Pólvora, 2023), the analysis of signals associated with the scope of the EIC Portfolios has provided additional insights and recommendations on how this funding program could be further developed to capture more and better breakthrough innovations.

When analysing the current selection of signals through this lens (see Figure 7), the authors once again highlight the importance of the Responsible and Sustainable Electronics portfolio, particularly through the signals related to digital technologies (both hardware and software) that aim to be more sustainable and energy-efficient. Additionally, Biotechnologies (applied specifically in the Health domain), as well as the EIC portfolios on Energy Systems and Advanced Materials, are among the most recurrent connections between the signals and the current EIC portfolio structure.

Figure 7. Distribution of the 30 selected signals across the EIC Portfolios.



Source: Authors.

Another noteworthy point relates to the selected signals (and the sectors, subsectors, and technologies associated with them) that do not connect with any EIC portfolio (see Table 2). This includes signals mentioning solutions in Biotechnologies (not applied to Health, Energy, or Agriculture & Food), as well as in Drones and Robotics.

Table 2. Signals not associated with at least one EIC Portfolio.

Signal number and title		Critical Tech Areas	Sector (primary)	Subsector (secondary)	Application/ Technology (terciary)
09	**Programmable DNA Machines Offer General-Purpose Computing**	Biotechnologies	Quantum, Advanced Computing & Semiconductors	Hybrid & High Performance Computing / Industrial Biotech & Biomanufacturing	Computing & Logic Systems
26	**First Splitable Six-in-One Drone for Higher Efficiency, Multi-Use Missions**	Robotics and Autonomous Systems	Mobility	Aviation & Airports	Autonomous Vehicles & Drones
27	**LLM-powered Robots for Faster Learning, Complex Task Completion**	Robotics and Autonomous Systems / Artificial Intelligence	AI, Data & ICT	Artificial Intelligence	Natural Language Processing (NLP) & Foundation Models / Robotics & Cyber-physical Systems

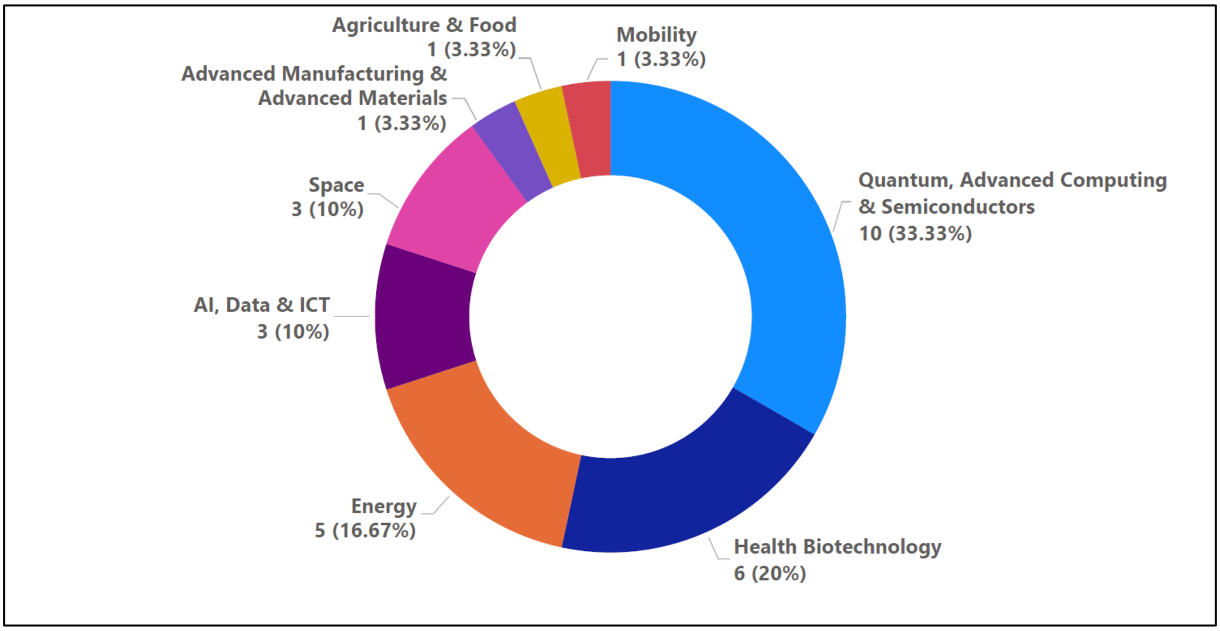
Source: Authors.

4.1.5 EIC Taxonomy

The version of the tailor-made EIC taxonomy used in this report, particularly its three levels and the vertical categories it includes (see Annex 1 for more details), allows for multiple analyses of the signal selection. Compared to other frameworks, this one, developed independently of the EIC Portfolios (see previous subsection), provides a more balanced distribution of sectors and additional granularity, through a detailed and diversified list of subsectors, technologies, and applications.

There is an apparent concentration of signals in certain key areas, such as Quantum, Advanced Computing & Semiconductors, Energy, and Health Biotechnology (see Figure 8).

Figure 8. Distribution of the 30 selected signals across the sectors (primary level) of the EIC Taxonomy.

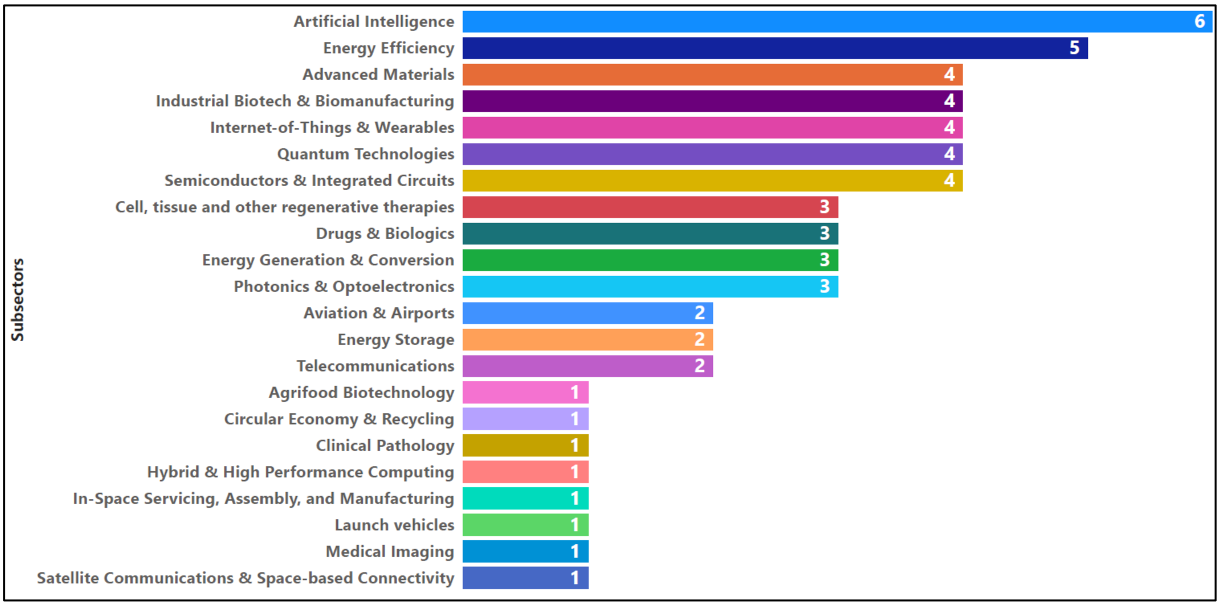


Source: Authors.

There are some noteworthy absences in the selected signals, particularly in the sectors of Climate & Environmental Tech, Built Environment and Medical Technologies. This does not necessarily indicate that those areas are less innovative, as the sample of signals is not large enough for such conclusions, and the criteria for their selection guided the final set into other domains.

However, when an analysis is done following the secondary and tertiary level, i.e. the list of subsectors, technologies, and applications, a significant diversity of topics among the signals emerges. In Figure 9, one can observe a notable recurrence of the fields of Artificial Intelligence, Energy Efficiency, Advanced Materials, Industrial Biotech & Manufacturing, Internet of Things & Wearables, Quantum Technologies, and Semiconductors & Integrated Circuits.

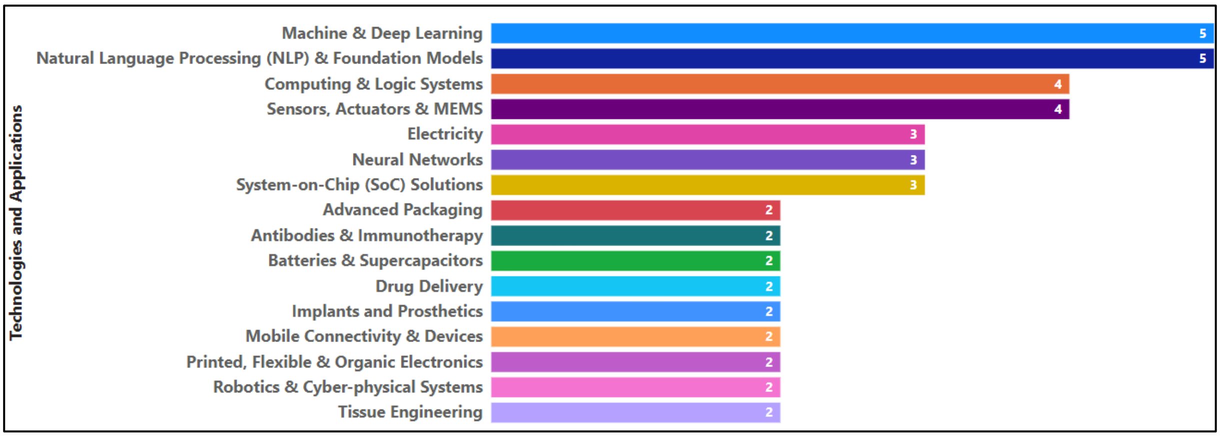
Figure 9. Distribution of the 30 selected signals across the subsectors (secondary level) of the EIC Taxonomy.



Source: Authors.

Lastly, Figure 10 shows the distribution among more specific technologies and applications (up to four per signal), where one can see that within the broader field of AI, the selected signals recurrently refer to Natural Language Processing as well as Machine & Deep Learning. Technologies related to Sensors and Computing & Logic Systems also feature prominently.

Figure 10. Distribution of the 30 selected signals across technologies and applications (tertiary level) of the EIC Taxonomy. (only technologies and applications connected with 2 or more signals were included).



Source: Authors.

4.2 EU agenda 2024-2029

The research leading to the publication of this report was conducted during a period of transition between the 2019-2024 and 2024-2029 political cycles. In this context, the authors consider it important to briefly analyse the priorities established by the European Council's strategic agenda (European Council, 2024) and the European Commission's political guidelines (European Commission, 2024), and to highlight the key messages regarding emerging technologies and breakthrough innovations they highlight. These priorities are taken into consideration in the recommendations put forward in the next section.

4.2.1 European Council - Strategic agenda 2024-2029

The European Council's Strategic Agenda 2024-2029 (European Council, 2024) emphasises the importance of advancing emerging technologies and breakthrough innovations in key areas such as digital transformation, green technologies, and sustainable development.

The document sets out the objective of building existing capacity in sensitive sectors and key technological domains, including space, defence, AI, quantum, semiconductors, advanced communications such as 6G, biotechnologies, mobility, chemicals and pharmaceuticals, and advanced materials.

The agenda prioritises investment in cutting-edge research and innovation to ensure the EU remains competitive globally, fosters economic growth, and addresses pressing challenges such as climate change and energy security.

4.2.2 European Commission - Political Guidelines 2024-2029

The European Commission's Political Guidelines for 2024-2029 (European Commission, 2024) emphasise the importance of fostering technological innovation and digital leadership to secure Europe's strategic autonomy. Key priorities include advancing artificial intelligence, quantum technologies, and cybersecurity, as well as promoting green and sustainable innovations. The guidelines highlight the need for robust regulatory frameworks that support innovation while protecting citizens' rights and addressing ethical concerns.

The EC underscores the importance of biotechnology as a key area for innovation, particularly in its potential to modernise entire industries such as health, farming, forestry, and energy. President Von der Leyen has set an ambition for the EU to capitalise fully on this biotech revolution, supported by AI and digital tools.

The document also emphasises the need for the EU to maintain a competitive edge in critical and emerging technologies with dual-use potential, as part of its strategy to enhance security, defence, and economic resilience. This includes ensuring that these technologies are developed responsibly and in a manner that supports both security and innovation objectives.

The EIC is highlighted as a crucial tool for supporting breakthrough innovations and scaling up high-impact technologies. The Commission aims to strengthen the EIC's role in driving Europe's technological leadership and ensuring that innovative solutions reach the market.

4.3 Cross-cutting analysis and recommendations

Across the 30 selected signals, there are thematic areas highly relevant to the EU context and which may warrant further R&D&I opportunities. These themes offer insights into potential approaches worth considering by the EIC Strategic Intelligence, either through the scope of its portfolios or via a cross-thematic challenges[14]' approach.

4.3.1 Computing and the green transition

Although sustainability and the green transition are expected to remain key areas for research and investment, an intriguing finding is the growing focus on addressing the challenges of scaling artificial intelligence computing, particularly given rising concerns about energy consumption.

Considering the current EIC Portfolio setting, this could lead to reinforced and continuous investment in responsible and sustainable electronics, while also highlighting the need for more systematic support for AI. Finally, the use of energy-efficient at-the-edge computing in domains covered by other specific EIC portfolios should not be overlooked (e.g., Space, Health, Agri&Food, etc.).

4.3.2 Multiple fronts of innovation in energy

There are multiple examples across the 30 selected signals of technologies and innovations dedicated to energy generation, efficiency, and storage. The signals indicate a diversification trend, highlighting both incremental developments in established fields (e.g., improved wave energy converters or photovoltaic panels) and more disruptive solutions in emerging domains (e.g., osmotic energy).

These multiple fronts of innovation can prompt the EIC to consider its role in the support to a variety of options at early maturity levels, rather than funnelling too early a limited number of solutions.

4.3.3 Advanced materials and biotechnologies

In the selected signals, we observe that advanced materials and biotechnologies have a wide array of applications that often intersect. This highlights that while AI and semiconductors dominate headlines, biotechnologies and advanced materials may play crucial long-term roles as enablers of new emerging technologies and other potential breakthroughs.

On one hand, this might require a reflection on the key role of the Advanced Materials portfolio at the EIC, and how, for instance, cross-portfolio challenges could be used to support advancements in many fields. On the other hand, regarding biotechnologies — and even considering that they are already within the scope of some EIC Portfolios (e.g., Health and Biotech; Agriculture & Food) — the EIC could benefit from a more dedicated focus that covered multiple areas of application at once, including but not limited to the domain of bio-computing and applications related to fighting pollution.

4.3.4 Robotics and autonomous systems

Robotics and autonomous systems are critical technologies that drive innovation across various domains, from manufacturing and healthcare to agriculture and mobility. Their ability to operate with

[14] The EIC challenges are the thematic funding calls.

high precision and efficiency enhances productivity and opens new possibilities in these sectors.

As dual-use technologies, they are also vital for the EU's strategic autonomy, providing advanced capabilities in defence and security while reducing dependency on external technologies. This dual-use potential makes them essential for ensuring both economic competitiveness and security resilience in Europe.

The evolving geopolitical landscape of the last two years is increasing the call for EC funding mechanisms to consider supporting dual-use technologies. This might extend the scope of programmes like the EIC, to cover innovations with both civil and defence-related applications, such as autonomous vehicles of various types (air, land, water, hybrid), as well as further developments in enabling technologies such as quantum sensing and navigation, AI decision-supporting systems and energy generation and storage.

In this context, an anticipatory focus of the EIC on the intersection of topics such as Mobility (including transport and logistics)[15] and Robotics could bring together most of these domains. While focusing primarily on civil applications, it could also allow for the development of additional application cases in the security and defence realms, leveraging the competitiveness of EU-based companies.

[15] In Anticipinnov's literature review report (Farinha, Vesnic-Alujevic, Alvarenga, & Polvora, 2023), as well as in Futurinnov's Volume 1 (Bailey, Farinha, Mochan, & Polvora, 2024), the topic of "logistics & mobility" was already highlighted as a potential EIC portfolio.

References

Advanced Navigation. (2024). *The Future Of Inertial Navigation Is Classical-Quantum Sensor Fusion*. Retrieved from Advanced Navigation: https://www.advancednavigation.com/tech-articles/the-future-of-inertial-navigation-is-classical-quantum-sensor-fusion

Afifi-Sabet, K. (2024). *China develops new light-based chiplet that could power artificial general intelligence — where AI is smarter than humans*. Retrieved from Live Science: https://www.livescience.com/technology/electronics/china-develops-light-based-chiplet-power-agi-artificial-general-intelligence

Afzali, A., Kheradmand, M., & Naghi, A. M. (2024). Bioreactor design-assisted bioprinting of stimuli-responsive materials for tissue engineering and drug delivery applications. *Bioprinting, 37*. Retrieved from https://doi.org/10.1016/j.bprint.2023.e00325

Ahlgren, L. (2024). *UK completes world's first flights for quantum navigation that could replace GPS*. Retrieved from The Next Web: https://thenextweb.com/news/uk-quantum-navigation-world-first-flight-replace-gps

Ahmadi, N., Schwertfeger, S., Werner, P., Wiese, L., Lester, J., Da Ros, E., . . . Cor. (2024). QUICK3 - - Design of a Satellite-Based Quantum Light Source for Quantum Communication and Extended Physical Theory Tests in Space. *Advanced Quantum Technologies*. Retrieved from https://doi.org/10.1002/qute.202300343

Allemann, M. N., Tessman, M., Reindel, J., Scofield, G. B., Evans, P., Pomeroy, R. S., . . . Simkovsky, R. (2024). Rapid biodegradation of microplastics generated from bio-based thermoplastic polyurethane. *Scientific Reports, 14*, 6036. Retrieved from https://doi.org/10.1038/s41598-024-56492-6

American Chemical Society. (2022). *A new wearable technology — for plants*. Retrieved from ACS News: https://www.acs.org/pressroom/presspacs/2022/acs-presspac-may-4-2022/a-new-wearable-technology-for-plants-video.html

Arena Wire. (2022). *Thermal energy: Can MGA fill a battery gap?* Retrieved from Arena Wire: https://arena.gov.au/blog/thermal-energy-can-mga-fill-a-battery-gap/

ARM. (2024). *What is a Chiplet?* Retrieved 07 31, 2024, from ARM web site: https://www.arm.com/glossary/chiplet

Aslam, N., Zhou, H., Urbach, E. K., Turner, M. J., Walsworth, R. L., Lukin, M. D., & Park, H. (2023). Quantum sensors for biomedical applications. *Nature Reviews Physics, 5*, 157–169. Retrieved from https://www.nature.com/articles/s42254-023-00558-3.pdf

Bailey, G., Farinha, J., Mochan, A., & Polvora, A. (2024). *Eyes on the Future - Signals from recent reports on emerging technologies and breakthrough innovations to support European Innovation Council strategic intelligence - Volume 1.* Luxembourg: Publications Office of the European Union. doi:10.2760/355

Barbosa, J. A., Freitas, V. M., Vidotto, L. H., Schleder, G. R., Oliveira, R. A., Rocha, J. F., . . . Lima, R. S. (2022). Biocompatible Wearable Electrodes on Leaves toward the On-Site Monitoring of Water Loss from Plants. *ACS Applied Materials & Interfaces, 14*(20), 22989-23001. Retrieved from https://pubs.acs.org/doi/pdf/10.1021/acsami.2c02943

Binai-Motlagh, A., Day, M. L., Videnov, N., Greenberg, N., Senko, C., & Islam, R. (2023). A guided light system for agile individual addressing of Ba+ qubits with 10−4 level intensity crosstalk. *Quantum Science and Technology, 8*(4). Retrieved from https://iopscience.iop.org/article/10.1088/2058-9565/ace6cb/meta

Blain, L. (2022). *Wave-riding generators promise the cheapest clean energy ever*. Retrieved from New Atals: https://newatlas.com/energy/swel-cheapest-wave-energy/

Brookes, T. (2021). *What Is a Chiplet?* Retrieved from How-To Geek: https://www.howtogeek.com/740584/what-is-a-chiplet/

Cadence. (2024). Retrieved 07 31, 2024, from All About Chiplet Technology: https://resources.pcb.cadence.com/blog/2023-all-about-chiplet-technology

California Institute of Technology. (2023). *Better Energy Harvesting with 'Law-Breaking' Device*. Retrieved from Caltech website: https://www.caltech.edu/about/news/better-energy-harvesting-with-law-breaking-device

Cerf, E. (2023). *SpikeGPT: researcher releases code for largest-ever spiking neural network for language generation*. Retrieved from UC Santa Cruz Newscenter: https://news.ucsc.edu/2023/03/eshraghian-spikegpt.html

Chen, H. T., Taylor, A. J., & Yu, N. (2016). A review of metasurfaces: physics and applications. *Reports on Progress in Physics, 79*(7). Retrieved from https://iopscience.iop.org/article/10.1088/0034-4885/79/7/076401

Chen, S. (2024). *Chinese scientists create swarming drones that can rapidly multiply mid-air to create a tactical shock*. Retrieved from South China Morning Post: https://www.scmp.com/news/china/science/article/3255809/chinese-scientists-create-swarming-drones-can-rapidly-multiply-mid-air-create-tactical-shock

Cheng, X., Li, C., Fang, B., Hong, Z., Jin, Y., & Jing, X. (2024). Metasurface-based wireless communication technology and its applications. *Journal of Applied Physics*, 120702. Retrieved from https://pubs.aip.org/aip/jap/article/135/12/120702/3279036/Metasurface-based-wireless-communication

Cherrat, E. A., Kerenidis, I., Mathur, N., Landman, J., Strahm, M., & Li, Y. Y. (2024). Quantum Vision Transformers. *Quantum, 8*, 1265. Retrieved from https://doi.org/10.22331/q-2024-02-22-1265

Choi, C. (2023). *Programmable DNA Machines Offer General-Purpose Computing*. Retrieved from IEEE Spectrum: https://spectrum.ieee.org/dna-computing

Choudhury, R. (2024). *Immune Response to Fight Tumours Boosted by Gut Bacteria: A Possible Development for Reasonably Priced Cancer Treatment*. Retrieved from Drug Today: https://www.drugtodayonline.com/medical-news/news-topic/18735-immune-response-to-fight-tumours-boosted-by-gut-bacteria-a-possible-development-for-reasonably-priced-cancer-treatment

Christensen, C. M. (1997). *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail.* Boston: Harvard Business School Press.

City University of Hong Kong. (2023). *CityU develops the world's first universal metasurface antenna for high-security 6G communications*. Retrieved from City University of Hong Kong News and Media: https://www.cityu.edu.hk/media/press-release/2023/12/03/cityu-develops-worlds-first-universal-metasurface-antenna-high-security-6g-communications

Cutress, I. (2021). *Intel Rolls Out New Loihi 2 Neuromorphic Chip: Built on Early Intel 4 Process*. Retrieved from Anandtech: https://www.anandtech.com/show/16960/intel-loihi-2-intel-4nm-4

Dannemand Andersen, P., Bevolo, M., Ilevbare, I., Malliaraki, E., Popper, R., & Spaniol, M. J. (2023). Technology Foresight for Public Funding of Innovation: Methods and Best Practices. (L. Vesnic-Alujevic, J. Farinha, & A. Polvora, Eds.) doi:10.2760/759692

Danninger, D., Pruckner, R., Holzinger, L., Koeppe, R., & Kaltenbrunner, M. (2022). MycelioTronics: Fungal mycelium skin for sustainable electronics. *SCIENCE ADVANCES, 8*(45). Retrieved from https://doi.org/10.1126/sciadv.add7118

Degen, C. L., Reinhard, F., & Cappellaro, P. (2017). Quantum sensing. *Review of Modern Physics, 89*(3), 035002. Retrieved from https://journals.aps.org/rmp/abstract/10.1103/RevModPhys.89.035002

DiCorato, A. (2023). *Bacterial injection system delivers proteins in mice and human cells*. Retrieved from MIT News: https://news.mit.edu/2023/bacterial-injection-system-delivers-proteins-mice-human-cells-0329

Dong, C., Carnicer-Lombarte, A., Bonafè, F., Huang, B., Middya, S., Jin, A., . . . Malliaras, G. G. (2024). Electrochemically actuated microelectrodes for minimally invasive peripheral nerve interfaces. *Nature Materials, 23*, 969–976. Retrieved from https://www.nature.com/articles/s41563-024-01886-0

Dutta, T., Chaturvedi, P., Llamas-Garro, I., Velázquez-González, J. S., Dubey, R., & Mishra, S. K. (2024). Smart materials for flexible electronics and devices: hydrogel. *RSC Advances, 14*(19), 12984-13004. Retrieved from https://www.sciencedirect.com/org/science/article/pii/S2046206924011264

ENGIE. (2024). *Emerging sustainable technologies 2024 by ENGIE Research & Innovation*. Retrieved from ENGIE Web site: https://innovation.engie.com/en/emerging-sustainable-technologies-2024

European Commission. (2023, October 3). COMMISSION RECOMMENDATION (EU) 2023/2113 of 3 October 2023 on critical technology areas for the EU's economic security for futher risk assessment with Member States. Strasbourg, France. Retrieved from https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:L_202302113

European Commission. (2024). *Political Guidelines 2024-2029*. Retrieved from European Commission's website: https://commission.europa.eu/document/e6cd4328-673c-4e7a-8683-f63ffb2cf648_en

European Council. (2024). *Strategic Agenda 2024-2029.* Retrieved from https://www.consilium.europa.eu/media/4aldqfl2/2024_557_new-strategic-agenda.pdf

European Parliament and European Council. (2024, February 29). REGULATION (EU) 2024/795 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 29 February 2024 establishing the Strategic Technologies for Europe Platform (STEP), and amending. Strasbourg, France. Retrieved from Official website of the European Union: https://eur-lex.europa.eu/eli/reg/2024/795/oj

European Space Agency. (2023). *Space Environment Report 2023.* Retrieved from https://www.esa.int/Space_Safety/ESA_s_Space_Environment_Report_2023

Fan, S. (2024). *A New Photonic Computer Chip Uses Light to Slash AI Energy Costs*. Retrieved from Singularity Hub: https://singularityhub.com/2024/04/15/a-new-photonic-computer-chip-uses-light-to-slash-ai-energy-costs/

Fano, G., & Blinder, S. (2019). Chapter 11 - Quantum chemistry on a quantum computer. *Mathematical Physics in Theoretical Chemistry*, 377-400. Retrieved from https://doi.org/10.1016/B978-0-12-813651-5.00011-5

Farinha, J., Vesnic-Alujevic, L., & Pólvora, A. (2023). *Scanning Deep Tech Horizons - Participatory collection and assessment of signals and trends.* Luxembourg: Publications Office of the European Union. doi:doi:10.2760/48442

Farinha, J., Vesnic-Alujevic, L., Alvarenga, A., & Polvora, A. (2023). *Everybody is looking into the Future! A literature review of reports on emerging technologies and disruptive innovation.* Luxembourg: Publications Office of the European Union. doi:10.2760/144730

Foley, E. V. (2024). *Thermal energy storage tech to bolster industry decarbonisation*. Retrieved from PV Magazine: https://www.pv-magazine.com/2024/06/21/thermal-energy-storage-tech-to-bolster-industry-decarbonisation/

Future Today Institute. (2024). *2024 Tech Trends Report.* Future Today Institute. Retrieved from https://futuretodayinstitute.com/wp-content/uploads/2024/03/TR2024_Executive_Summary_FINAL_LINKED.pdf

Garanovic, A. (2021). *SWEL starts open sea trials offshore Cyprus*. Retrieved from OffShore Energy Today: https://www.offshore-energy.biz/swel-starts-open-sea-trials-offshore-cyprus/

Garrett, M., Liu, Y., Merklein, M., Bui, C. T., Lai, C. K., Choi, D.-Y., . . . Eggleton, B. J. (2023). Integrated microwave photonic notch filter using a heterogeneously integrated Brillouin and active-silicon photonic circuit. *Nature Communications, 14*, 7544. Retrieved from https://doi.org/10.1038/s41467-023-43404-x

Genetic Engineering & Biotechnology News. (2023). *Gut Microbiome Alters Body's Response to Cancer Immunotherapy*. Retrieved from Genetic Engineering & Biotechnology News: https://www.genengnews.com/news/gut-microbiome-alters-bodys-response-to-cancer-immunotherapy/

Geospatial World. (2023). *German Firms Launch World's First Microgravity Service for Biotech R&D*. Retrieved from Geospatial World: https://www.geospatialworld.net/news/german-companies-microgravity-biotech/

Geraud, A. (2024). *Tech vs. Tech: Microgravity reactors vs. 3D bioprinting ... in space!* Retrieved from L'Atelier BNP Paribas: https://atelier.net/insights/microgravity-reactors-3d-bioprinting

Guo, P., Zhu, H., Ye, H., Li, T., & Chen, T. (2024). Revisiting 3D visual grounding with Context-aware Feature Aggregation. *Neurocomputing, 601*, 128195. Retrieved from https://www.sciencedirect.com/science/article/pii/S0925231224009664

Han, K., Long, D. A., Bresler, S. M., Song, J., Bao, Y., Reschovsky, B. J., . . . & LeBrun, T. W. (2024). Low-power, agile electro-optic frequency comb spectrometer for integrated sensors. *Optica, 11*, 392-398.

He, L., Shi, J., Tian, B., Zhu, H., & Wu, W. (2024). Self-healing materials for flexible and stretchable electronics. *Materials Today Physics, 44*, 101448. Retrieved from https://www.sciencedirect.com/science/article/pii/S254252932400124X

Hertz, J. (2024). *6G Technology and Policy Barrels Toward Its 2030 Launch*. Retrieved from All About Circuits: https://www.allaboutcircuits.com/news/6g-technology-policy-barrels-toward-its-203

Hill, J. H. (2023). *Australian thermal storage start-up secures $8.25m towards "1,000 blocks a day" goal*. Retrieved from Renew Enconomy: https://reneweconomy.com.au/australian-thermal-storage-start-up-secures-8-25m-towards-1000-blocks-a-day-goal/

IBM. (2024). *What is a qubit?* Retrieved 07 31, 2024, from IBM web site: https://www.ibm.com/topics/qubit

Irving, M. (2024). *Extra-strong spore-loaded plastic eats itself when it hits landfill*. Retrieved from New Atlas: https://newatlas.com/environment/plastic-embedded-bacteria-spores-degradable-tougher/

Jiang, B., Chen, X., Liu, W., Yu, J., Yu, G., & Chen, T. (2023). MotionGPT: Human Motion as Foreign Language. *NeurIPS*. Retrieved from https://motion-gpt.github.io/

Kar, S. (2023). Metasurfaces—fundamentals, physics, modelling, and applications. *Metamaterials and Metasurfaces - basics and trends*, 6.1-6.51. Retrieved from https://iopscience.iop.org/book/mono/978-0-7503-5532-2/chapter/bk978-0-7503-5532-2ch6

Kim, H., Lee, J., Heo, U., Jayashankar, D. K., Agno, K.-C., Kim, Y., . . . Jeong, J.-W. (2024). Skin preparation–free, stretchable microneedle adhesive patches for reliable electrophysiological sensing and exoskeleton robot control. *SCIENCE ADVANCES, 10*(3). Retrieved from https://www.science.org/doi/full/10.1126/sciadv.adk5260

Kreitz, J., Friedrich, M. J., Guru, A., Lash, B., Saito, M., Macrae, R. K., & Zhang, F. (2023). Programmable protein delivery with a bacterial contractile injection system. *Nature, 616*, 357–364. Retrieved from https://www.nature.com/articles/s41586-023-05870-7

Kwiat, P., & James, D. (2005). Quantum Optics - Entanglement and Quantum Information. *Encyclopedia of Modern Optics*, 256-264. Retrieved from https://doi.org/10.1016/B0-12-369395-0/00964-7

Labios, L. (2024). *Biodegradable 'Living Plastic' Houses Bacterial Spores That Help It Break Down*. Retrieved from UC San Diego Today: https://today.ucsd.edu/story/biodegradable-living-plastic-houses-bacterial-spores-that-help-it-break-down

Lin, Z., Li, T., Yang, S., Ji, B., & Wang, Z. (2024). Revolutionizing flexible electronics with liquid metal innovations. *Device, 2*(5), 100331. Retrieved from https://www.sciencedirect.com/science/article/pii/S2666998624001236

Lv, H., Xie, N., Li, M., Dong, M., Sun, C., Zhang, Q., . . . Fan, C. (2023). DNA-based programmable gate arrays for general-purpose DNA computing. *Nature, 622*, 292–300. Retrieved from https://www.nature.com/articles/s41586-023-06484-9

McFadden, C. (2024). *China 'develops' maple-seed-inspired splittable drone to swarm enemies*. Retrieved from Interesting Engineering: https://interestingengineering.com/innovation/china-maple-seed-inspired-splittable-drone

Mereu, M. (2023). *This technology breaks the enigma of wave energy*. Retrieved from Innovation Origins: https://innovationorigins.com/en/this-technology-breaks-the-enigma-of-wave-energy/

MGA Thermal. (2024). *MGA Thermal Demonstration Plant*. Retrieved from MGA Thermal Web site: https://www.mgathermal.com/pilot

Morgan, T. (2024). *Sandia pushes the neuromorphic ai envelope with Hala Point "supercomputer"*. Retrieved from The Next Platform: https://www.nextplatform.com/2024/04/24/sandia-pushes-the-neuromorphic-ai-envelope-with-hala-point-supercomputer/

Mortati, M. M. (2023). Data in design: How big data and thick data inform design thinking projects. *Technovation, 122*. doi:https://doi.org/10.1016/j.technovation.2022.102688

NASA. (2023). *NASA Makes Award for In-Space Liver Tissue Manufacturing Demonstration*. Retrieved from NASA: https://www.nasa.gov/science-research/nasa-makes-award-for-in-space-liver-tissue-manufacturing-demonstration/

Nichols, N. (2024). *MGA Thermal raises $5.7m despite minor setback for pilot energy storage program*. Retrieved from Business News Australia: https://www.businessnewsaustralia.com/articles/mga-thermal-raises--5-7m-despite-a-minor-setback-for-pilot-energy-storage-program.html

NIST. (2024). *Spotlight: Chip-Scale Frequency Combs Can Be Integrated With Other Sensors*. Retrieved from National Institute of Standards and Technology - USA: https://www.nist.gov/news-events/news/2024/04/spotlight-chip-scale-frequency-combs-can-be-integrated-other-sensors

Ottati, F. (2023). *TrueNorth: A Deep Dive Into IBM's Neuromorphic Chip Design*. Retrieved 07 31, 2024, from Open Neuromorphic: https://open-neuromorphic.org/blog/truenorth-deep-dive-ibm-neuromorphic-chip-design/

Pesheva, E. (2023). *To Boost Cancer Immunotherapy's Fighting Power, Look to the Gut*. Retrieved from Harvard Medical School news & research : https://hms.harvard.edu/news/boost-cancer-immunotherapys-fighting-power-look-gut

Pietrobelli, C., & Puppato, F. (2016). Technology foresight and industrial strategy. *Technological Forecasting and Social Change, 110*, 117-125. doi:10.1016/j.techfore.2015.10.021

Pirandola, S., Bardhan, B., Gehring, T., Weedbrook, C., & Lloyd, S. (2018). Advances in photonic quantum sensing. *Nature Photonics, 12*, pages724–733. Retrieved from https://www.nature.com/articles/s41566-018-0301-6

Planchenault, V. (2022). *À la frontière entre mers et rivières jaillit l'énergie bleue*. Retrieved from CNRS Le Journal: https://lejournal.cnrs.fr/nos-blogs/un-ocean-de-decouvertes/a-la-frontiere-entre-mers-et-rivieres-jaillit-lenergie-bleue

Rao, R. (2024). *Quantum Computers Can Now Run Powerful AI That Works like the Brain*. Retrieved from Scientif American: https://www.scientificamerican.com/article/quantum-computers-can-run-powerful-ai-that-works-like-the-brain/

Rossel, P. (2012). Early detection, warnings, weak signals and seeds of change: A turbulent domain of futures studies. *Futures, 44*(3), 229-239. doi:10.1016/j.futures.2011.10.005

Rosser, J., & Thomas, D. J. (2018). Bioreactor processes for maturation of 3D bioprinted tissue. *3D Bioprinting for Reconstructive Surgery*, 191-215. Retrieved from https://www.sciencedirect.com/science/article/pii/B9780081011034000107

Saballa, J. (2024). *China Says Developed Drone That Can Split Six Ways*. Retrieved from The Defense Post: https://www.thedefensepost.com/2024/03/26/china-drone-split-six/?expand_article=1

Saran, C. (2024). *UK hails first test of quantum aircraft navigation*. Retrieved from Computer Weekly: https://www.computerweekly.com/news/366583590/UK-hails-first-test-of-quantum-aircraft-navigation

Schweber, B. (2023). *Researchers Poke a Hole in Kirchhoff's "Other" Law—or Maybe Not*. Retrieved from Electronic Design: https://www.electronicdesign.com/technologies/analog/article/21275590/electronic-design-researchers-poke-a-hole-in-kirchhoffs-other-lawor-maybe-not

Semiconductor Engineering. (2024). *Chiplets*. Retrieved from Semiconductor Engineering website.

Shayegan, K. J., Biswas, S., Zhao, B., Fan, S., & Atwater, H. A. (2023). Direct observation of the violation of Kirchhoff's law of thermal radiation. *Nature Photonics, 17*, 891–896. Retrieved from https://doi.org/10.1038/s41566-023-01261-6

Strain, D. (2024). *Engineers unveil new patch to help people control robotic exoskeletons*. Retrieved from University of Colorado Boulder news: https://www.colorado.edu/today/2024/01/31/engineers-unveil-new-patch-help-people-control-robotic-exoskeletons

Sun, S., He, Q., Hao, J., Xiao, S., & Zhou, L. (2019). Electromagnetic metasurfaces: physics and applications. *Advances in Optics and Photonics, 11*(2), 380-479. Retrieved from https://opg.optica.org/aop/abstract.cfm?uri=aop-11-2-380

Taherkhani, A., Belatreche, A., Li, Y., Cosma, G., Maguire, L. P., & McGinnity, T. M. (2020). A review of learning in biologically plausible spiking neural networks. *Neural Networks, 122*, 253-272. Retrieved from https://doi.org/10.1016/j.neunet.2019.09.036

Technical University of Munich. (2024). *Satellites for quantum communications*. Retrieved from Technical University of Munich news and events: https://www.tum.de/en/news-and-events/all-news/press-releases/details/satellites-for-quantum-communications

The University of NewCastle Australia. (2020). *The missing block to build an all-renewable grid*. Retrieved from The University of NewCastle Australia news: https://www.newcastle.edu.au/newsroom/stories/the-missing-block-to-build-an-all-renewable-grid

The University of Sidney. (2023). *https://www.sydney.edu.au/news-opinion/news/2023/12/01/photonic-semiconductor-fits-together-like-lego-opens-door-to-local-industry.html*. Retrieved from The University of Sidney News: https://www.sydney.edu.au/news-opinion/news/2023/12/01/photonic-semiconductor-fits-together-like-lego-opens-door-to-local-industry.html

Thomsen, S. (2024). *Renewable energy startup MGA Thermal tops up with $5.7 million raise*. Retrieved from Startup Daily: https://www.startupdaily.net/topic/funding/renewable-energy-startup-mga-thermal-tops-up-with-5-7-million-raise/

Timmer, J. (2023). *IBM has made a new, highly efficient AI processor*. Retrieved 07 31, 2024, from Ars Technica: https://arstechnica.com/science/2023/10/ibm-has-made-a-new-highly-efficient-ai-processor/

Tomic, D. (2024). *Intel Builds the World's Largest Neuromorphic System*. Retrieved from ICT Business: https://www.ictbusiness.biz/technology/intel-builds-the-worlds-largest-neuromorphic-system

Tremain, A.C. et al. (2023). Synthetically glycosylated antigens for the antigen-specific suppression of established immune responses. *Nature Biomedical Engineering, 7*, 1141-1155. Retrieved from https://doi.org/10.1038/s41551-023-01086-2

Triou, N. (2023). *Énergie osmotique, ce rêve bleu*. Retrieved from Radio France podcast La Science: https://www.radiofrance.fr/franceculture/podcasts/la-science-cqfd/energie-osmotique-ce-reve-bleu-3810463

Tripathi, A. (2024). *World's largest neuromorphic computer by Intel works like human brain*. Retrieved from Interesting Engineering: https://interestingengineering.com/innovation/intel-neuromorphic-computer-hala-point

UK Space Agency. (2023). *New UK funding for space technology projects*. Retrieved from GOV.UK news: https://www.gov.uk/government/news/new-uk-funding-for-space-technology-projects

UNICEF. (2024). *Renewable energy: emerging technologies and innovations.* Retrieved from https://www.unicef.org/innovation/media/18721/file/Insight%20Report:%20Renewable%20Energy.pdf

University of Cambridge. (2024). *Robotic nerve 'cuffs' could help treat a range of neurological conditions*. Retrieved from University of Cambridge research news: https://www.cam.ac.uk/research/news/robotic-nerve-cuffs-could-help-treat-a-range-of-neurological-conditions

University of Glasgow. (2024). *Self-eating rocket could help uk take a big bite of space industry*. Retrieved from University of Glasgow News: https://www.gla.ac.uk/news/archiveofnews/2024/january/headline_1033908_en.html

University of Michigan. (2023). *When LLMs and robots meet*. Retrieved from Computer Science and Engineering - University of Michigan news: https://cse.engin.umich.edu/stories/when-llms-and-robots-meet

University of Oxford. (2023). *Autoimmune disorders found to affect around one in ten people*. Retrieved from University of Oxford News: https://www.ox.ac.uk/news/2023-05-06-autoimmune-disorders-found-affect-around-one-ten-people

University of Strathclyde Glasgow. (2023). *Strathclyde one of 23 space technology projects funded by UK Space Agency*. Retrieved from University of Strathclyde Glasgow News: https://www.strath.ac.uk/whystrathclyde/news/2023/strathclydeoneof23spacetechnologyprojectsfundedbyukspaceagency/

University of Waterloo. (2023). *Waterloo researchers make a significant step towards reliably processing quantum information*. Retrieved from Waterloo news: https://uwaterloo.ca/news/media/waterloo-researchers-make-significant-step-towards-reliably van Veen, B. L., & Ortt, J. R. (2021). Unifying weak signals definitions to improve construct understanding. *Futures, 134*. doi:10.1016/j.futures.2021.102837

Vels, E. (2024). *Ocean Grazer to test energy storage system in sand quarry*. Retrieved from Innovation Origins: https://innovationorigins.com/en/ocean-grazer-to-test-energy-storage-system-in-sand-quarry/

Vincent, J. (2024). *How much electricity does AI consume?* Retrieved from The Verge: https://www.theverge.com/24066646/ai-electricity-energy-watts-generative-consumption

Vreeken, J. (2003). Spiking neural networks, an introduction. Retrieved from https://typeset.io/pdf/spiking-neural-networks-an-introduction-2pmoklvwaw.pdf

Vries, A. (2023). The growing energy footprint of artificial intelligence. *Joule, 7*(10), 21911-2167. Retrieved from https://www.cell.com/action/showPdf?pii=S2542-4351%2823%2900365-3

Ward-Foxton, S. (2023). *What Is Holding Back Neuromorphic Computing?* Retrieved from EE Times: https://www.eetimes.com/what-is-holding-back-neuromorphic-computing/

Wardill, H. R., & Gibson, R. J. (2017). *How our gut bacteria affect cancer risk and response to treatment*. Retrieved from The Conversation: https://theconversation.com/how-our-gut-bacteria-affect-cancer-risk-and-response-to-treatment-75699

Warnke, P., & Heimeriks, G. (2008). Technology Foresight as Innovation Policy Instrument: Learning from Science and Technology Studies. (C. Cagnin, M. Keenan, R. Johnston, & F. Scapolo, Eds.) *Future-Oriented Technology Analysis*. doi:10.1007/978-3-540-68811-2_6

Weaver, T. (2024). *Jam-resistant quantum navigation tech takes flight for the first time*. Retrieved from Engineering and Technology: https://eandt.theiet.org/2024/05/13/jam-resistant-quantum-navigation-tech-developed-uk-has-taken-flight-first-time

Wegorzewska, M. (2024). *Gut bacteria boost immune response to fight tumors*. Retrieved from Washington University School of Medicine in St. Louis news: https://medicine.wustl.edu/news/gut-bacteria-boost-immune-response-to-fight-tumors/

Wilkins, A. (2022). *Computer chip made using mushroom skin could be easily recycled*. Retrieved from New Scientist: https://www.newscientist.com/article/2346702-computer-chip-made-using-mushroom-skin-could-be-easily-recycled/

Williams, A. (2023). *Enabling Technologies Programme funds UK space sector projects*. Retrieved from Electronics Weekly: https://www.electronicsweekly.com/news/business/enabling-technologies-programme-funds-uk-space-sector-projects-2023-12/

Williams, S. (2023). *"Inverse vaccine" shows potential to treat multiple sclerosis and other autoimmune diseases*. Retrieved from The University of Chicago - Pritzker School of Molecular Engineering: https://pme.uchicago.edu/news/inverse-vaccine-shows-potential-treat-multiple-scleros

Willyard. (2023). *How inverse vaccines might tackle diseases like multiple sclerosis*. Retrieved from MIT Technology Review: https://www.technologyreview.com/2023/09/22/1080014/inverse-vaccines-tolerance-immunology/

World Economic Forum. (2023). *Top 10 Emerging Technologies of 2023.* Retrieved from https://www3.weforum.org/docs/WEF_Top_10_Emerging_Technologies_of_2023.pdf

Wu, G.-B., Dai, J. Y., Shum, K. M., Chan, K. F., Cheng, Q., Cui, T. J., & Chan, C. H. (2023). A universal metasurface antenna to manipulate all fundamental characteristics of electromagnetic waves. *Nature Communications, 14*, 5155. Retrieved from https://doi.org/10.1038/s41467-023-40717-9

Xu, Z., Zhou, T., Ma, M., Deng, C., Dai, Q., & Fang, L. (2024). Large-scale photonic chiplet Taichi empowers 160-TOPS/W artificial general intelligence. *Science, 384*(6692), 202-209. Retrieved from https://www.science.org/doi/10.1126/science.adl1203

Yamazaki, K. V.-H.-K. (2022). Spiking Neural Networks and Their Applications: A Review. *Brain Sciences, 12*, 863. Retrieved from https://doi.org/10.3390/brainsci12070863

Yu, C.-J., von Kugelgen, S., Laorenza, D. W., & Freedman, D. E. (2021). A Molecular Approach to Quantum Sensing. *ACS Central Science, 7*(5), 712-723. Retrieved from https://pubs.acs.org/doi/full/10.1021/acscentsci.0c00737

Zeng, F., Gan, W., Wang, Y., Liu, N., & Yu, P. S. (2023). Large Language Models for Robotics: A Survey. *arXiv*. Retrieved from https://arxiv.org/pdf/2311.07226

Zhang, C., Chen, J., Li, J., Peng, Y., & Mao, Z. (2023). Large language models for human–robot interaction: A review. *Biomimetic Intelligence and Robotics, 3*(4), 100131. Retrieved from https://doi.org/10.1016/j.birob.2023.100131

Zhong, Z.-J. (2011). 2.14 - Bioreactor Engineering. *Comprehensive Biotechnology (Second Edition)*, 165-177. Retrieved from https://doi.org/10.1016/B978-0-08-088504-9.00097-0

Zhu, R.-J., Zhao, Q., Li, G., & Eshraghian, J. K. (2024). *SpikeGPT: Generative Pre-trained Language Model with Spiking Neural Networks*. Retrieved from arXiv: https://arxiv.org/abs/2302.13939

List of abbreviations and definitions

The following list contains the most recurring abbreviations used throughout this report. For all others, please consult the body text or footnotes.

Abbreviations	Definitions
°C	Degrees Celsius
3D	Three Dimensional
4D	Four Dimensional
6G	Sixth-generation wireless
AI	Artificial Intelligence
AVs	Autonomous Vehicles
BMIs	Brain-Machine Interfaces
CO^2	Carbon dioxide
CPU	Central Processing Unit
CRM	Critical Raw Materials
DNA	Deoxyribonucleic Acid
EC	European Commission
EIC	European Innovation Council
EISMEA	European Innovation Council and SMEs Executive Agency
ELM	Engineered Living Materials
EM	Electromagnetic
ESG	Environmental, Social and Governance
EU	European Union
FUTURINNOV	FUTURe-oriented detection and assessment of emerging technologies and breakthrough INNOVation
GNSS	Global Navigation Satellite Systems (inc. Galileo, GPS, GLONASS, Baidu, etc)
GPS	Global Positioning System
GPT	Generative Pre-training Transformer
GPU	Graphics Processing Unit
I/O	Input / Output
IC	Integrated Circuit
IoT	Internet of Things
ISO	International Organization for Standardization
JRC	Joint Research Centre
KWs	Kilowatts
Li-ion	Lithium ion
LLM	Large Language Model
MEMS	Micro-Electromechanical Systems
MGA	Miscibility Gap Alloys
ML	Machine Learning

Abbreviations	Definitions
MWs	Megawatts
NLP	Natural Language Processing
nm	Nanometre
PNT	Positioning, Navigation, and Timing
R&D	Research and Development
R&D&I	Research, Development and Innovation
RF	Radiofrequency
RFID	Radio-Frequency Identification
RNA	Ribonucleic Acid
SNN	Spiking Neural Networks
SoC	System-on-Chip
STEP	Strategic Technologies for Europe Platform
TES	Thermal Energy Storage
TOPS/W	Tera Operations Per Second per Watt
TRL	Technology Readiness Level
UK	United Kingdom
US/USA	United States of America
VUCA	Volatility, Uncertainty, Complexity and Ambiguity
WLANs	Wireless Local-Area Networks

List of figures

List of tables

List of boxes

Annexes

Annex 1. EIC taxonomy

The EIC taxonomy used in this report represents an evolution of the version presented in Volume 1 and is a new draft of the final list being developed by the EIC in collaboration with the European Investment Bank (EIB).

It is aimed at internal feedback for policy and external reporting on funding allocations and impact assessments. Its simultaneous multilevel and non-hierarchical structure makes it a good framework for future-oriented technology analysis, allowing the association of signals and trends with multiple fields and domains and highlighting novel aspects and spill-over effects.

The taxonomy it is not yet publicly available. The authors disclose only the full list of primary levels, the rules used to apply it and the classifications used in the final selected signals (Sections 3 and Subsection 4.1.5).

1) List of sectors (primary level)

- Agriculture & Food
- Energy
- Climate & Environmental Tech
- Built Environment
- Mobility
- Health Biotechnology
- Medical Technologies
- Space
- Advanced Manufacturing & Advanced Materials
- AI, Data & ICT
- Quantum, Advanced Computing & Semiconductors

2) Rules for use of the EIC taxonomy, adopted through this report

- **Sector** (primary level):
  - 1 mandatory selection.
- **Sub-sector** (secondary level):
  - Main: 1 mandatory selection from the sector chosen before.
  - Additional: 1 optional selection from any sectors.

Note 1 – some exceptions can be made to add a second additional sub-sector, namely when a signal contains very strong connections with multiple sectors (e.g. Semiconductors developed for energy-efficient AI).

- **Technologies/applications** (tertiary level):
    - Main: 1 mandatory selection from the sector chosen before.
    - Additional: 3 optional selections from any sector.

  Note 2 – technologies/applications are not necessarily connected with a specific sub-sector.

  Note 3 – for the "Social Innovation, Culture & Creative Industries" sector, the technologies/ applications should be chosen from other sectors.

- **Verticals** (only applicable if one or more of the following sectors are chosen: "Health Biotechnology"; "Medical Diagnostics"; and "Energy" and/or the subsector "Advanced Materials":
    - 1 mandatory selection from the respective sector or subsector

  Note 4 - Verticals are not necessarily connected with a specific sub-sector (except for "Advanced Materials") or a specific technology/application.

  Note 5 – The verticals for the 2 sectors related with health are the same.

Annex 2. List of 10 critical technology areas

This list includes non-exhaustive examples of each area, following the annex to the Commission Recommendation on 03.10.2023 on critical technology areas for the EU's economic security for further risk assessment with Member States. For more information please visit: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=OJ:L_202302113

— **Advanced semiconductors technologies**

- Microelectronics, including processors
- Photonics (including high energy laser) technologies
- High frequency chips
- Semiconductor manufacturing equipment at very advanced node sizes

— **Artificial intelligence technologies**

- High Performance Computing
- Cloud and edge computing
- Data analytics technologies
- Computer vision, language processing, object recognition

— **Quantum technologies**

- Quantum computing
- Quantum cryptography
- Quantum communications
- Quantum sensing and radar

— **Biotechnologies**

- Techniques of genetic modification
- New genomic techniques
- Gene-drive
- Synthetic biology

— **Advanced connectivity, navigation and digital technologies**

- Secure digital communications and connectivity, such as RAN & Open RAN (Radio Access Network) and 6G
- Cyber security technologies incl. cyber-surveillance, security and intrusion systems, digital forensics
- Internet of Things and Virtual Reality
- Distributed ledger and digital identity technologies

- Guidance, navigation and control technologies, including avionics and marine positioning

— **Advanced sensing technologies**

- Electro-optical, radar, chemical, biological, radiation and distributed sensing
- Magnetometers, magnetic gradiometers
- Underwater electric field sensors
- Gravity meters and gradiometers

— **Space & propulsion technologies**

- Dedicated space-focused technologies, ranging from component to system level
- Space surveillance and Earth observation technologies
- Space positioning, navigation and timing (PNT)
- Secure communications including Low Earth Orbit (LEO) connectivity
- Propulsion technologies, including hypersonics and components for military use

— **Energy technologies**

- Nuclear fusion technologies, reactors and power generation, radiological conversion/enrichment/recycling technologies
- Hydrogen and new fuels
- Net-zero technologies, including photovoltaics
- Smart grids and energy storage, batteries

— **Robotics and autonomous systems**

- Drones and vehicles (air, land, surface and underwater)
- Robots and robot-controlled precision systems
- Exoskeletons
- AI-enabled systems

— **Advanced materials, manufacturing and recycling technologies**

- Technologies for nanomaterials, smart materials, advanced ceramic materials, stealth materials, safe and sustainable by design materials
- Additive manufacturing, including in the field
- Digital controlled micro-precision manufacturing and small-scale laser machining/welding
- Technologies for extraction, processing and recycling of critical raw materials (including hydrometallurgical extraction, bioleaching, nanotechnology-based filtration, electrochemical processing and black mass)

Annex 3. List of the 3 targeted investment areas of the strategic technologies for Europe platform (STEP)

The list includes indicating and non-exhaustive examples[16] of technologies listed in each of the 3 target investment areas - foreseen in the Regulation (EU) 2024/795 of the European Parliament and of the Council of 29 February 2024, establishing the Strategic Technologies for Europe Platform (STEP). For more information and details on each example please visit: https://strategic-technologies.europa.eu/index_en

— **Digital technologies and deep tech innovation**

- Advanced semiconductors technologies
- Artificial intelligence technologies
- Quantum technologies
- Advanced connectivity, navigation, and digital technologies
- Advanced sensing technologies
- Robotics and autonomous systems

— **Clean and resource efficient technologies**

- Solar technologies
- Onshore wind and offshore renewable technologies
- Battery and energy storage technologies
- Heat pumps and geothermal energy technologies
- Hydrogen technologies
- Sustainable biogas and biomethane technologies
- Carbon capture and storage technologies
- Electricity grid technologies
- Nuclear fission technologies
- Sustainable alternative fuels technologies
- Hydropower technologies
- Other renewable energy technologies
- Energy system-related energy efficiency technologies
- Renewable fuels of non-biological origin technologies

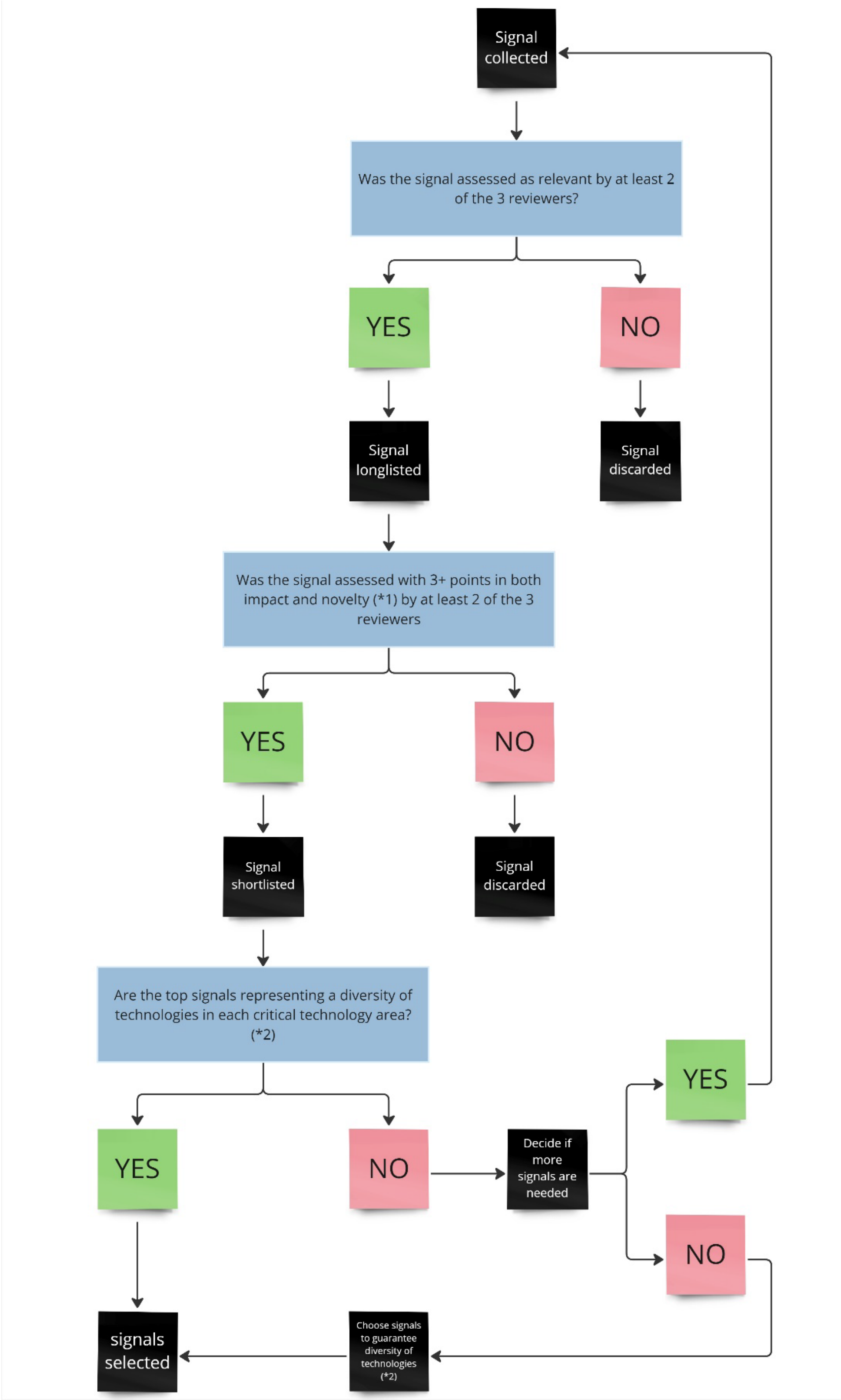
[16] As foreseen in the initiative's website at the time of this report's submission for publication.

- Biotech climate and energy solutions
- Transformative industrial technologies for decarbonisation
- CO^2 transport and utilisation technologies
- Wind and electric propulsion technologies for transportation
- Other nuclear technologies
- Other clean and resource efficient technology areas
- Advanced materials, manufacturing, and recycling technologies
- Technologies vital to sustainability such as water purification and desalination
- Circular economy technologies

— **Biotechnologies**

- DNA/RNA
- Proteins and other molecules
- Cell and tissue culture and engineering
- Process biotechnology techniques
- Gene and RNA Vectors
- Bioinformatics
- Nanobiotechnology

Annex 4. Decision tree and process flow for the assessment and selection of signals.



(*1) - The impact rating refers to the potential contribution of the technologies present in the signal for the EU's technological development and leadership. The novelty dimension refers to the signal's uniqueness, and how it could bear fewer known developments to the wider public, independently of the maturity level of the technologies behind it. (*2) - at least two signals per critical technology area and avoid repeating enabling technologies or combination of enabling technologies.

Getting in touch with the EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

— at the following standard number: +32 22999696,

— via the following form: european-union.europa.eu/contact-eu/write-us_en.

Finding information about the EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

Science for policy

The Joint Research Centre (JRC) provides independent, evidence-based knowledge and science, supporting EU policies to positively impact society

EU Science Hub
Joint-research-centre.ec.europa.eu

Publications Office
of the European Union