

EIC TECH REPORT

2023

BACKING VISIONARY ENTREPRENEURS

eic.ec.europa.eu
@EUeic

European
Innovation
Council



TABLE OF CONTENTS

INTRODUCTION 6

THE EUROPEAN INNOVATION COUNCIL 6

SCOPE OF THE REPORT 7

LOOKING FORWARD 7

CHAPTER 1 8

TOPICS 10

DIGITAL, INDUSTRY & SPACE 12

ADVANCED MATERIALS 13

ARTIFICIAL INTELLIGENCE 13

NEXT GENERATION OF ELECTRONIC DEVICES, MATERIALS AND ARCHITECTURES 13

MEASUREMENT SYSTEMS 15

QUANTUM TECHNOLOGIES 15

SPACE 15

CLEANTECH 16

AGRI-FOOD 17

CONSTRUCTION 17

ENERGY STORAGE 18

RENEWABLE FUELS AND CHEMICALS 18

TRANSPORT AND MOBILITY 19

HEALTH 20

MEDICAL IMAGING 20

MEDICAL DEVICES 21

BIOTECH – THERAPEUTICS 21

BIOTECH – DISEASE MODELLING

CHAPTER 2 22

REVOLUTIONISING INDUSTRIES WITH QUANTUM TECHNOLOGIES 24

SUSTAINABILITY OF MICROELECTRONIC DEVICES BASED
ON NOVEL MATERIALS AND DESIGNS 28

PROPELLANT-LESS TECHNOLOGY FOR ACTIVE DEBRIS REMOVAL (ADR) 32

FUELS AND CHEMICALS FROM THE SUN– A POTENTIAL GAME CHANGER
FOR OUR CURRENT ENERGY AND PRODUCTION SYSTEM 36

ACCELERATED DISCOVERY OF NOVEL MATERIALS TO SUPPORT THE
ENERGY TRANSITION 41

TOWARDS CARBON NEUTRAL AND CARBON NEGATIVE CONSTRUCTION 46

SAFEGUARDING EUROPEAN ENERGY SECURITY AND NET ZERO TARGETS 51

NOVEL TECHNOLOGIES FOR RESILIENT AND SUSTAINABLE
FOOD SUPPLY CHAINS 56

CURRENT TRENDS IN PRECISION ONCOLOGY 61

THE HYBRID FUTURE OF MEDICAL TECHNOLOGY: MANUFACTURING FULL BODY
PARTS FOR THERAPEUTIC REPLACEMENT 66

ENDNOTES 70

DISCLAIMER

Deep Tech Europe

European Innovation Council Tech Report 2023

EISMEA - European Innovation Council and SMEs Executive Agency

B- 1210 Brussels

Manuscript completed in October 2023

The views expressed in this document are the sole responsibility of the authors and do not necessarily reflect the views of the European Commission.

More information on the European Union is available on the internet (<http://europa.eu>).

Luxembourg: Publications Office of the European Union, 2023

© European Union, 2023

Project Number: 2023.4735

Title: EIC TECH REPORT 2023

LINGUISTIC VERSION	MEDIA/ VOLUME	CATALOGUE NUMBER	ISBN	DOI
EN PDF	PDF/Volume_01	EA-07-23-382-EN-N	978-92-9469-619-9	10.2826/412394

Reuse is authorised provided the source is acknowledged. The reuse policy of European Commission documents is regulated by Decision 2011/833/EU (OJ L 330, 14.12.2011, p. 39).

For any use or reproduction of photos or other material that is not under the EU copyright, permission must be sought directly from the copyright holders

THE EUROPEAN INNOVATION COUNCIL TECH REPORT 2023

INTRODUCTION

The European Innovation Council

Deep tech innovations are rooted in cutting edge science, technology and engineering and have the potential to deliver transformative solutions that can address the most pressing societal challenges and achieve key policy ambitions such as those surrounding the twin Green and Digital transitions.

As underlined in the Commission's New European Innovation Agenda, Europe is well placed to lead on deep tech innovation. The European Innovation Council (EIC), a European Commission initiative and part of the Horizon Europe program, was established as a flagship initiative to identify, develop and scale up emerging deep technologies and breakthrough innovations.

With over €10 billion of funding, the EIC supports the most talented and visionary European researchers and entrepreneurs, along the path from ground-breaking ideas to success in EU and global markets.

Support from the EIC is delivered through a mix of Open and Challenge-based calls under three core schemes: **EIC Pathfinder** supports deep tech research and development; **EIC Transition** carries

ideas from lab to business; **EIC Accelerator** supports startup development and scaling up, including through the **EIC Fund** which provides investments from seed to early growth. These schemes build on a history of funding for emerging technologies and innovations through the Future and Emerging Technologies (FET) programme, the SME instrument, and EIC Pilot activities under the Horizon 2020 Programme. The EIC has also adopted a new way of managing its funding: high-level domain experts, EIC Programme Managers, develop ambitious proposals for future breakthrough technologies and innovations and manage one or more EIC portfolios to help achieve these goals.

To date, under Horizon Europe, the EIC has attracted over 10 000 proposals across its three core programmes and funded over 700 projects. This has enabled the EIC to build on and develop a strong portfolio of activity in technological and economic sectors critical to Europe's future strategic autonomy and prosperity, such as renewable hydrogen, cell and gene therapies, quantum technologies, agrifood, among others.



Scope of the Report

For the EIC to achieve its mission it must be at the forefront of developments in science and technology and look to identify technologies emerging from the science base that could create new value propositions and/or disrupt existing markets.

To this end, technologies and sectors to be supported by the EIC must be assessed through an anticipatory lens, an essential starting point for which is a robust analysis of the EIC's current portfolio of activity.

Chapter 1 of this report therefore highlights novel technologies and innovations submitted to the EIC under Horizon Europe, with an emphasis on early-stage research projects funded following extensive independent expert review. It also includes some areas of technology that have attracted high quality proposals, but not funded to date by the EIC. This identification was supported by an ongoing partnership with the European Commission's Joint Research Centre (JRC) that informs EIC activities through qualitative and quantitative foresight and subsequently informed by discussions with EIC Programme Managers, who bring domain expertise to guide and connect projects and companies in key parts of the EIC portfolio.

The main criterion for selection was the relative novelty of the topics to the EIC. The listed technologies have not been prioritised based on their potential scientific, technological, economic, environmental, and social impacts, nor benchmarked against wider global technology trends. Such benchmarking and assessment will be essential to inform future priorities. Further, topics with a longer history of support by current and legacy EIC programmes are not highlighted in this Chapter.

Chapter 2 of the report complements the analysis in Chapter 1 and provides the perspective of the 10 EIC Programme Managers on parts of their portfolio. These 'deep dives' consider the potential of some of the relevant technologies identified in Chapter 1 and provide an overview of EIC activity and wider trends alongside insights on gaps and/or other barriers that may need to be overcome.

Looking Forward

The analysis shared here will help inform future explorations of the EIC portfolio, mapping internal EIC data to global trends based on patents, publications, funding and investments.

More detailed studies will be taken forward relying on the role of EIC Programme Managers, the continuous support of JRC qualitative and quantitative foresight, and inputs from external experts. The ambition is subject to further explorations on the scope of the annual EIC Tech Report, to identify new and emerging areas that could in time inform future priorities and activities where relevant through the EIC, or more broadly, across the Commission and/ or at national and regional levels.

CHAPTER 1



The EIC's portfolio of support for cutting-edge deep technology projects spans all stages of technology and market maturity.

This Chapter identifies technologies within the EIC portfolio, and in some cases submitted to the EIC but not funded, that may merit more detailed future analysis. The topics were identified via a mixed methods approach where data from the EIC Pathfinder Open programme (Horizon Europe, 2021-23) was quantitatively and qualitatively filtered and analysed,

and later combined with internal expert assessment by EIC Programme Managers.

The first step of this analysis relied on reviewing foresight work by the European Commission's Joint Research Centre (JRC) with whom there is an ongoing collaboration to support strategic intelligence gathering activities. The main sources and methodological processes used in this step were:

- Text mining and analysis for detection of signals of innovation in EIC internal data:** this stream was conducted via the JRC TIM Analytics tools¹ that aggregates algorithmic techniques and scientometric indicators. It was focused on EIC Pathfinder Open and EIC Transition Open calls with coverage of funded and non-funded proposals between 2021 and 2022. To assess the validity of the signals captured they were subject of a pilot comparative analysis with patent data (EPO PATSTAT)² and peer-reviewed publications (SCOPUS)³ that confirmed their nascent character. In future-oriented technology assessment, signals are early warnings of potential innovations that identify emerging topics and raise awareness on possible and plausible developments. They do not however allow for an accurate assessment of future impacts. The results of this JRC mining process offered a targeted overview of the potential novelties present in EIC internal data, plus a set of signal-related keywords that supported the subsequent explorations conducted at qualitative level for this report.

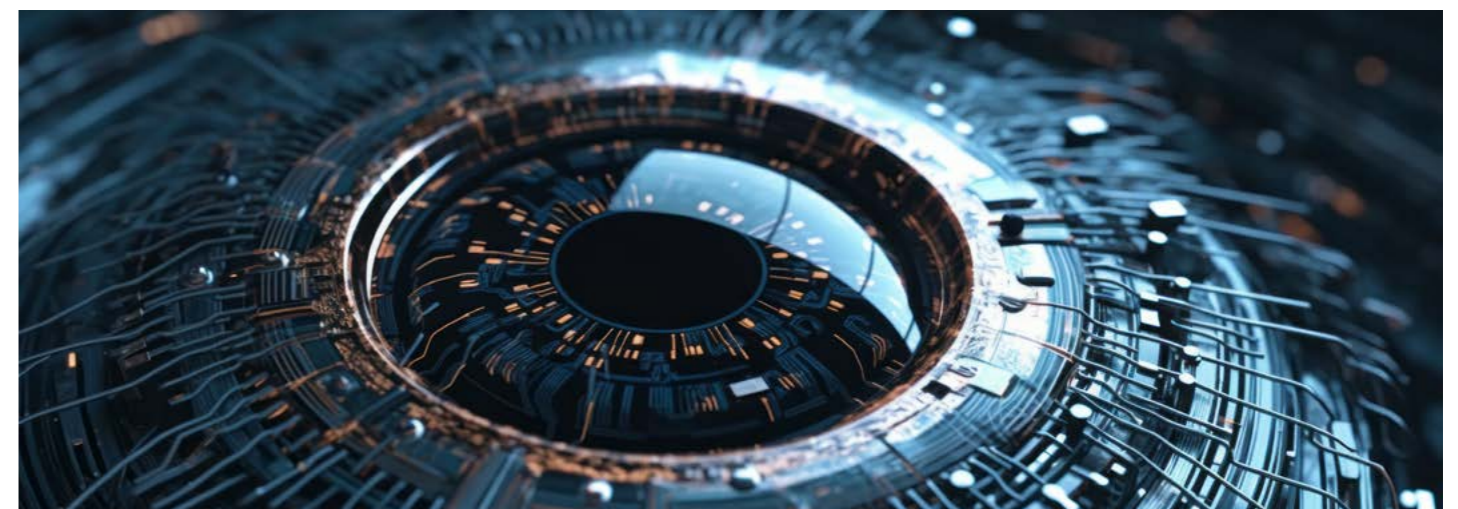
- Expert-based horizon-scanning for detection and assessment of signals of innovation and trends in internal and external data:** this stream was based on qualitative data collection via surveys⁴ and 8 participatory workshops in EIC relevant fields⁵, with engagement of 155 top-level experts and the participation of the European Research Council (ERC). The main focus was the identification, filtering and assessment of relevant signals and trends for the foresight work of EIC Programme Managers who co-coordinated the exercise with the JRC. 1037 initial signals and trends were collected from surveys and mining of internal and external data, and a selection of 58 top signals and trends were prioritised by the experts at the end of these workshops for further exploration by the relevant EIC Programme Managers. The results of this integrated horizon scanning process helped contextualise internal EIC data in relation to innovation signals and trends detected and assessed by the experts during the workshops and helped frame a majority of the topics presented in this Chapter.

- Literature review of third-party reports on signals and trends of innovation:** this stream was derived from desk research on an initial list 170 sources from research and technical organizations, business intelligence and consultancy firms, or top industry, market, and investment players.⁶ A final set of 24 reports was selected by JRC and the EIC for deeper dives, including horizontal reviews, such as 'Deloitte Insights Tech Trends' (2023) or 'Future Today Institute Tech Trends' (2023), and vertical, such as 'RAND: Future Uses of Space Out to 2050' (2022), 'ITONICS: Game-Changing Technologies for Energy' (2022), or 'USA National Intelligence Council: The Future of Biotech (2022)'. A final list of top 106 signals and trends was selected, analysed, and mapped by JRC and external experts against fields where EIC is or could be active through Open and Challenge calls. For the purposes of this report, the outputs helped contextualise the positioning of these areas of interest to the EIC, through comparison with others involved in technology and innovation foresight.

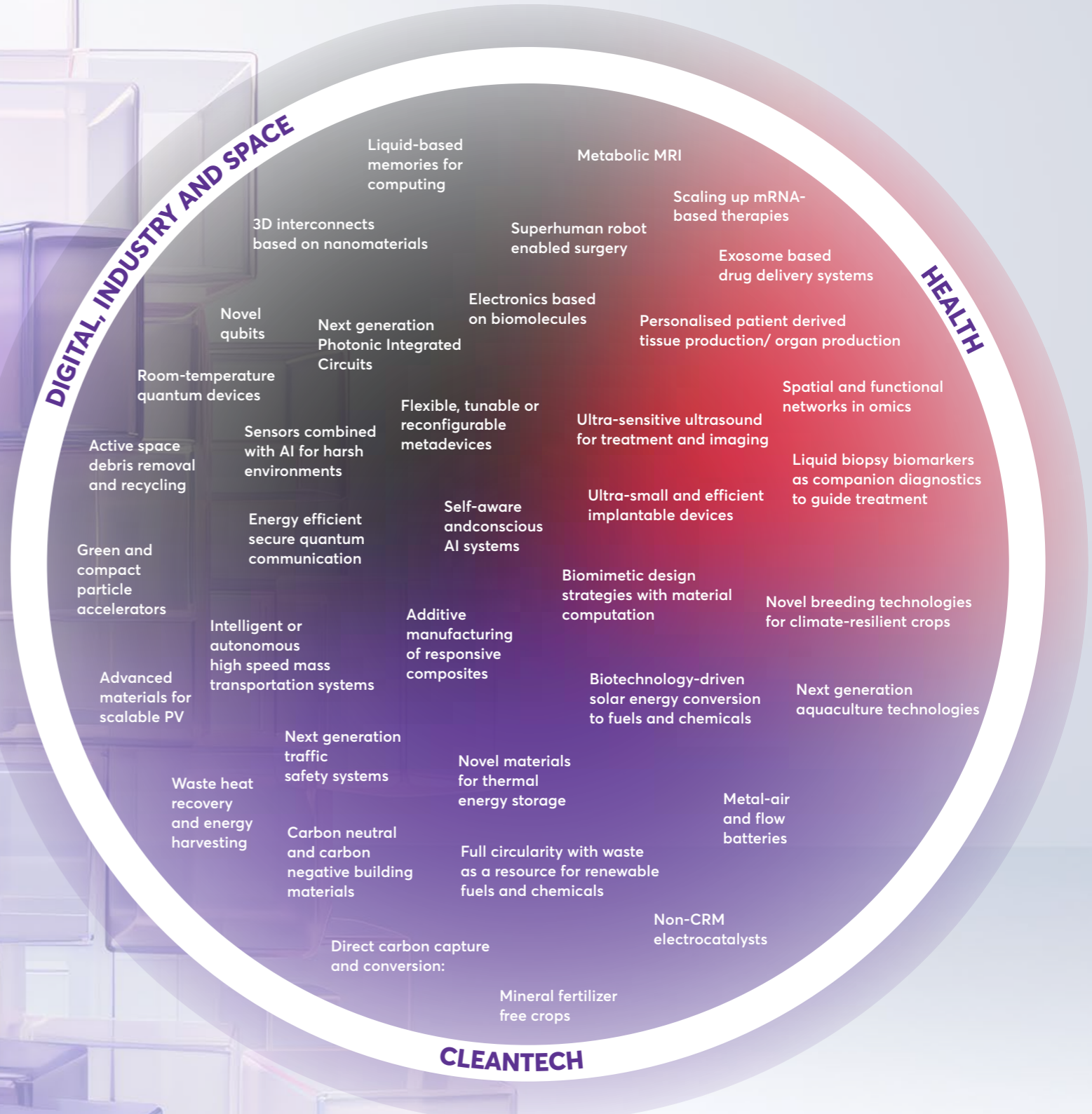
The final step of analysis for this report was anchored on a combination of the results provided by the JRC with an internal review of the EIC portfolio with a focus on the EIC Pathfinder Open programme. The Pathfinder, focused on early TRLs, has attracted over 3000 applications and supported nearly 250 early-stage high-risk / high gain inter and transdisciplinary projects under Horizon Europe (2021-23), which are likely to underpin future technological and innovation breakthroughs.

The in-house review was conducted with the support of the EIC Programme Managers in their respective fields of expertise. The goal was to identify topics that were new to the EIC. This resulted in the list of topics presented below with each topic aggregating relevant scientific and technical developments from 2 to 5 projects and/ or highly ranked proposals. More established fields that have been described in prior publications such as the EIC Impact Report 2022, are not included in this Chapter.

For ease of reference the topics listed below have been grouped under three broad policy headings. It should be emphasised that these topics are not prioritised on the basis of their potential scientific, technological, economic, environmental, and social impacts, nor have they been benchmarked against global technology trends. It is also recognised here that the underpinning nature of scientific and technological developments in these topics may lead to a broader set of applications from low to higher TRLs, including pairings with other topics for new breakthrough processes or products.



CHAPTER 1 TOPICS



DIGITAL, INDUSTRY & SPACE

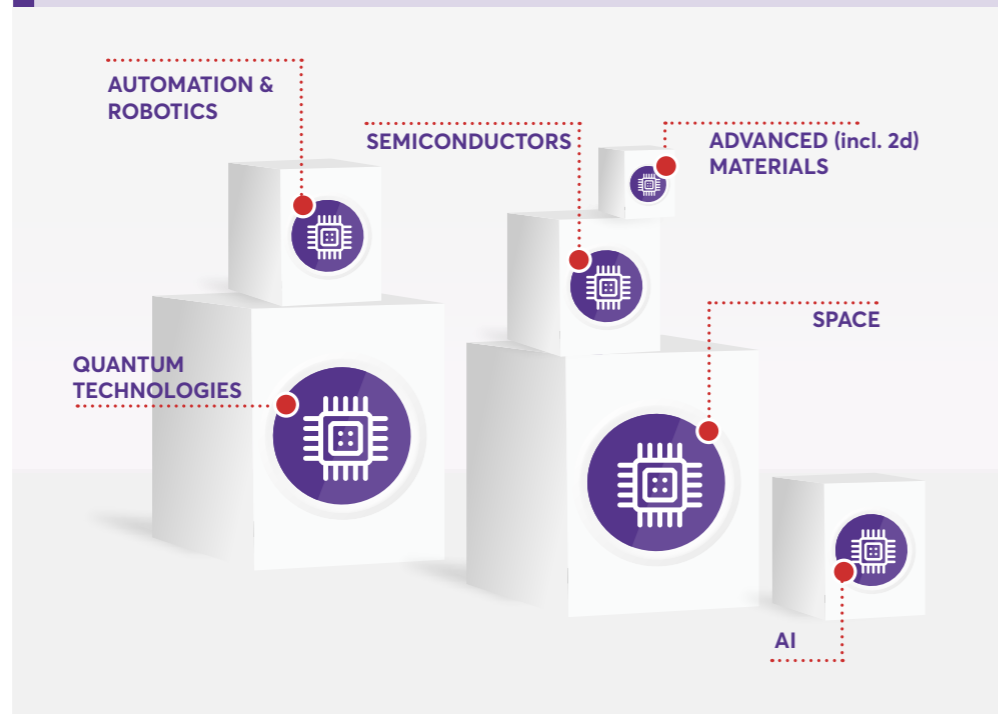
The EU's New Industrial Strategy and associated initiatives such as the European Chips Act, aim to strengthen Europe's technological leadership and strategic autonomy in key technologies such as Artificial Intelligence, Quantum Technologies, Space and Semiconductors, areas in which the EIC has a strong history of support, as detailed for example in the EIC Impact Report 2022.

The EIC has looked to build on these strengths with efforts made under Horizon Europe to catalyse the development of emerging technologies in some of these areas through for example EIC Pathfinder Challenges that have under Work Programmes 2021 and 2022 supported:

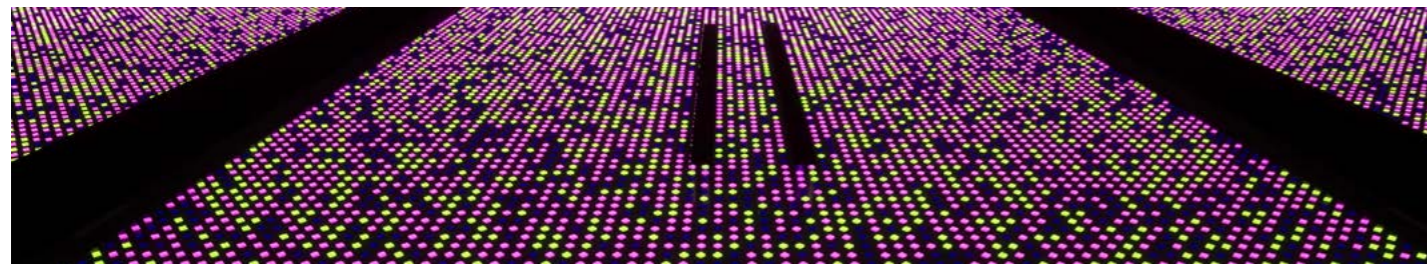
- DNA-based digital data storage
- Alternative Quantum Information Processing, Communication, and Sensing
- Awareness inside
- Engineered living materials

The technologies identified below cover new areas of activity proposed to, and generally supported by the EIC under Horizon Europe that align with the Digital, Industry and Space agenda of the EU.

KEY TECHNOLOGIES AND RELATIVE SCALE IN DIGITAL & INDUSTRY



EIC's Digital, Industry and Space Portfolio (2014-21)
(the size of the box corresponds to the relative scale of activity)



ADVANCED MATERIALS

Additive manufacturing of responsive composites: Additive manufacturing is a transformative fabrication approach capable of building parts made of different materials with free form and complex geometries. Adding functionalities to polymeric composites, such as efficient reaction to an external "stimulus", so-called responsivity, via additive manufacturing opens new applications for composite polymers with tailored properties.

Non-CRM electrocatalysts: Several materials exhibit high electrocatalytic performances, mainly due to the presence of some Critical Raw Materials (CRMs) such as platinum group metals. The large-scale deployment of some electrochemical devices for the energy transition therefore raises significant concerns about the

availability and cost of electrocatalysts. New solutions take either a circular approach to electrocatalysts or the design and development of CRM-free electrocatalysts incorporating the use of Artificial Intelligence and Machine Learning to accelerate material discovery.

Advanced materials for scalable PV: Photovoltaic (PV) panels are driving the energy transition, pushed by a dramatic decrease in silicon PV module prices. The development of novel materials or device architectures in place of conventional materials or designs could open novel applications and even widen the degree of deployment of PV technologies. Amongst other factors the candidate materials need to be earth-abundant low-cost raw materials with scalable, environmentally sustainable and cost-effective manufacturing processes.

ARTIFICIAL INTELLIGENCE

Self-aware and conscious AI systems: The concepts of awareness and consciousness for artificial systems explores AI capability to develop, for example cognitive attention, anticipation, imagination, and prospection and allow symbiotic interaction with external systems. Various conceptual and technological approaches aim for better understanding of interaction with smart technologies leading to development of resilient and human-centric self-aware AI systems.



NEXT GENERATION OF ELECTRONIC DEVICES, MATERIALS AND ARCHITECTURES

3D interconnects based on nanomaterials: 2D electronic architectures suffer from "unscalable" interconnects, making it difficult for them to compete with biological neural systems in terms of real-time information-processing capabilities with comparable energy consumption. Recent advances in materials science, device technology and synaptic architectures have the potential to fill this gap with novel disruptive technologies that go beyond conventional CMOS technology. A promising solution comes from the use of nanomaterials such as the development of vertical nanowire field-effect transistors or the fabrication of high-performance devices enabled by the integration of self-assembled CNT nanocircuits using DNA-templates.

Electronics based on biomolecules: Current efforts for more sustainable electronics can lead to a new type of all-protein based electronics, so called "proteonics". This new horizon promises passive and active electronic components to be fully CO₂-neutral, bio-compatible and bio-degradable, but also allow a natural interface with biological systems which may open completely new opportunities in many areas of science and health. In soft robotics, inspired by mimicking marine worms, stimuli-driven modular morphing robots built from smart shape-memory DNA hydrogels are able to respond to stimuli and adapt to the environment. The use of DNA (cellular or synthetic) has also proved to be a very promising avenue for more energy-efficient, environmentally friendly, and technically robust data storage and archiving.

Flexible, tunable or reconfigurable metadevices: Metadevices are devices characterised by unique functionalities (e.g. tunable, switchable, and nonlinear) enabled by man-made specific subwavelength structures of functional matter. Combining metasurfaces and plasma physics ensure benefits such as non-natural electromagnetic properties enabled by 2D metamaterials and unprecedented reconfigurability and tunability at high frequencies enabled by plasma, both inaccessible for conventional devices. These plasma-based metadevices e.g. tunable lenses for antennas or time-variant 3D reconfigurable components may start a new era for telecommunications with high potential impact on the economy and society. Smart skin enabled by sparse, curved, integrated and flexible metasurfaces using surface and leaky waves can be deployed in applications such as contactless haptics and far-field communication which could open up a wide range of applications in robotics and in medical fields. Recent developments in flexible wearables and IoT bring high-performance sensors based on printed nanosheet networks with increased inter-sheet interaction enabled by chemical crosslinking and physical synthesising of high aspect ratio nanosheets.

Liquid-based memories or computing: Enhancing performance and making electronic devices and components truly sustainable has become urgent. This requires novel and affordable technological solutions for computing and storing information. Use of liquid in this context does not seem to be the most natural path, but recent ideas include the use of colloidal nanoparticles and nanocapillary arrays for low-cost high-density memory (over 100Gbit/mm²) and chemical reservoir computing based on purely molecular information processing systems.

Next generation Photonic Integrated Circuits: Latest developments in photonics and materials science are providing a foundation for a new class of high performance, low-cost Photonic Integrated Circuits (PIC) resulting in compact solutions for a wide range of devices: sensing, computing, etc. Novel ideas include use of functional materials and integrated optical circulators able to distribute exclusively light between passive and active integrated functions, dual comb spectrometers for wide band and high resolution optical (mid-IR) spectroscopy with new level of sensitivity for on chip integrated sensors, or nanoelectromechanical programmable silicon photonics for massive parallel optical interconnects enabling large networks of independent and fully controllable nodes.

Sensors combined with AI for harsh environments: Harsh environments require electronic devices to withstand specific, often extreme, environmental or medium conditions e.g. water or high level of electromagnetic interference or radiation. Long-standing technological challenges for underwater optical wireless communication, related to high-speed connectivity, low or self-power requirements and respect for the environment could be overcome using blue optical phased arrays combined with a large-scale array of DACs and coherent receivers. Radiation measurements, including high-energy is another rapidly developing area where technologies such as AI and nanotechnology (e.g. inorganic nanocrystals) can bring ground-breaking developments leading to high speed and accurate radiant source detection and localization devices.

MEASUREMENT SYSTEMS

Green and compact particle accelerators: Particle accelerators, widely used in many applications, are currently large and costly systems with a large environmental footprint. Next-generation devices with excellent beam properties in terms of stability, reproducibility, spectrum, duration and time delivery are being developed building on a new concept of accelerating structure which should ensure 100 MeV/m energy gain gradient needed for industrial applications and enlarge time access for preclinical and clinical phase studies.

QUANTUM TECHNOLOGIES

Novel qubits: Like bits in classical computing, qubits are the smallest data storage units in quantum systems. However, qubits exist in a superposition state of 0 and 1 simultaneously. This ability to store multiple states at once makes quantum computers highly powerful. However, short qubit coherence times hamper the implementation of error correction techniques. New types of qubits based on hybrid superconductor-semiconductor platforms can be a viable approach to achieving fault tolerant computation. Such new types of qubits can be generated by encoding quantum information in a topologically protected system that will be engineered by creating arrays of quantum dots with superconducting coupling in two-dimensional electron gases.

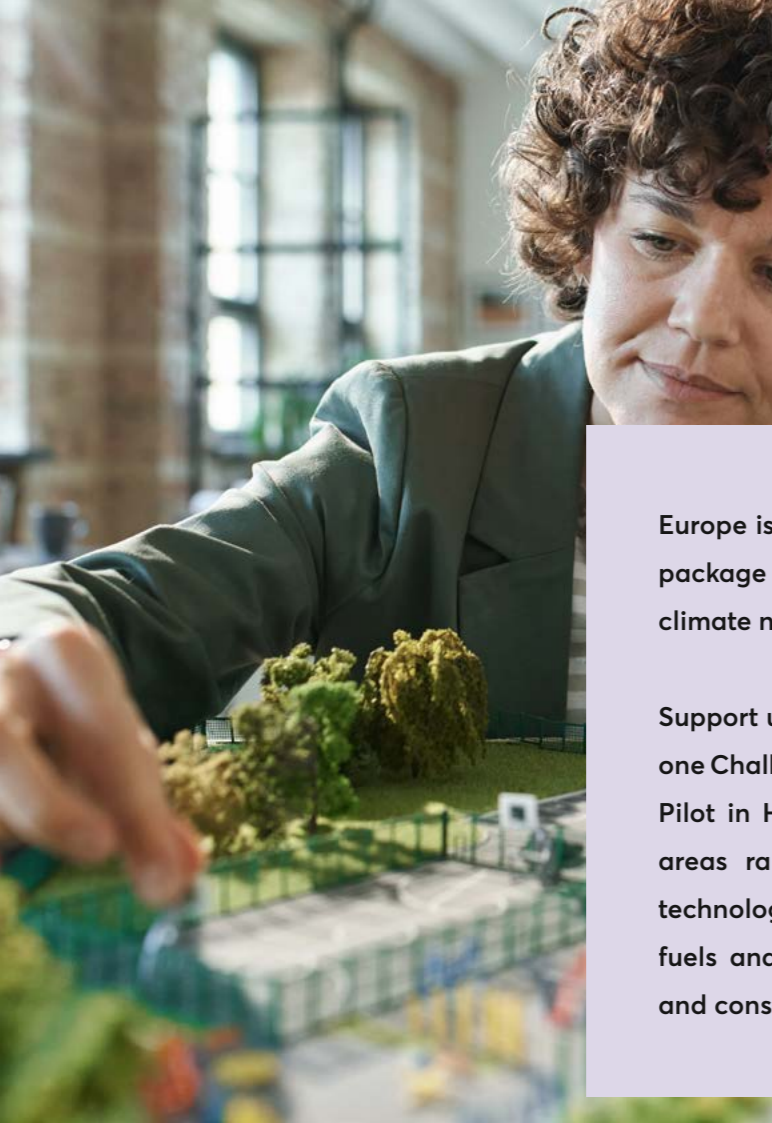
Room-temperature quantum devices: The main limit for quantum technology-based devices is linked to their high sensitivity to environmental factors which are often overcome by focusing operation at very low

temperatures i.e., a cryogenic setting for quantum devices. New approaches for room-temperature quantum technology platforms include the use of Atomically Precise graphene nanoRibbons (APRs) which are intrinsically predisposed for complex quantum states. These can exhibit novel physical properties such as topological quantum phases and spin polarization controlled by their topology and edge structure.

Energy efficient secure quantum communication: A range of approaches are being explored including the integration of reservoir computing and quantum technology, so called quantum reservoir computing (QRC), which could lead to robust and power-efficient quantum communication and sensing. Likewise, the use of integrated photonic platforms, allowing for low-footprint, alignment-free and mass-manufacturable quantum nodes, could facilitate real-life applications of quantum networks.

SPACE

Active space debris removal and recycling: The development of green, compact and affordable concepts for active space debris removal are critical due to escalating debris growth. Removal approaches considered include the use of magnets, de-orbiting mechanisms, nets, harpoons, tethers, space-based lasers and solar sails. The most promising green and affordable concepts are tethers, space-based lasers and solar sails, as they do not require the use of chemical propellants. In the longer-run various concepts for in-space recycling and the reuse of rocket bodies, defunct satellites or fragments of old satellites will emerge. These could include breaking down materials for in-space manufacturing or reusing spacecraft components (e.g., tanks, structural components, electronics) in new ways. This nascent capability will result in numerous applications, ensuring space debris reduction for the benefit of future exploration missions.



CLEANTECH

Europe is at the forefront of the green transition, with the 'Fit for 55' package aiming to reduce EU emissions by 55% by 2030 and achieve climate neutrality by 2050.

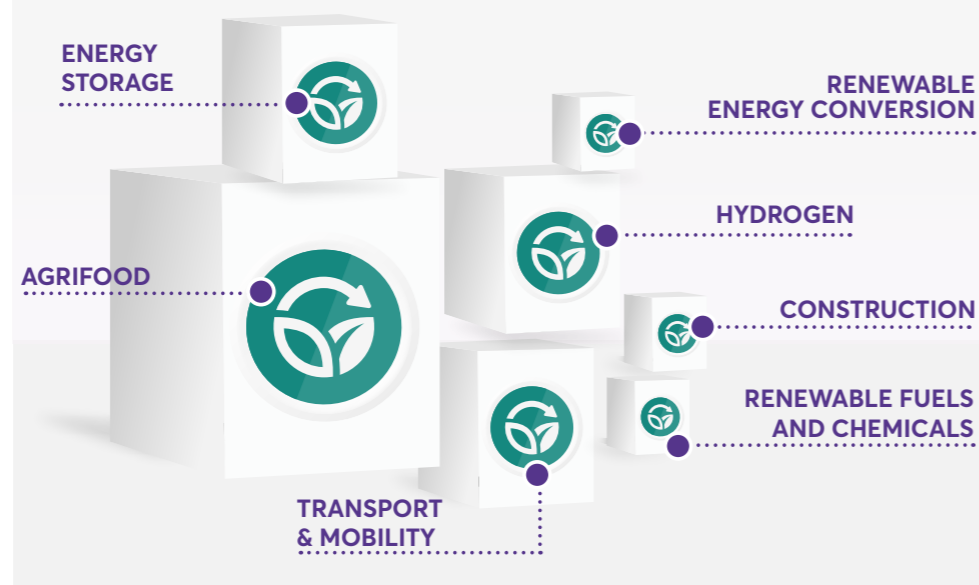
Support under the EIC Open calls and under Horizon 2020 including one Challenge call targeting the Green Deal under the EIC Accelerator Pilot in Horizon 2020, have led to a strong portfolio of activity in areas ranging from renewable energy conversion and storage technologies to agrifood innovations, from hydrogen and renewable fuels and chemicals, to low-carbon technologies for the transport and construction sector.

A combination of Open and Challenge calls under Horizon Europe continues to build on these efforts to support the transition to a more resource-efficient and competitive economy with Challenge calls under the EIC Pathfinder under Work Programmes 2021 and 2022 supporting:

- Novel routes to green hydrogen production
- Carbon Dioxide & Nitrogen management and valorisation
- Mid-long term, systems-integrated energy storage

The technologies identified below cover new areas of activity proposed to, and generally supported by the EIC under Horizon Europe that align with the Green agenda.

KEY GREEN TECHNOLOGIES AND RELATIVE SCALE



EIC's Cleantech Portfolio (2014-21)

(the size of the box corresponds to the relative scale of activity)

AGRI-FOOD

Next generation aquaculture technologies: Developments in this field are focused on algae-based, fish and shellfish food production in the seas and oceans. This includes microalgae-based marine biotechnology to produce a range of products from nutraceuticals to packaging materials from jellyfish biomass to mollusk shells including with precision fermentation technologies. Novel technologies are also being developed to increase the yield and sustainability of farmed fish and seafood, from the health management (and antibiotic replacement) of farmed fish to the production of several high value species, not yet available through conventional aquaculture.

Novel breeding technologies for climate-resilient crops: The goal of these solutions is to enable soil-based food production with lesser fossil fuel dependency and adapted to harsh environmental conditions, primarily heat and drought. Novel developments in the field include novel tomato and rapeseed breeds that absorb more CO₂ (C sinks) and AI-assisted photosynthesis regulation to increase harvest yields.

Mineral fertilizer free crops: Advances in this domain strive to provide alternatives to the mainstream but polluting mineral fertilisers from fossil fuels, primarily with fertilisers of microbial origin. Recent developments include novel processes for the direct green conversion of CO₂ and NO_x into fertilisers, digital twins for optimised crop production fertiliser use or advanced software and hardware for soil protection and restoration (optoelectronic chips for detection of soil contaminants or bionic earthworm robots to monitor soil health).

Precision fermentation: This relates to the production of high value food and feed, as well as non-edible materials, from low quality inputs and food waste. This cluster is a very important element of decoupling food production from soil depletion and increasingly harsh environments. Precision fermentation is also capable of supporting personalised nutrition plans. Developments observed in the EIC portfolio include, fermentation of edible mushrooms roots and food waste into edible products, data analytics & fermentation control to increase dairy farm milk yield, or biopolymer production from agricultural residues.

CONSTRUCTION

Biomimetic design strategies with material computation: Generative computational technologies emulate organic maximal performance with minimal resources through local material property variation and prioritize a paradigm shift to material-based rather than current geometric form-generation. Triggered by natural structures, hierarchical material architectures allow designers and fabricators to imagine radical new opportunities for emergent properties, tailored functionalities and the merging of properties and functionalities in single objects.

Carbon neutral and carbon negative building materials: Carbon-neutral materials, like sustainably sourced timber, aim to balance emissions during production. The latest advancements include precision engineering to optimize resource use. On the other hand, carbon-negative materials, like carbon-sequestering concrete, actively remove more carbon dioxide from the atmosphere than

they emit during production. Recent breakthroughs involve the development of novel binders and aggregates, enhancing their carbon-capturing capabilities.

Hybrid and Engineered Living Materials for construction: These contain living cells that remain biologically active in use-cases through several assemblage techniques that allow materials and structures to grow bottom-up as emergent self-reproducing behaviour of protocells. For more integrated built environments we now see mycelia-based structures as frontrunners as together with similar class materials they offer radically new and tailored functionalities over non-living materials, for example self-regeneration, natural adaptation to environmental cues (light, temperature, chemicals), self-growing morphogenesis across hierarchies of scale and structure.

ENERGY STORAGE

Metal-air and flow batteries: These electrochemical battery technologies are being developed to reach higher energy density, scalability and longer cycle life. We observe breakthrough developments in a) the use of raw materials widely available in the EU and using sustainable processes to convert them into electrochemically active components which are inherently safe to use and to operate, b) capability to provide solutions for the optimization of the electricity system.

Novel materials for thermal energy storage: Novel materials such as phase-change materials are being developed for energy storage resulting in significant innovations.

Waste heat recovery and energy harvesting: New thermoelectric materials are under development for waste heat recovery from industrial to residential sectors, with recent advances in multinary metal halides, 2D topological materials and other xenex, or quantum-confined nanomaterials leading to more efficient and cost-effective solutions also connected to new generations of thermoelectric generators and supercapacitors. Promising research trends include energy harvesting from ambient moisture, from mechanical vibrations, from ambient heat or indoor light.

RENEWABLE FUELS AND CHEMICALS

Biotechnology-driven solar energy conversion to fuels and chemicals: Solar cell factories are unicellular microorganisms (cyanobacteria, microalgae) which convert sunlight, water and CO₂ directly into a fuel or chemical. The latter are excreted from the cell and can be harvested. Genetic engineering allows a broad range of possible products, ranging from hydrogen to synthetic fuels or pharmaceuticals.

Direct carbon capture and conversion: Carbon dioxide is a key enabling resource in the production of synthetic fuels and chemicals. However, its capture process is energy intensive. A highly novel approach is to capture carbon with advanced materials and to convert it

within the same process into a fuel or chemical. By integrating capture and conversion, the process becomes significantly more energy efficient.

Full circularity with waste as a resource for renewable fuels and chemicals: Water, carbon dioxide and nitrogen are the main resources needed to produce synthetic fuels and chemicals. When scaling up to the global level, one has to make sure that their supply is fully sustainable. Novel approaches seek to turn waste, e.g. wastewater or flue gasses, into a valuable resource replacing e.g. the need for ultrapure drinking water.



TRANSPORT AND MOBILITY

Intelligent or autonomous high speed mass transportation systems: The mobility sector is experiencing transformational shifts and enters a new age of innovation in terms of autonomous mass transit and other smart public transportation with potential replacement of legacy individual vehicles with shared commuting solutions for instance. Early-stage developments can be highlighted for ultra-fast 'last-mile' collective solutions with on-demand services, and new energy efficiency integration models between high-speed mass transportation and urban smart grids.

Next generation traffic safety systems: With increasing complexity and dynamism of traffic systems comes an increasing risk of accidents. Next generation traffic safety systems are needed to safeguard the well-being of urban dwellers and inhabitants. Emerging technologies making waves in this field include cycling safety prediction models, solar-powered luminescent roadway lighting and advanced driver assistance systems for soft and individual mobility.



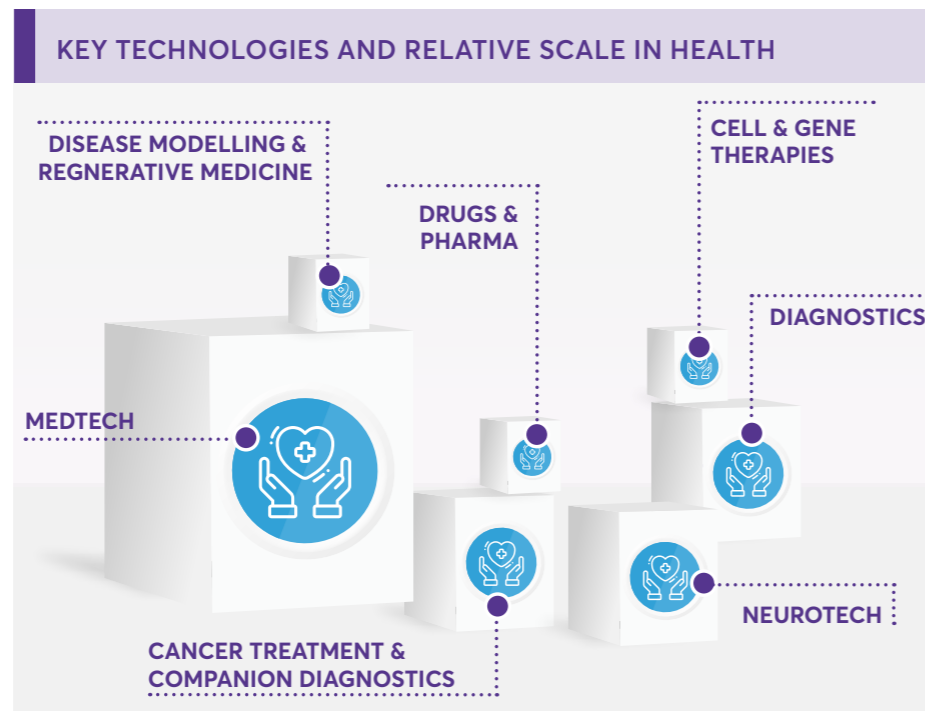
HEALTH

The EIC has a large Health and care portfolio which includes the outputs of EIC Pathfinder Challenge calls in 2021-22 targeting:

- Tools to measure & stimulate activity in brain tissue
- Emerging Technologies in Cell & Gene Therapy
- Cardiogenomics
- Healthcare Continuum technologies

This is complemented by a long history and ongoing support following EIC Open calls for developments leading to novel medical devices and imaging technologies alongside a portfolio of activity responding to the COVID-19 pandemic under the Horizon 2020 programme.

The technologies identified below cover new areas of Health and Care activity proposed to, and generally supported by the EIC under Horizon Europe.



EIC's Health Portfolio (2014-21)

(the size of the box corresponds to the relative scale of activity)

MEDICAL IMAGING

Metabolic MRI: Metabolic magnetic resonance imaging (MRI) is a non-invasive technique to acquire images and metabolic information from the human body. Its development and subsequent application will enable a range of clinical conditions, where metabolic processes are central to the diagnosis, to be evaluated. The ability to image cell development within developing clusters is likely to enhance/supersede more traditional anatomical imaging using MRI and other techniques.

Ultra-sensitive ultrasound for treatment and imaging: The use of focused ultrasound waves to target structures such as the brain could become a non-invasive alternative to surgery. Early indications suggest it may have some significant advantages over other non-invasive techniques by allowing deeper targets to be reached without impacting non-target tissue.

MEDICAL DEVICES

Superhuman robot enabled surgery: Robot-controlled decision-making enabled by Artificial Intelligence, which goes beyond mere robot-assisted procedure execution, is now becoming feasible. This knowledge and capability can also be used outside the operating-room to achieve unprecedented automation with robotic architectures autonomously designing and executing complete experiments with precision

Ultra-small and efficient implantable devices: Developing nano/micrometre scale biocompatible connected devices that are self-powered, using metabolic energy for example, could support a range of functions including assisting communication, movement etc. Such implantable devices could also be used to enable the targeted delivery of micro-litre scale payloads of therapeutic factors in the body.

BIOTECH: THERAPEUTICS

Scaling up mRNA-based therapies: RNA production for therapeutics is reliant on costly in vitro transcription methods. Alternative approaches for producing, isolating and purifying mRNA with high purity and stability at a significantly reduced cost could play a significant role in accelerating the use of RNA based therapies.

Approaches for sample retrieval and analysis continue to evolve and offer promising avenues for more personalised treatment.

Liquid biopsy biomarkers as companion diagnostics to guide treatment: Non invasive methods such as liquid biopsies offer an easier approach to sample, monitor and devise targeted treatments.

Exosome based drug delivery systems: Exosomes are small extracellular vesicles used by cells to communicate with one another. Harnessing these could enable their use as drug delivery systems for small molecules, DNA, RNA and other biological payloads for the targeted delivery of therapies for a range of diseases including cancer.

BIOTECH: DISEASE MODELLING

Spatial and functional networks in omics: Spatial multi-omics covers a wide range of spatial approaches including sequencing-based, transcripts-based, proteins-based and spatial metabolomics. Understanding the molecular basis of complex diseases provides new opportunities for the development of therapies including in the treatment of cancer.

Personalised patient derived tissue production/organ production: In vitro self-assembly of three-dimensional cellular structures from patient derived tissues could enable the development of biocompatible organs at reduced cost without the requirement for immunosuppressive drugs. The underpinning technology could also be used to produce living 3D micro tumours cultured in a gel, which when combined with immune cells and fibroblasts, model the cancer microenvironment enabling immune-oncology applications.



CHAPTER 2

The goal of the EIC is to position the EU at the forefront of deep tech innovation. To achieve this challenging ambition, a key novelty introduced by the EIC is the role of Programme Managers.

EIC Programme Managers are leading experts in their respective fields capable of leveraging their scientific background, understanding of technology developments and related markets and associated networks to enable the EIC to both identify emerging trends and inform future activities.

Programme Managers apply a portfolio approach in their respective areas of expertise and look to identify opportunities for investment in key technologies to guide development from a very early stage towards the most promising future applications. This comprises the identification of the state-of-the-art, as well as scenario building

including on social aspects, where relevant, to understand the implications of the wide uptake of such technologies. Moreover, they also seek to develop a standardised framework for a techno-economic assessment of emerging technologies and look to create a framework for consensus building among the key stakeholders from academia, industry and policy.

This Chapter focuses on providing greater detail on some areas overseen by EIC Programme Managers, highlighting technologies they have identified to be of particular interest and placing them into a wider context of opportunities and associated broader developments. Their contributions further connect, where relevant, the topics identified in Chapter 1 of this report and specific projects in the evolving EIC portfolios they manage.

DEEP DIVES INTO 10 TECHNOLOGY DOMAINS

DIGITAL, INDUSTRY & SPACE

REVOLUTIONISING INDUSTRIES WITH QUANTUM TECHNOLOGIES >

SAMIRA NIK - *EIC Programme Manager for Quantum Tech and Electronics*

SUSTAINABILITY OF MICROELECTRONIC DEVICES BASED ON NOVEL MATERIALS AND DESIGNS >

ISABEL OBIETA VILALLONGA - *Responsible electronics*

PROPELLANT-LESS TECHNOLOGY FOR ACTIVE DEBRIS REMOVAL (ADR) >

STELLA TKATCHOVA - *Space systems & technologies*

CLEANTECH

FUELS AND CHEMICALS FROM THE SUN – A POTENTIAL GAME CHANGER FOR OUR CURRENT ENERGY AND PRODUCTION SYSTEM >

CARINA FABER - *Renewable energy conversion and alternative resource exploitation*

ACCELERATED DISCOVERY OF NOVEL MATERIALS TO SUPPORT THE ENERGY TRANSITION >

FRANCESCO MATTEUCCI - *Advanced materials for energy and environmental sustainability*

TOWARDS CARBON NEUTRAL AND CARBON NEGATIVE CONSTRUCTION >

FRANC MOUWEN - *Architecture engineering construction technologies*

SAFEGUARDING EUROPEAN ENERGY SECURITY AND NET ZERO TARGETS >

ANTONIO MARCO PANTALEO - *Energy systems and green technologies*

NOVEL TECHNOLOGIES FOR RESILIENT AND SUSTAINABLE FOOD SUPPLY CHAINS >

IVAN STEFANIC - *Food chain technologies, novel & sustainable food*

HEALTH

CURRENT TRENDS IN PRECISION ONCOLOGY >

IORDANIS ARZIMANOGLU - *Health and biotechnology*

THE HYBRID FUTURE OF MEDICAL TECHNOLOGY: MANUFACTURING FULL BODY PARTS FOR THERAPEUTIC REPLACEMENT >

ENRIC CLAVEROL - *Medical technologies and medical devices*

REVOLUTIONISING INDUSTRIES WITH QUANTUM TECHNOLOGIES

What's at stake

Quantum technologies is a rapidly developing field with the potential to revolutionise numerous industries, including computing, communication, sensing, and cryptography. The global market for quantum technologies is projected to grow rapidly in the coming years and their economic, and strategic potential make them a promising area for research and investment by Governments and industries around the world, hoping to gain competitive advantage from its commercialisation.

The US, China, Canada, Japan, UK, Switzerland, France, Germany, and Netherlands are among the countries with the largest public investments in quantum technologies. The European Quantum Flagship⁷, launched in 2018, is the most important EU initiative in support of quantum technologies. With €1 billion allocated over a period of 10 years, it looks to consolidate and expand European scientific leadership and excellence in this area; kick-start a competitive European industry in quantum technologies; and make Europe a dynamic and attractive region for innovative research, business, and investments in this field. Globally, the

greatest share of these private investments is still in companies in the United States (49%), followed by those in the United Kingdom (17%) and Canada (14%). Only about 6% of private investments in the field to date are in China and Europe.

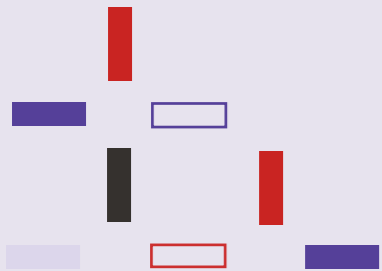
Quantum technologies however require even more significant capital investment, with the appreciation that the return on investment may not be realised for several years.

The EIC is funding quantum projects at all stages of technology and market maturity and this support looks to align with and complement the Quantum Flagship and EU Digital strategies. Furthermore, the EIC's investments in quantum technologies through the EIC Accelerator and associated EIC Fund can play an important role in attracting private investment in European quantum start-ups, as its presence as a shareholder de-risks investments by private investors reluctant to invest in high-risk technologies.

This article presents an overview of the emerging technology trends in the EIC projects, and the global position of the EU in the quantum revolution.



SAMIRA NIK
EIC Programme Manager responsible for Quantum Tech and Electronics



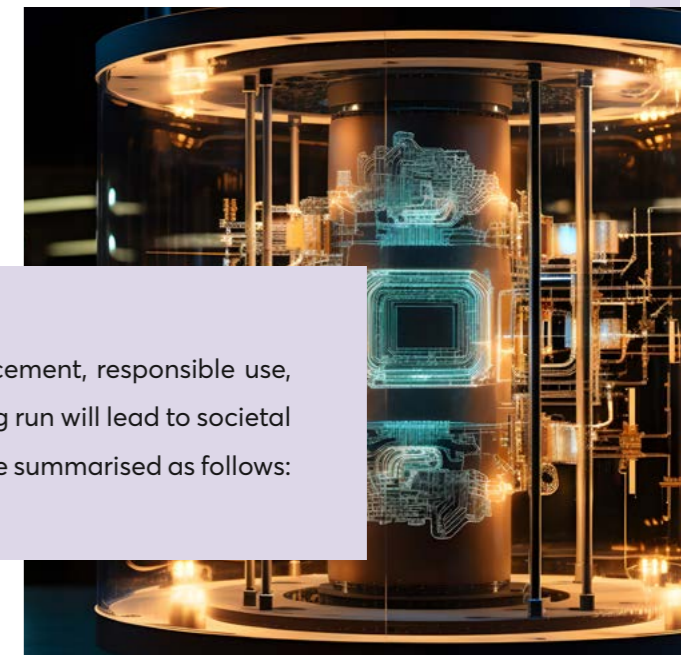
Related identified topics in Chapter 1

QUANTUM TECHNOLOGIES

- Novel qubits: Novel qubits are being developed by several research groups, including those of the EIC, which could lead to the development of quantum devices that are more powerful and efficient than current devices. This is due to their ability to store and process information in a way that is fundamentally different from classical devices. Novel qubits are being developed by several research groups, including those of the EIC, which could lead to the development of quantum devices that are more powerful and efficient than current devices. This is due to their ability to store and process information in a way that is fundamentally different from classical devices.
- + Room-temperature quantum devices: Room-temperature quantum devices are being developed by several research groups, including those of the EIC, which could lead to the development of quantum devices that are more powerful and efficient than current devices. This is due to their ability to store and process information in a way that is fundamentally different from classical devices.
- + Energy-efficient quantum technologies: Energy-efficient quantum technologies are being developed by several research groups, including those of the EIC, which could lead to the development of quantum devices that are more powerful and efficient than current devices. This is due to their ability to store and process information in a way that is fundamentally different from classical devices.

High potential technologies and the EIC portfolio

The enabling environment created by the EU promotes the advancement, responsible use, and equitable distribution of quantum technologies, which in the long run will lead to societal and economic benefits. The key trends and activity in this area can be summarised as follows:



QUANTUM SENSORS

Quantum sensors measure physical properties including temperature, magnetic field, gravity, and rotation, with extreme sensitivity. They have many advantages compared to classical sensors, for instance: better, safer autonomous navigation of vehicles on the ground, in the air and at sea; detailed and accurate medical diagnostics imaging with lower cost and fewer potential side effects for patients; more accurate and less vulnerable guidance systems in space and underwater; reliable detection, imaging, and mapping of underground environments; deeper, more active sensing of gravitational changes and tectonic shifts.

In other words, quantum sensors have the potential to revolutionise many application areas and it is thus timely to support their development and boost their lab-

to-market transition, a key strand of which will link to the operating conditions and ability to create quantum devices that operate at room temperature. Moreover, quantum sensors are expected to have a great impact in the development of other quantum technologies, such as quantum computers.

The EIC's portfolio features a number of projects taking forward early-stage research focused on the development of quantum sensors covering topics such as quantum metrology, microscopy, and medical imaging. The EIC Transition portfolio currently features projects looking to commercialise the application of such sensors for the remote sensing of environmental gases and pollutants in the atmosphere and security.

QUANTUM SOFTWARE

Quantum computing is not only a technological advancement but also a new general-purpose paradigm for software development, which can radically influence how a software system is conceived and developed. The interdisciplinary nature of quantum computing leads to complexity in the field. For instance, compared to classical computers, quantum computers have very different properties, such as quantum superposition, entanglement, and no cloning. Therefore, classical software engineering needs to be entirely reworked and extended into the quantum domain,

including foundations, quantum computational models, languages and compilers, methods and tools, as well as novel quantum possibilities.

The EIC's portfolio currently features only a limited set of projects focused on software and simulation, but this is a potentially significant opportunity for the EU, including widening countries, as human capital in this area is limited, whereas the US and other countries have programmes for talent acquisition from all over the world, including Europe.

NOVEL QUBITS

Quantum computing is a rapidly advancing field, but large-scale fault-tolerant quantum computers are still in the early stages of development. Quantum computers with a few dozen to a few hundred qubits have been developed, but they are prone to errors and require error correction for most applications. Even quantum communication technologies such as quantum key distribution (QKD), which have reached a relatively high level of maturity and are available commercially, lack widespread adaptation and integration into existing communication infrastructure, and further developments are required.

Qubits currently require extremely low-temperature conditions, constant cooling and enhanced isolation from noise. Start-ups are therefore designing advanced

qubit architectures and control methods to mitigate the practical applications of qubits. Novelities in qubit design, high-fidelity quantum gates and room-temperature controllers allow noise-resilient and decoherence-free functioning. This way, technological innovations open new ways to scale up multi-qubit devices. The impact of novel qubits on quantum technologies will be very high as it can potentially lead into qubits scalability, less extreme performance conditions and better performance of quantum computers.

The EIC has targeted this opportunity through a dedicated Pathfinder Challenge, with the portfolio now featuring several projects focusing on the development of novel qubits.

HYBRID COMPUTING

As long as pure quantum applications are not mature enough for the market, hybrid quantum computing will be one of the most promising approaches for industrial applications. The combination of quantum elements and classic computers optimises both to solve highly complex problems. Hybrid systems adopt quantum power for various applications, including investment projection, route optimisation, city planning, energy distribution, and more. While waiting for the full-scale deployment of quantum computing, hybridisation provides early access to quantum computing for business problems. The impact of hybrid quantum applications on different

technology areas and applications is expected to be very high and Europe is already very active in this area. This important field has been supported by the European High-Performance Computer Quantum Simulator hybrid (HPCQS) initiative.⁸ This initiative seeks to integrate and couple two quantum simulators, each capable of controlling more than 100 qubits, with two existing European Tier-0 supercomputers, and deploy an open European federated hybrid HPC-QS infrastructure that will provide non-commercial cloud access to public and private European users. To date, there is limited EIC activity in this area.

Conclusion

The EIC and its funding instruments are playing a key role in helping the European quantum ecosystem to transfer European innovation from lab-to-fab and specifically support European start-ups and SMEs to scale up and further develop the highest potential quantum technologies with full potential. So far, the EIC has invested in twenty outstanding European quantum start-ups all over Europe, which have strived for larger investment rounds. Several EIC quantum beneficiaries have received investment from co-investors including venture capital funds, impact investment funds and corporate venture funds. The EIC will look to build on these efforts, attracting more private investments to Europe and nurturing an ecosystem of quantum researchers and entrepreneurs.

SUSTAINABILITY OF MICROELECTRONIC DEVICES BASED ON NOVEL MATERIALS AND DESIGNS

What's at stake

Electronics is everywhere and the global demand for electronics-embedded products continues to increase. By 2024, this will amount to a staggering 35 billion Internet of Things (IoT) devices installed and connected worldwide, with the wider market for electronic goods expected to double by 2050.

The EU has under the Chips Act⁹ set an ambitious goal of increasing its share of the global electronic chips market to 20% by 2030, ensuring European sovereignty in certain strategic value chains. Delivering against these ambitions will require a shift towards more sustainable electronics to reduce the demand for energy and water in manufacture, more careful management of energy consumption in the use of digital technologies including artificial intelligence and edge

computing and a reduction in / shift from the use of rare earth metals, which are both finite and generally sourced from outside Europe. Furthermore, growth in the EU's market share will require diversification beyond its two biggest markets for home-grown electronics which centre on mobility (mostly but not only automotive) and industry.

However, semiconductors have a well-established and complex value chain that is difficult to break. The substitution of current silicon-based approaches is extremely complicated and in general, needs high investment and long development times. Efforts must span fundamental understanding of physics and breakthrough ideas though to their commercialisation by start-ups.

Related identified topics in Chapter 1

- 3D Interconnects based on nanomaterials
- + Flexible, tunable, or reconfigurable metasurfaces
- + Electronics based on biomolecules
- + Organic electronics

High potential technologies and the EIC portfolio

MATERIALS AND PROCESSES FOR SUSTAINABLE ELECTRONICS

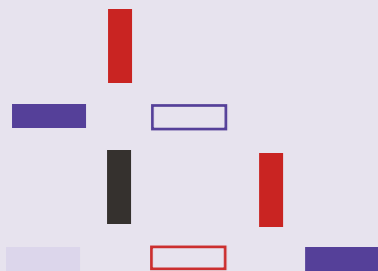
This focuses on the development and use of novel materials and processes with lower environmental impacts. The EIC's portfolio already features projects that, for example, use electronics based on biomolecules, such as protein-based solutions, PRINGLE¹⁰, hybrid organic interfaces, PROGENY¹¹, and 3D-Biofabricated high-performance DNA-carbon nanotube digital electronics 3D-BRICKS.¹² Such efforts were further re-enforced through a Pathfinder Challenge in 2022 focused on DNA digital data storage.

Novel manufacturing processes from etching-based to additive 5D Nanoprinting¹³ are also being explored, alongside efforts to reduce energy and / or water consumption and avoid the use of certain harmful chemicals e.g., by using complex chemical reaction networks for breakthrough scalable reservoir computing, using photo-piezo-actuators based on light sensitive composite, and using mixed ionic and electronic transport in conjugated polymers. While many of the approaches under consideration are at the earliest stages of R&D, the potential for exploitation in the longer term appear promising.



ISABEL OBIETA VILALLONGA

EIC Programme Manager for Responsible Electronics





NOVEL DEVICES WITH REDUCED ENERGY CONSUMPTION

The EIC is supporting early-stage research through the Pathfinder scheme to improve the understanding of phonons TOCHA¹⁴ and other particles that could help reduce energy consumption and / or heat dissipation issues. Devices with reduced energy consumption are particularly relevant for edge computing and IoT applications and, to this end, the applicability of emerging research results and the scalability of the associated processes to specific devices are also being analysed to accelerate commercialisation.



INTEGRATION OF DEVICES

2D materials and photonic integrated circuits show considerable potential in reducing the energy consumption of devices. Approaches for novel interconnections such as under FVLLMONTI¹⁵ and efficient packaging solutions under ORIGENAL¹⁶ also need to be explored, and recyclability and lifetime extension should be analysed holistically. Moreover, issues surrounding reliability need further analysis.

Conclusion

Global and European policy ambitions are pushing the electronics sector towards more sustainable and circular approaches that will decrease the environmental impact of the sector and the resulting products. Sustainable electronics have the potential to create new business opportunities for European industry, which is in turn vital for European competitiveness, sustainability and security, and the EIC will build on its current portfolio through a new Pathfinder Challenge in 2023 focused on supporting the shift from fossil-based materials to bio-based materials, and on the use of material and energy-efficient manufacturing processes, including a decrease in the use of critical raw materials and hazardous chemicals.

However, while sustainability considerations for the sector are becoming more prevalent, there are also limitations to its development due to the high levels of risk, the long-term nature of investment returns, complex supply chains with high barriers to entry into a well-established high performing sector, and the scale of the capital required. Furthermore, as many of the promising approaches under consideration by the EIC are at a low Technology Readiness Level (TRLs), efforts must be made to maintain support throughout the development cycle and ensure exploitation, by not only tackling performance requirements but also by ensuring the sustainability of all approaches under consideration.

PROPELLANT-LESS TECHNOLOGY FOR ACTIVE DEBRIS REMOVAL (ADR)

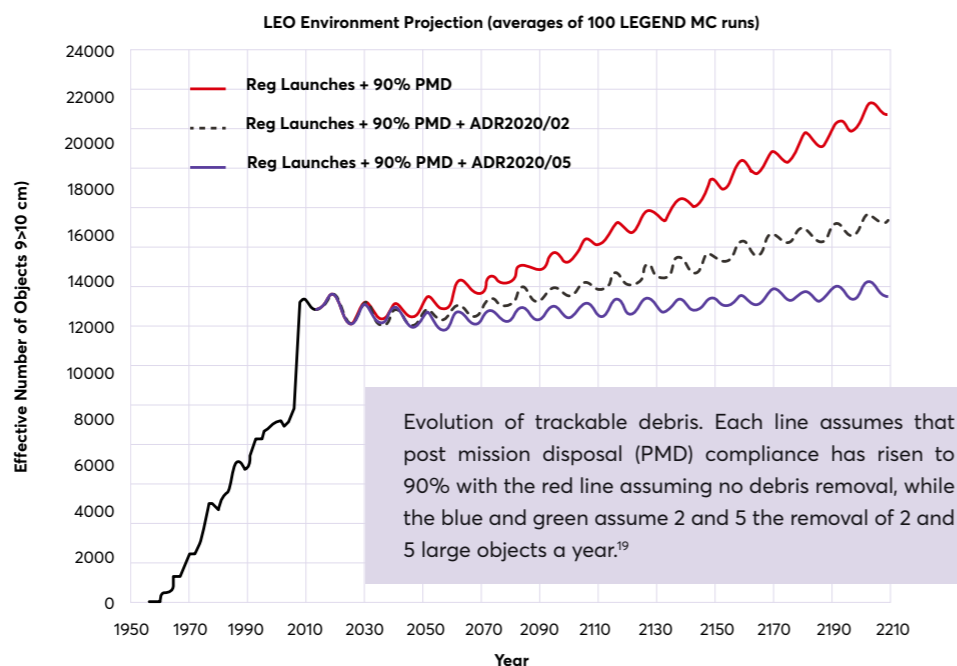
What's at stake

An increasing number of satellite launches and constellations leads to ever increasing space debris: current estimates point to more than 11,000¹⁷ tonnes in total mass of all space objects in Earth's orbit according the latest ESA statistics, with 1,990 rocket bodies and 2,250 dysfunctional satellites. Increasing debris in turn increases the probability of collision. Also known as the Kessler syndrome, this is a scenario under which the density of space debris in certain orbits results in a cascade effect, with each collision generating additional space debris and increasing the likelihood of further collisions.

Collisions between space debris and operational satellites lead

to losses of communication, earth observation and navigation services. Satellite owners incur not only losses of critical space infrastructure, but also revenue from paying commercial customers.

Numerous studies point to a market potential of up to \$980 million by 2031 for active debris removal in space,¹⁸ as debris above 650km up to 800km orbits may take up to 100-150 years to de-orbit. With the need to sustain the usability of Earth's orbits, space debris remediation, covering moving, removing or reusing debris is becoming critically important, as demonstrated by the figure below, which shows the effect of space debris removal over a 200-year timespan.



STELA TKATCHOVA

EIC Programme Manager responsible for Space systems & technologies

Today a range of remediation approaches are under consideration, such as active debris removal and reusing space debris. There are number of de-orbiting technologies, such as involved de-orbiting mechanisms, the use of magnets or robotic arms, nets, harpoons, and others.

However, there are also green de-orbiting solutions, such as tethers, space-based lasers and solar sails, referred to as propellant-less technologies. These offer a number of advantages: firstly, a significant cost saving in terms of mass, due to the absence of a propellant and in the use of natural resources. Secondly, unlike propellant-based technologies, their lifetime is not limited by the amount of propellant onboard. Finally, some propellant-less technologies like Electrodynamic tethers (EDTs) operate passively, typically resulting in simple and light systems.

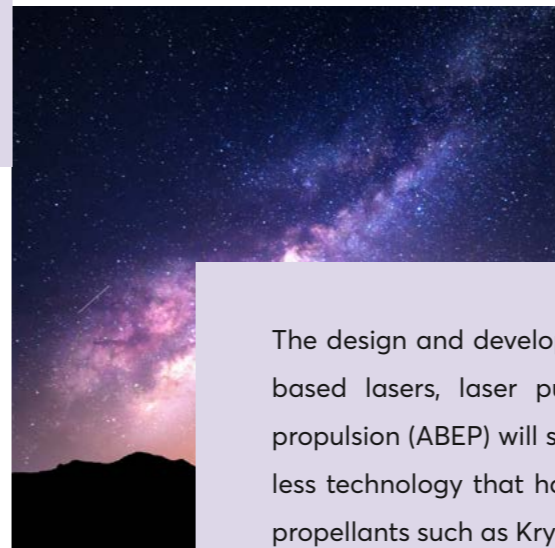
Such systems could also lead to a reduction in space debris and the development of technologies enabling greater European autonomy, thanks to a reduced dependency on imported propellants.

In the long-run, approaches for in-space recycling of space debris such as rocket bodies, defunct satellites and fragments of old satellites are also likely to emerge. These will enable the conversion and transformation of debris into valuable in-space resources such as fuel to ensure long-term orbital sustainability. In-space recycling and the reuse of space assets in orbit could also enable the circular reutilisation of resources in Space Assembly and Manufacturing (ISAM) markets, that will ensure efficient approaches to reutilising and / or removing space debris.

Related identified topics in Chapter 1

- **Active space debris removal and recycling:** The development of green, compact and affordable concepts for active space debris removal and recycling to reduce the space debris growth. Removal approaches considered include the use of magnets, de-orbiting mechanisms, nets, harpoons, tethers, space-based lasers and solar sails. The most promising green and affordable concepts are tethers, space-based lasers and solar sails, as they do not require the use of chemical propellants. In the longer-run various concepts for in-space recycling and the reuse of rocket bodies, defunct satellites or fragments of old satellites will emerge. These include breaking down materials for in-space manufacturing or reusing spacecraft components (e.g., tanks, structural components, electronics) in new ways. This nascent capability will result in numerous applications, ensuring space debris reduction for the benefit of future exploration missions.
- + **Active space debris removal and recycling**

CHAPTER 2 / SPACE



High potential technologies and the EIC portfolio

The design and development of de-orbiting technology, such as tethers, solar sails, space-based lasers, laser pushed light sails, aerobraking or atmosphere breathing electric propulsion (ABEP) will support the emergence of disruptive and game changing propellant-less technology that have a reduced environmental impact and dependency on chemical propellants such as Krypton and Xenon.

Pathfinder (TRL 1-4)

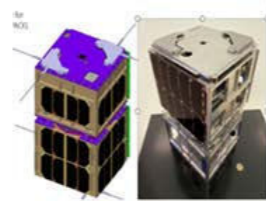
1. E.T.PACK
2. DISCOVERER



Courtesy: DISCOVERER project - SOAR

Transition (TRL 4-6)

1. E.T. PACK-F
2. BMOM



Courtesy: E.T.Pack-F project – EIC Transition

Accelerator (TRL 6-9)

1. Aurora Plasma Brake (APB) (Deorbiting device)
2. Endurance (In-orbit Satellite servicing)
3. CASSIOPEE (Space debris identification with optical stations)



Courtesy: CASSIOPEE - Share My Space

ELECTRODYNAMIC (EDT) TETHERS

These are long conducting wires deployed by a tether spacecraft. Once an EDT is deployed it operates on electromagnetic principles. Thanks to an electrodynamic effect, the tether captures electrons from the ambient plasma passively. A small electron emitter emits the electrons back to the plasma, yielding a steady electric current. In the case of the EIC funded E.T.Pack project²⁰, the EDT produces a propulsive force by using the natural space environment that includes

the geomagnetic field and the ambient plasma and a bare-photovoltaic tether, enhancing its performance by harvesting energy from the Sun. The action of the geomagnetic field on the tether current gives a Lorentz force which in low earth orbit is the drag force that produces the re-entry (deorbit) of the spacecraft, while providing power for on-board use. The E.T.Pack project is developing a de-orbiting kit that will aim to remove the upper stages of launchers or satellites.

ATMOSPHERE BREATHING ELECTRIC PROPULSION (ABEP)

At very low earth orbits (VLEOs), spacecraft are exposed to strong aerodynamic drag. To maintain an orbit at these altitudes the spacecraft should constantly generate thrust to compensate for continuous drag. The use of ABEP for VLEOs enables the collection of residual gases and their use as a propellant for an electric thruster and appears to be a promising approach for future space missions that are also sustainable due to In

Situ Resource Utilisation (ISRU) and enhanced payload performance due to low altitude operations.²¹ Under the EIC Pathfinder funded DISCOVERER project,²² the team has investigated ABEP under five mission scenarios: circular orbit maintenance, orbit raising and de-orbiting around Earth, elliptical orbit maintenance around Earth, circular orbit maintenance around Mars and space tug and refuelling missions on Earth and Mars.

SPACE-BASED LASERS

The use of space-based laser beams to push space debris or a satellite and move it to a lower orbit could permit faster de-orbiting. The benefits of a space-based laser is that it does not pass through the atmosphere and avoids beam deformation. There are a number of concepts looking at the use of space-based lasers to perform debris remediation. For example, in the US

concepts such as the Laser Ablative Debris Removal by Orbital Impulse Transfer (L'ADROIT) look at using space-based lasers for removing small debris from 1-10cm in Low Earth Orbits. Others such as Japan are investigating the possibility of using space-based lasers to de-tumble satellites or even use small lasers on board small satellites for de-orbiting large debris.

SOLAR SAILS

This concept uses the radiation pressure from Sunlight reflected on large sails. The sail captures the momentum of photons and pushes the spacecraft forward without using any fuel. Solar sails can be used also for de-orbit space debris. Bottom-up solar sail innovations have emerged with the "Gamma Alpha" mission and the Drag Augmentation Deorbiting System (ADEO) breaking sail.²³ The Gamma Alpha mission launched a

6 U Cubesat with 12kg mass and sail on board, with the objective to deploy and control the sail in space. The ADEO mission is a technology

demonstrator testing a large aluminium-coated polyamide membrane attached to four metallic booms, following its jack-in-a-box deployment.²⁴

Conclusion

The design and development of groundbreaking de-orbiting technology will support the emergence of game changing propellant-less technology. Each will have different applications, such as active debris removal of dysfunctional satellites or of large debris, orbit raising/correction of satellites/space tugs and station-keeping.

However, to date, few of these propellant-less technologies have reached a prototype and in-space technology demonstration level. The EIC space portfolio, building on the legacy of the FET-OPEN has under Work Programme 2023 sought to support European space companies take advantage of this opportunity, through an Accelerator Challenge to scale up ideas in collision avoidance capabilities; the collection, recovery and transformation of space debris; and mature in-orbit satellite servicing and active debris removal.

These innovations will secure green de-orbiting technologies and markets, by ensuring the usability of earth-orbits, address the need to tap into in-orbit satellite markets and further grow the innovative in-space servicing activities, extend satellites lifetime and generating revenue for satellite owners.

FUELS AND CHEMICALS FROM THE SUN – A POTENTIAL GAME CHANGER FOR OUR CURRENT ENERGY AND PRODUCTION SYSTEM

What's at stake

The current energy crisis underlines our over-dependence on fossil resources across all industrial sectors: energy generation and the provision of everyday goods is heavily reliant on the steady extraction and utilisation of fossil resources, which serve both as a source of energy and of carbon, e.g., to produce polymers for plastics.

Removing CO₂ from the atmosphere or from industrial waste streams and turning it from a pollutant into a valuable resource coupled with renewable energy conversion technologies, such as photovoltaics offers a route out of this dependency on fossil fuels and their associated impacts on the climate and economic security.

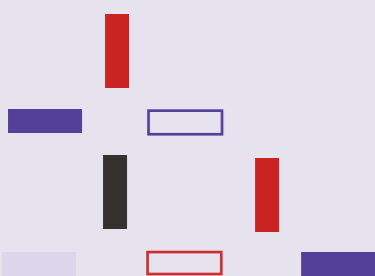
A peculiarity of the field of renewable fuels and chemicals is the breadth of technology options under consideration. Often, these approaches have emerged from different

research communities, which are not necessarily connected and may thus employ different terminology and language to describe process and device performances.

The EIC actively supports EU initiatives (mainly the European SUNERGY²⁵ initiative, a merger of the finished SUNRISE and ENERGY-X coordination and support action) to create a European innovation ecosystem around solar fuels. The development of a common vision and roadmap around solar fuels and chemicals are among its main goals. At international level, the Mission Innovation IC5 2.0 – Sunlight to X task force brings together governmental representatives around the topic under the leadership of the European Commission. For Carbon Capture and Utilisation, CO₂ Value Europe – an international and non-profit organisation - unites the respective communities.



CARINA FABER
EIC Programme Manager responsible for renewable energy conversion and alternative resource exploitation



Related identified topics in Chapter 1

- + Biotechnology-driven solar energy conversion into fuels and chemicals
- **Artificial photosynthesis** (AP) involves using light energy to drive the conversion of CO₂ and water into fuels and chemicals. AP is a promising technology for producing sustainable and cost-effective manufacturing processes.
- + Full circularity with waste as a resource for fuels and chemicals
- + Capturing greenhouse gas from air and using it to produce sustainable and cost-effective manufacturing processes.
- + Advanced materials for scalable PV

High potential technologies and the EIC portfolio

There are number of complementary approaches that can be adopted and deployed at scale to achieve a climate-neutral Europe by 2050:



ARTIFICIAL PHOTOSYNTHESIS

Stand-alone devices directly converting sunlight to produce gases and liquids take their inspiration from nature. As in the case of photosynthesis, solar energy, water, and abundantly available molecules such as CO₂ and nitrogen are converted into a manifold of products, including drop-in fuels and platform chemicals.

The field remains very rich in terms of technological approaches and could also support a move from centralised production systems to a model meeting local needs through local production from local resources, thereby enabling regional resilience in terms of energy and goods.

To achieve a higher efficiency, and therefore a smaller land footprint compared to photosynthesis, there are currently two main routes:

- **Power-to-X, carbon capture and utilisation technologies:** These provide a solution in the short and medium term. To go from the resource (i.e., the Sun) to the final product, multiple steps must be carried out, including renewable electricity production, carbon dioxide capture, electrolysis and thermochemical or biological upgrading. The resulting products are called efuels, electrofuels or powerfuels and large pilot plants are being developed to demonstrate industrial feasibility. Besides the use of renewable electricity, solar heat can also drive the splitting of water and the reduction of CO₂. These renewable heat-based technologies are currently at an intermediate technology readiness level with certain large-scale pilot demonstration projects under development. The ambition to achieve full circularity with waste, such as waste heat or industrial waste gas streams, as a resource for fuels and chemicals has also gained increasing importance in recent times.

Solar-to-X technologies: These consist of single devices covering the whole chain, from light absorption to chemical conversion. Approaches such as biotechnology-driven solar energy conversion bare the promise of highly reduced balance-of-plant requirements compared to the indirect approaches. Not requiring electrical grid infrastructure, it is especially adapted for remote locations. Currently, these technologies are at a low technological maturity level. In view of the urgent need to provide solutions to the energy and climate crisis, the current ambition here is to quickly marry concepts with engineering and to bring the field to the next step, through the development of scalable prototypes.

The EIC's thematic project portfolio on renewable fuels and chemicals includes relatively mature, electricity-based technologies to provide a pragmatic solution in the short-to-medium term for hard-to-abate sectors. The challenge is to de-risk these technologies for their future widespread industrial application. These projects under the EIC Pathfinder have proven the

general feasibility and attractiveness of technologies converting sunlight, water and carbon dioxide into fuels and chemicals including the Aleaf,²⁶ Diacat,²⁷ SoFia²⁸ or Licrox²⁹ projects with some of the recently completed projects offering valuable insights on the state-of-the-art of the field and future requirements.

ELECTRIFICATION

The provision of electricity for industry and wider society has been enabled by significant technological progress in photovoltaic technology alongside associated cost reductions. Scalable PV technology using novel advanced materials to facilitate the production of renewable electricity and its direct use in electrical engines, for example, is a very efficient way of deploying renewable energy. However, there are sectors and applications where energy supply must be very dense and compact as in the case of cross continental air travel, or where there is a need for carbon-containing

resources for the fabrication of goods. Sectors such as chemicals cannot be simply "decarbonised", rather "defossilised" by providing fossil-free feedstock from abundantly available, local resources. Renewable fuels and chemicals³⁰ are an important route towards defossilisation for sectors that are hardly electrifiable.³¹

The EIC Accelerator supports for example INERATEC GmbH with its ImPower2X project³² for the renewable production of aviation fuel.

FROM RENEWABLE HYDROGEN TO COMPLEX HYDROCARBONS AND AMMONIA

The most prominent example of a renewable fuel is renewable or green hydrogen obtained via the electrolysis of water. This pathway is well supported by the European Commission in particular via the Clean Hydrogen Joint Undertaking,³³ and in the EU Member States via various national hydrogen strategies. However, producing complex hydrocarbons or ammonia by combining this hydrogen with carbon oxides or nitrogen to obtain a range of chemicals such as renewable ammonia and renewable methane, is a challenge.

The stability of CO₂ and molecular nitrogen makes their conversion into fuels and chemicals an additional technical challenge with a requirement for significant increases in the demand for renewable energy. The resulting products could however provide seasonal storage of renewable energy and enable energy resilience by relying on local resources. The variety of end products will enable multiple sectors to be addressed with the processes and products customised to the local environment, with respect for the locally available resources and specific product needs.

The EIC Pathfinder Challenge focused on the Green Hydrogen portfolio brings together nine projects around the production of hydrogen from water and aims to contribute to a future sustainable and cost-efficient hydrogen supply. This includes Electrochaea GmbH with the Echaesa project³⁴ on the biological conversion of hydrogen and carbon dioxide into methane. EIC Transition has also supported the development of an electrolyzer directly turning water and CO₂ into the platform molecule carbon monoxide within the

SolarCO2Value project.³⁵ The EIC Pathfinder supported among others the FuturoLEAF³⁶ project exploring the production of sustainable chemicals from water and CO₂ via cyanobacteria. However, a cost-efficient and sustainable supply of CO₂ through, for example, direct carbon capture and conversion is crucial for the economic viability of such processes and more work is needed to improve the capture of CO₂ to drive down energy costs.

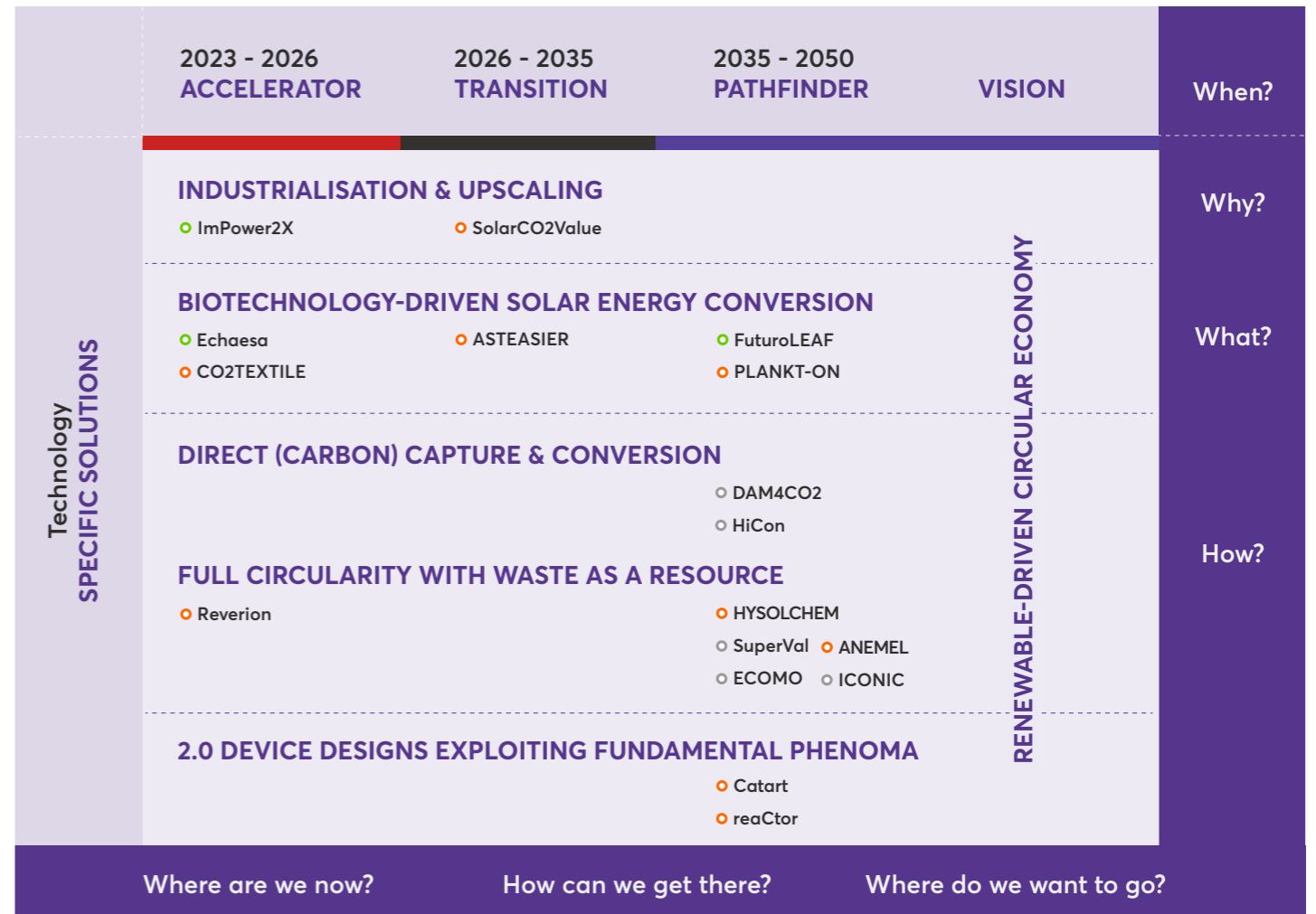


Figure 1: Clustering of selected EIC projects to showcase current and emerging trends in the field of renewable fuels and chemicals
(Orange: running projects; Green: completed projects; Gray: projects under preparation)

Conclusion

There is a clear political will to establish a carbon-neutral future running on renewable energy sources. Political, societal and ecological drivers from now to 2050 include increasing our renewable capacity, decreasing our fossil-fuel dependence and scaling-up low-carbon industrial processes.

Short to medium-term efforts could focus on the valorisation of waste carbon oxides from industrial point sources, and the production of sufficient quantities of green hydrogen which can then be combined with these carbon oxides and nitrogen from ammonia and a range of other valuable hydrocarbons using renewable electricity to de-fossilise diverse sectors and achieve industrial symbiosis.

In the longer term, standalone devices producing a range of molecules from sunlight, water and carbon dioxide/ nitrogen could support decentralised production and the strengthening of local economies.

The timely development and upscaling of these technologies will require clear legislation on renewable energy production and CO₂ - unclear legislation on renewable CO₂ sourcing and carbon taxing are the major bottlenecks for profitable business cases and to retain private investments. In addition, a peculiarity of this field are high CAPEX investments when passing from the prototype to the industrial demonstration scale, often involving several players in the value chain, covering the provision of carbon dioxide, renewable energy, conversion technologies and refineries. All the bricks of the value chain have to be optimised with respect to each other to achieve cost and energy-efficient processes, and this must be coupled with the de-risking and market creation strategy enabled by public funding.



FRANCESCO MATTEUCCI

EIC Programme Manager responsible for advanced materials for energy and environmental sustainability

ACCELERATED DISCOVERY OF NOVEL MATERIALS TO SUPPORT THE ENERGY TRANSITION

What's at stake

The world must run toward a net-zero emissions economy. This will require fundamental technology shifts across industries and product value chains at an unprecedented speed. Advanced Materials (AMs) are materials that are processed, synthesised, fabricated, and manufactured to feature performance properties exceeding the corresponding properties of already existing materials.³⁷ They are an enabling technology to accelerate the transformation of the European energy system and provide game-changing solutions, potentially driving the green and digital transformation.^{38, 39}

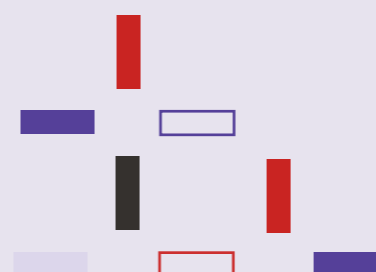
Europe has a very limited presence in the value chain for mining, refining/processing, and the trade of critical raw materials (CRMs), defined as raw materials of both high economic importance and high supply risk.⁴⁰ Some of these are also enablers for many renewable energy technologies.⁴¹

Drastic measures are required to ensure adequate manufacturing capacities for net-zero technologies throughout the whole value chain, from the product down to raw materials, reducing

Europe's dependence on third countries to access CRMs. Not taking urgent action will pose a considerable risk for the EU's future energy security and its decarbonisation ambitions.^{42, 43} AMs for energy without CRMs will merit more and more attention to prevent nation's controlling CRM production having disproportionate economic and geopolitical power.

Europe should focus on the discovery of AMs without CRMs for energy application, in addition to applying a circular economy approach to the mining, exploration and extraction activities of CRMs.

The EU ecosystem of innovation, including EU public and private research organisations as well companies, needs to increase and accelerate the investments dedicated to the development of modern approaches for the discovery of AMs. It will have to combine a bottom-up exploration approach to materials discovery (mostly addressing the fundamental aspects of materials science with a strong scientific impact), with a top-down exploitation approach, based on solving well defined problems with a strong economic impact.



By way of example, current state-of-the-art green hydrogen production methods use water electrolysis. The main technologies for water electrolysis are: Alkaline, Polymer Exchange Membrane (PEM-EL), Solid Oxide (SOE) and Anion Exchange Membrane (AEM). Due to its operational responsiveness and flexibility – enabling higher efficiencies when dealing with the ups and downs of variable renewable energy sources (RES) as well as to its higher output pressure and small size, PEM-EL is currently the most promising water electrolysis technology to be coupled with RES. However, one of the main barriers to reducing PEM-EL cost is the use of CRMs for the different components of the electrolyzers, such as electrocatalysts, membrane-electrode assemblies (MEAs), diffusion layers, stacks, etc. PEM-EL's electrocatalysts rely on platinum group metals (PGMs) such as platinum and iridium. Based on current technology and worldwide iridium production, the demand for iridium for PEM-EL cells will be a bottleneck in the realisation of the EU's planned production in the coming years.^{44,45} The urgent need to find alternatives is underlined by the surge in patents related to non-noble metal electrocatalysts, indicating that R&D is struggling to find new solutions to mitigate the effect of material scarcity.^{46,47} If no alternative catalysts to PGMs can be discovered, their availability and prices will affect the speed at which the renewable hydrogen market can grow. Similar considerations apply for the use of rare earth elements and cobalt in high temperature solid oxide electrolysis.⁴⁸

The potential for new CRM-free materials discoveries is however high, as the periodic table offers numerous elements which can be combined in multinary material systems, offering an almost unlimited, and yet mostly unexplored search space for new materials.⁴⁹

The traditional materials science approach (i.e., experimentation, theory, computation⁵⁰) remains too slow, costly, and highly inefficient to discover, design, develop, manufacture, and deploy increasingly complex, safe-and-sustainable-by-design AMs.⁵¹ By applying data and computer science to materials research, so called materials informatics, we now have a way to accelerate the materials lifecycle from discovery to deployment.⁵² The use of interlinked digital tools enables the fast screening of a list of predicted materials compositions and also understand the effects of the short (i.e., light absorption) and long-term (i.e., structural imperfections) interactions.⁵³ It combines empirical data, obtained experimentally, with theoretical data, obtained computationally, frequently starting from different databases (i.e., computation-based materials databases). Thanks to innovative methods such as machine learning as well as significant improvements in computing power (i.e., high performance computing), computational materials research is shifting from explaining properties to predicting new materials. Examples of different applications of data-driven and physics-informed Artificial Intelligence for the modelling of AMs span from text mining for data extraction from different literature databases to the identification and computation of descriptors that strongly correlate with the targeted complex materials properties, to surrogate modelling of more complex simulations to create digital twins that faithfully reproduce the response of the actual material.⁵⁴ This is the dawn of a new era, where the combination of computational materials science, machine learning and high-throughput methods,⁵⁵ concurrently used according to a multi-scale approach,⁵⁶ will allow the AMs ecosystem of innovation to reach, among others, the ambitious goal of developing CRM-free AMs to support Europe's energy transition.



Related identified topics in Chapter 1

- Non-CRM electrocatalysts
- + Metal-air and flow batteries
- + Advanced materials for scalable PV

High potential technologies and the EIC portfolio



The EIC is supporting the discovery of advanced materials for energy through its evolving portfolio of activity. Projects funded through the EIC Pathfinder Challenges focus on 'Novel routes to green hydrogen production', 'Carbon dioxide and nitrogen management and valorisation', and 'mid to long term and systems integrated energy storage' are now working towards approaches that avoid or limit the use of toxic and critical raw materials, while implementing a circular life cycle approach. A number of these projects are employing interlinked digital tools to discover advanced materials.

The increasing use of these enabling technologies will help leverage prior knowledge – stored in databases or extracted by computational means from electronically available literature – to enable the identification of advanced materials and associated production processes in support of the EU's policy ambitions for the energy transition.

COMPUTATIONAL MATERIAL SCIENCE

The field of computer simulations of materials is a central pillar in modern materials science. It can enable understanding of the complex interplay of interactions and phenomena considering the many effects happening from very small (i.e., quantum interaction) to large length scales (i.e., macroscopic properties) in real materials.

MACHINE LEARNING (ML)

ML is a subset of Artificial Intelligence that contributes markedly to materials informatics, by using a range of algorithms to build models based on patterns in data that can be used to make predictions^{57, 58, 59} starting from experimental and computational data. ML has recently been shown to accelerate discovery and optimise functional materials for real world applications, such

as catalysts, photovoltaics, optoelectronic materials, and thermoelectrics^{60, 61, 62, 63, 64, 65} by complementing expensive, time and resource-intensive first-principles electronic structure calculations to provide insights into complex, multidimensional structure–property relations.^{66, 67, 68, 69, 70, 71, 72, 73, 74}



HIGH-THROUGHPUT METHODS (HTM)

A range of high throughput approaches such as high-throughput synthesis (HTS), high throughput characterisation (HTC) and high-throughput data analysis (HTDA) are accelerating the discovery of advanced materials for energy.

Among the many HTS approaches, worth a mention are: a) inkjet printing used to prepare candidate advanced materials libraries, as in the case of Oxygen Reaction Reduction (ORR) electrocatalysts,⁷⁵ or b) sputtering of thin film libraries, used as a unique platform to perform

combinatorial synthesis, and enabling fast materials screening.⁷⁶ The construction of autonomous HTM platforms, with the ability to assist materials scientists from the selection of synthetic routes to the synthesis and characterisation of the molecules and materials is still a work in progress. HTC techniques remain time consuming, when studying local properties such as the composition or crystal structure. In this sense, HTC with the ability to study materials libraries in parallel have yet to be developed.

MULTI-SCALE MODELLING APPROACH

This approach with derivate algorithms describes behaviour at a given length scale based on the physics at a finer scale (electrons, atoms, molecules of mesoscale such phases or grains) differently from conventional phenomenological paradigm, which describes material behaviour directly at a coarser scale. This multi-scale approach provides a link between fine and coarse scales potentially accelerating the development of advanced materials.⁷⁷ In fact, such an approach allows one to

concurrently design new advanced materials while designing the industrial process where the materials will be produced or used. To give an example, in the case of new catalysts it is worth designing the most suitable pelletising process, the type of reactor where the catalyst should be placed, the regeneration process, etc., and finally evaluate all aspects that contribute to determining the economic feasibility of the advanced materials under consideration.

Conclusion

To remain competitive in the transition to a green and resilient energy system, and to overcome the challenges of a resilient and sustainable society, Europe needs to accelerate the discovery of scalable advanced materials and processes for energy without CRMs.

Identifying and effectively balancing the trade-off between technical performance and the nature, or criticality of, the raw materials in use will enable the development of “marketable” technologies, with component suppliers and manufacturers that will deliver solutions that ensure the security of Europe’s supply of raw material for energy, in line with the EU’s CRM Act.

The EIC, with its hands-on portfolio approach, provides both funding and strategic scientific and business guidance to its beneficiaries, and endeavours to apply enabling technologies to a range of fields such as the generation and storage of energy, renewable H2 production, storage, and use, as well the production of useful chemicals by combining CO2 and Nitrogen compounds. The EIC portfolio approach is a novelty within the European institutions, which promises to deliver ground-breaking research results in the field of advanced materials for energy from basic science to market uptake.



TOWARDS CARBON NEUTRAL AND CARBON NEGATIVE CONSTRUCTION

What's at stake

To accommodate the largest wave of building growth in human history, from 2020 to 2060, data suggests an addition of about 240 billion m² of new floor area to the global building stock, the equivalent of adding an entire New York City to the world, every month, for 40 years.^{78, 79}

Concrete and cement are by far the most widely used building materials. However, cement production in particular accounts for around 8% of global CO₂ emissions. Innovative pathways are thus essential to decarbonise cement and concrete to achieve net-zero emissions by 2050.

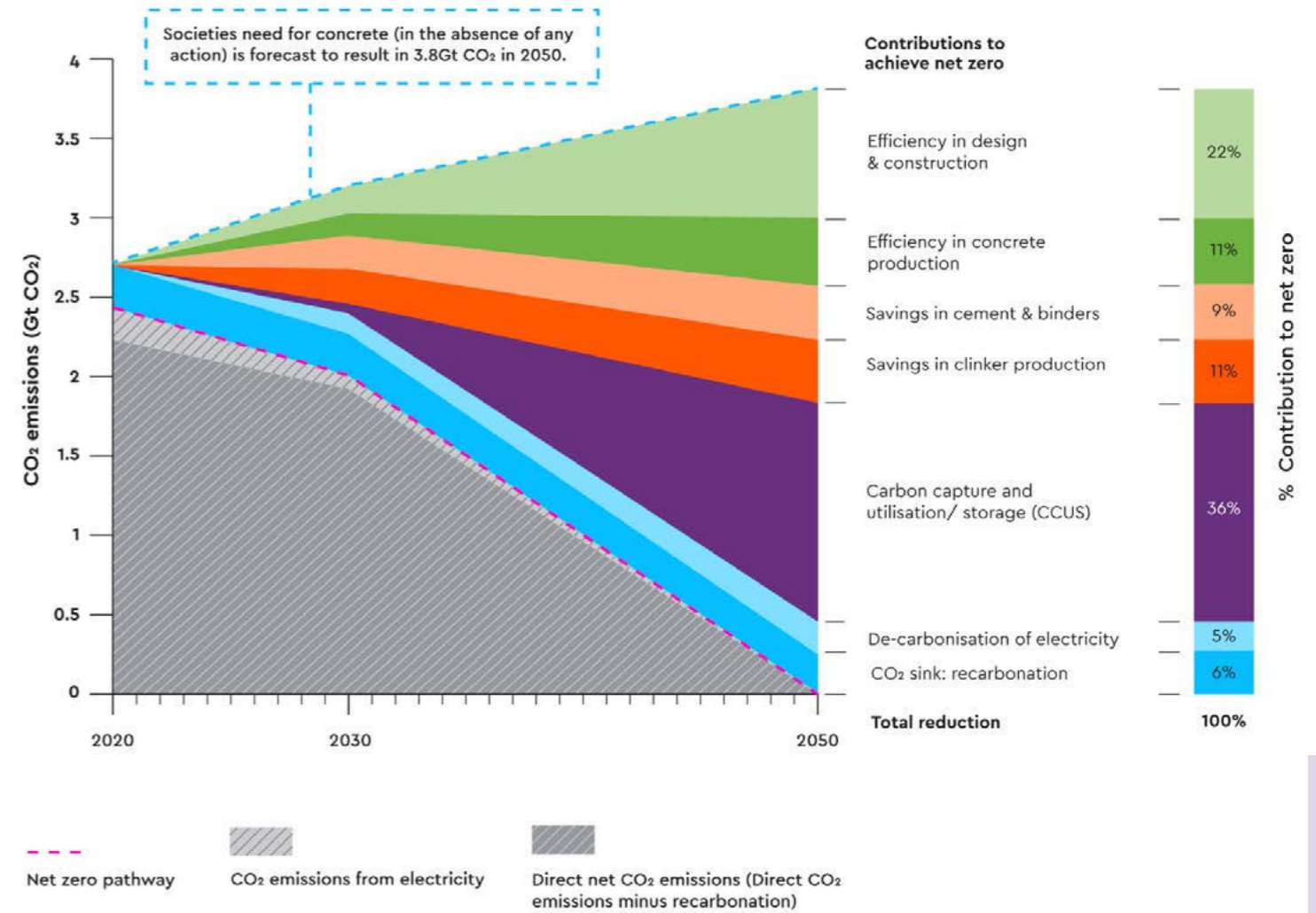
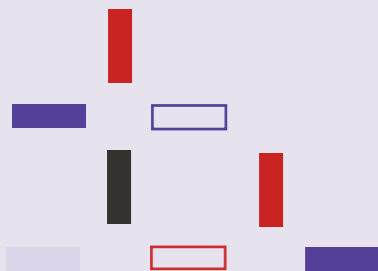
The Figure below summarises some of the approaches under consideration from both the side of supply and demand of cement and concrete to reduce its carbon emissions.

Conventional supply-side strategies for reducing carbon emissions include carbon capture and storage (CCS), renewable fuels, the electrification of kilns, reduction of clinker fraction in cement (SCM, slag, fly ash) and the reduction of cement fraction in concrete (mix design, process optimisation, fillers, admixtures). Emerging supply-side strategies push these strategies even further (e.g., LC3) or aim to substitute hydraulic Portland cement clinker all together. For example, the EIC Accelerator funded start-up, MATERRUP, develops technologies around uncalcined crosslinked clay cement to reduce carbon emissions.⁸⁰ These supply-side strategies are also complemented by demand-side strategies that focus on material efficient design.

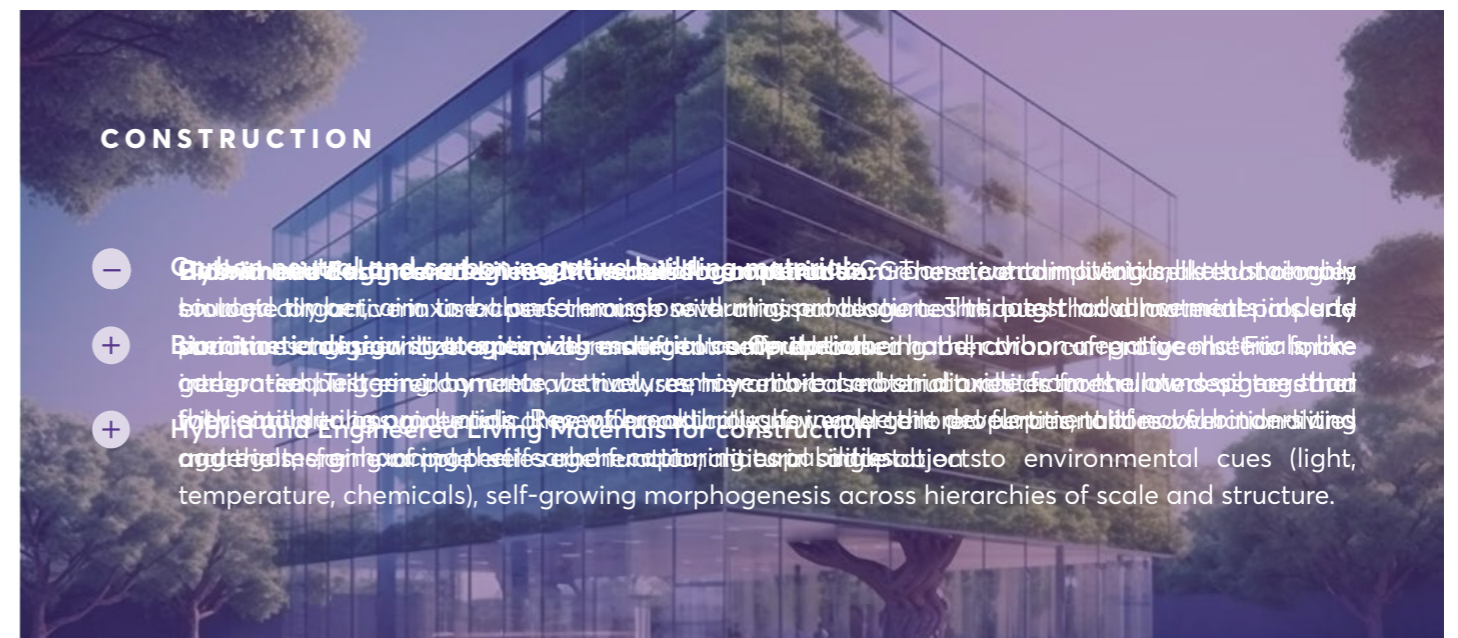


FRANC MOUWEN

EIC Programme Manager responsible for architecture engineering construction technologies



Cement and concrete decarbonisation options^{81, 82}



High potential technologies and the EIC portfolio

CARBON NEUTRAL AND CARBON NEGATIVE BUILDING MATERIALS

Modern concrete is a carefully designed mixture of sand, aggregates, additives, and fillers bonded by hardened cement. Cement is about 10% of the concrete mix and is the high-cost component and largest carbon emitter. The most common form of cement is by far Ordinary Portland Cement (OPC) which is essentially made from limestone (calcium carbonate), clay and supplements at very high temperatures in a cement kiln. The dominance of OPC is a result of the abundance and accessibility of its main mineral ingredients in the earth's crust: an essential factor for all innovations that aim to substitute OPC with alternative materials.

When considering decarbonisation strategies, it is important to draw a distinction between hydraulic cements such as OPC, and non-hydraulic cements. Hydraulic cements harden through hydration reactions between cement and water. Non-hydraulic cements reverse calcination by extracting and mineralising CO₂ from the air in a carbonation process: offering an interesting decarbonization option.

The main approaches for alternative low-carbon cement clinkers are alkali activated binders (geopolymers), reactive belite-rich portland clinker (RBPC), belite-ye'elimite-ferrite clinker (BYF), carbonatable calcium silicate clinker (CCSC), and the use of magnesium oxides derived from magnesium silicates (MOMS). To date, the first four approaches offer interesting albeit incremental improvements to existing processes that have yet to scale. Successful scaling depends among other considerations on local availability of raw materials and competition with other uses for these materials. The fifth approach, MOMS, is being researched but offers great potential for carbon-neutral or even carbon-negative construction in the future.

Research suggests that magnesium-based cements and concrete can potentially provide superior mechanical properties to OPC, which may in turn reduce consumption. Further, basic thermodynamic considerations suggest that the minimum energy requirement to decompose a magnesium-rich mineral by means of a yet unspecified industrial process is about 0.86 GJ per tonne of MgO produced, which is about half of the energy needed for OPC clinker. Further, as magnesium oxide can harden either by hydration (in reaction with hydrated magnesium carbonates) or by carbonation (to give magnesium carbonates), it is conceivable that hardened MOMS-based binders could even become a net carbon sink. As these carbonates are stable and can be stored for a very long time, they offer value of secure "permanence" in (future) carbon markets.

MOMS binders are in the early stages of research and therefore of low innovation maturity. The key unresolved issue for MOMS surrounds the exploration, extraction, and processing of magnesium oxide from magnesium silicate rocks in a cost efficient, energy efficient, and carbon efficient way at an industrial scale. Variations in the composition of magnesium silicate rocks can also pose a challenge for product quality. Novel computational material science approaches (including AI and Machine Learning) may accelerate or even leapfrog developments in this area.

Finally, while global reserves of magnesium silicates (preferably magnesium-rich olivine) are more than sufficient to meet global cement demand, they are much less well-distributed than limestones. Magnesium silicates are often the host rocks for valuable ores (nickel, chromium). Therefore, extracting magnesium silicates from existing mine wastes can be an attractive option to explore further.



BIOMIMETIC AND COMPUTATIONAL DESIGN STRATEGIES WITH NOVEL MATERIALS

Demand-side strategies aim to reduce carbon emissions by designing and using efficient/ alternative materials with low or negative carbon emissions. Here, nature provides much inspiration as it uses few materials in endlessly complex ways unlike humans who use a wide array of materials in relatively simple, but wasteful ways.

The key for this transformation is the symbiotic triad of computational design, digitalised fabrication, and novel materials, where the state of the art is now extending the art of the possible. For example, advanced algorithmically designed 3D-printed floor slabs consume 50% less concrete while computationally designed complex 3D "shell" structures made of a composite of woven fabric and a minimal amount of sprayed concrete also pre-empt the use of wasteful temporary formwork. Hierarchically structured "metamaterials" aim to do even more with less by introducing ever finer hierarchical structuring inside the volume of materials.

The EIC is currently supporting several promising projects in this area. For example, the Pathfinder project "BOHEME" develops bio-inspired hierarchical metamaterials.⁸³ The Pathfinder project "ADAM^2" aims

to introduce microstructures into the Computer Aided Design (CAD) paradigm.⁸⁴ The EIC Accelerator funded start-ups SVELTEDCA PARTNERS⁸⁵ and Odico⁸⁶ are developing digital fabrication technologies to translate visions of complex curved shapes into reality, while Modvion⁸⁷ is developing design and industrialised production technologies that substitute steel for engineered timber in large tubular wind turbine towers.

The degree of sophistication to fully leverage these capabilities has yet to be reached, however. By taking inspiration from nature, which efficiently exploits hierarchically structured metamaterials from the macro- to nanoscale, there is tremendous scope to draw further value and inspiration from the natural pool of proven concepts.

To stimulate more advanced research and innovation in this domain, the EIC has therefore launched two Challenge competitions under EIC Work Programme 2023 targeting both early-stage research and the commercialisation and scaling of more mature concepts.





Conclusion

Supply and demand side innovations which can contribute to carbon neutral construction are now attracting increasing interest and investment from private investors including VCs across the globe. These moves are also underpinned by several roadmaps⁸⁸ developed for the cement industry outlining collective commitments of the world's leading cement and concrete companies to emissions reductions by making more efficient use of cement and concrete, as well as novel processes emitting less CO₂, or even permanently trapping CO₂ in our built environment.

However, breakthrough technologies have to date required decades of R&D and the scale of funding from the public and private sector must scale with the challenges facing the sector as well its sheer size and contribution to our economy. By way of an illustrative example, EU funding of €3.6 million to a consortium of research partners involving the start-up Solidia⁸⁹ under the EU's LIFE programme required over €100m of further private investment in Solidia through fundraising in the US and the EU to complete the development and scale commercialisation of its low-carbon cement technology based on CCSC technology (carbonatable calcium silicate clinker).

Large investments in new plants at different locations will also be required rather than smaller adjustments involving "drop-in" technologies or adaptations of existing cement plants. Further, given that most of the growth in demand for cementitious materials is expected in non-OECD regions like Africa and India "robustness" will need to be built into any innovation from the start i.e., they must be easy implementable at very large scale, at low cost while accounting for the realities of these regions.⁹⁰

SAFEGUARDING EUROPEAN ENERGY SECURITY AND NET ZERO TARGETS

What's at stake

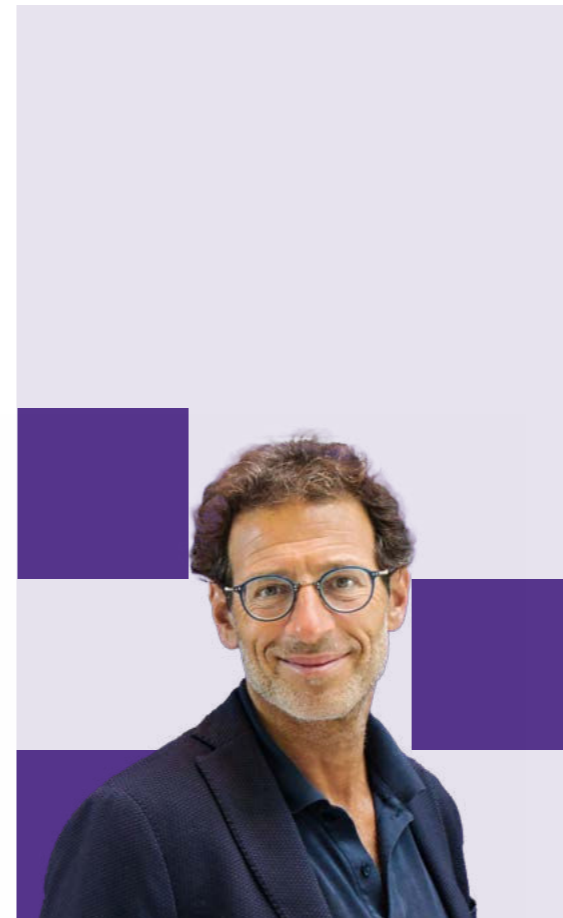
Global energy systems cannot be optimised in isolation, or with one solution that fits all systems and needs. There is for instance an inextricable link between water and energy use (the so-called water-energy nexus), with large amounts of energy needed for water extraction, treatment, irrigation on one side, and for energy generation (now including hydrogen production) on the other.⁹¹ Such dependencies are also evident in the trade-off of natural resources for food and energy production.

The demand for energy from fossil fuel also continues to increase (alongside corresponding CO₂ emissions) for the production of materials and chemicals in critical and

hard to abate sectors such as steel and other metals, cement and non-metallic minerals, or plastic and rubber.^{92, 93}

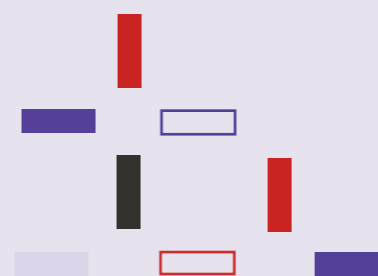
Addressing these demands with the associated security of supply issues and de-industrialization risks due to increasing energy costs, calls for visionary innovations in the area of energy efficiency, in the use of domestic resources and circular approaches to materials and processes, which must in turn be complemented by an overarching system level thinking to decarbonize the whole supply chains and integrate energy – water – and land use including considerations for biodiversity.⁹⁴

⁹⁵



ANTONIO PANTALEO

EIC Programme Manager
responsible for energy systems
and green technologies



+ Full circularity with waste as a resource

- Advances in recovery of waste heat and energy harvesting

+ Self-aware and conscious AI systems

+ Self-aware and conscious AI systems

+ Mineral fertilizer free crops

+ New chemical solutions for energy storage and carriers

High potential technologies and the EIC portfolio

There are three pillars of activity with associated technologies to facilitate a sustainable transition to a net zero economy with energy security.



TECHNOLOGIES IMPROVING EFFICIENCY AND ENERGY DEMAND

Recent figures from the IEA's 2019 'World energy balances' report point to a dramatic overall loss of 64% of primary energy in its conversion to heat and useful work,⁹⁶ as confirmed also by other researches.⁹⁷

This underlines the urgent need for higher efficiencies, which could be delivered through a range of approaches including:

- Waste heat recovery and flexible power generation:** waste heat, mainly produced from burning fossil fuels, represent a major fraction of this two thirds of all primary energy rejected. The EIC has funded several successful SMEs such as Kraftblock,⁹⁸ EnergyNest⁹⁹ and Seaborg¹⁰⁰ focusing on the recovery and re-use of waste heat from industrial processes or excess renewable electricity via modular thermal energy storage. Thermal energy storage can also be coupled to power generation technologies to increase system flexibility, such as in the mid-long duration storage approach proposed by the start up Energy Dome¹⁰¹ with the CO₂ battery that stores energy in the form of liquid CO₂ and sensible heat. The EIC Transition project Thermobat¹⁰² aims to convert radiative heating into electricity with thermophotovoltaics and latent heat storage with molten metals at temperatures above 1500°C. This scalable and modular solution could offer capex reduction at scale and performance increase similar to that achieved by photovoltaic (PV) technologies in recent decades. Such thermal storage solutions with high durability, fast dynamic response, low energy losses and high energy density are also key components to increase dispatchability of nuclear power plants, in particular in the case of modular decentralized nuclear reactors that can be coupled to heat and power demand. This has a strategic relevance for the EU in particular if major breakthroughs from fusion ignition will be achieved, in order to scale up this technology to a commercial level in the coming decades.

- Efficient combustion:** disruptive approaches to improve the consumption of fuel can deliver energy efficiency and emission reduction where it is most needed. The approach pursued by the EIC funded SME Efenco¹⁰³ for example, involves the introduction of a pyroelectric driven and plasma assisted combustion process for natural gas boilers.

- Heat pumps and heat electrification:** Achieving ambitious EU net zero building and industrial targets implies the development of specific innovations to increase the seasonal coefficient of performance (COP) of heat pumps (HP), in particular for the high temperature lifts needed by the existing, and largely energy inefficient, EU residential building stock. Here, the EIC is funding solutions such as thermoacoustic HP (with BHE Renewables), absorption HP (with Flaminco), or geothermal storage coupled to HP (Envola¹⁰⁴) (World's first storage heat pump | ENVOLA) that specifically address these requirements.

Energy efficiency in hard to abate industrial sectors could also be pursued via heat electrification through industrial HP to produce high temperature heat, as in the case of the Stirling engines of the EIC funded Highlift project¹⁰⁵ or for specific components that can combine more functionalities, as in the wet compressors of the company Otechos,¹⁰⁶ that offers a range of applications including waste heat recovery, improved efficiency in industrial processes and hydrogen compression.

- Clean Cooling:** Technologies for efficient cooling are an important segment in reducing total energy consumption. The 2023 EIC Pathfinder Challenge on Clean Cooling Technologies looks to address the demand for cooling for both industrial and tertiary applications, focusing on increased efficiency, cascade heat recovery or enhanced maintenance to enable the early detection of operating conditions at low efficiency (soft fault detection).

- Demand management and digital solutions for energy systems:** the real time match of generation and demand, the shift from centralized to distributed energy systems and sectors coupling require high computing capabilities (including quantum computing) for real time monitoring and control of such complex systems, generative AI for load and generation forecasting or demand aggregation, cyber-attach protection strategies, digital twins and responsive tools to guarantee power systems stability. Consumers awareness and societal engagement is crucial for the energy transition and advanced digital energy solutions, including big data analytics, are key enablers for proper end users investment decisions or behavioral changes. This should be recognized also in proper energy market mechanisms, possibly unified at EU level, where energy consumers can operate also as generators and viceversa.

DOMESTIC RESOURCES AND CIRCULARITY

The second pillar for enabling the energy transition relates to circularity and the use of domestic resources instead of critical and imported raw materials. The EIC has sought to address this challenge in support of the EU's renewable hydrogen production capacity, with a €30 million Pathfinder Challenge competition, which will support a portfolio of projects to focus on the valorisation of locally available bio-based resources without relying on critical raw materials. The projects in this portfolio will aim to convert cellulose, ethanol, glycerol, lignin (for instance from refurbishment of existing biorefineries) for the co-production of hydrogen and green chemicals via co-electrolysis, or

lignocellulosic biomass to green hydrogen and biochar for steel manufacturing via thermochemical pyrolysis. In all cases, the multidisciplinary research supported by the EIC is tailored to address the specific needs and opportunities of the EU, such as the deployment of local resources, job creation, and the combination of production and use of energy and materials in applications where the overall environmental and economic benefits can be maximised. It is the case, for instance of the use of green hydrogen produced from biomass in biorefineries where it can be converted into e-biofuels for applications where there electricity or hydrogen cannot be used (i.e. aviation).



SECTORAL INTEGRATION

The third pillar of a sustainable transition is the ambition to capture further system-level benefits, that go beyond decarbonisation or ensuring security of supply for the energy sector alone.

Energy is a key component for sustainable growth, with an interconnection to biodiversity, food security, freshwater production, land-use change and climate adaptation, and these issues should be tackled together.

Climate change is exacerbated by factors such as the loss of productive agricultural land and desertification, loss of soil biodiversity, or scarcity of fresh water for irrigation. We can capture CO₂ from the atmosphere and push it back to the atmosphere combining it with hydrogen into molecules of various degree of complexity, so achieving the net zero. A cross-sectorial approach, however, shows that there could be other options even carbon negative. For instance, converting agricultural and forestry residues into biochar, carbon can be stored over a long, period of time while supporting agricultural soil biodiversity, improving water retention and producing energy or biofuels, with carbon negative rather than net zero technologies.

This is the case of the EIC Accelerator funded CarboCulture, which aims to produce biochar from forestry or agricultural residues via slow pyrolysis, to

restore biogenic carbon in the soil and renewable heat generation. Similar examples include the efforts of the start-up Agrobiogel,¹⁰⁷ producing water-absorbent biochar for crops, or Coval energy (www.covalenergy.com) that proposes a combination of electrochemical and biological processes for the co-production of sustainable aviation fuels and proteins from electricity and carbon from biogenic or fossil sources. Outside the EIC accelerator programme, other innovation supported by HEU in this direction include the Ecofining project,¹⁰⁸ where fossil refineries are reconverted into biorefineries to produce sustainable aviation fuels via hydrotreated vegetable oils (HVO) using non-edible biomass, and potentially in combination to green hydrogen (to produce e-biofuels rather than e-fuels). This pathway has the potential to be combined with biochar production to fertilise the same soils as those producing the bio-oil. Such approaches result in no competition in the use of bio-based materials for food and do not impact land-use.

The portfolio of projects selected under the EIC Pathfinder Challenge on CO₂ and Nitrogen (N) management, and valorisation aims to capture and convert biogenic CO₂ and N into valuable products, pursuing a cascade approach prioritised in the order of final use: starting with food through to feed, materials and finally energy.



Conclusion

Approaches being supported by the EIC underline the importance of adopting holistic system level approaches to aid the energy transition. In the case of biomass, it is clear that resources are limited and cannot by themselves fulfill increasing energy needs. However, in several cases, the revenues from energy and biofuels production can cover the costs for re-converting land for food and feed, thereby achieving positive land-use change or biodiversity effects. From this perspective, the marginalisation of agricultural land is a major issue, accounting for 8.5 Mha in Southern Europe alone, where over 40% of the soil has less than 1.5% of solid organic content.

A proper recognition of the system level benefits of such energy generation processes - for instance in carbon accounting mechanisms - could help to capture all these aspects and help deliver on the EU's policy ambitions for net zero.



NOVEL TECHNOLOGIES FOR RESILIENT AND SUSTAINABLE FOOD SUPPLY CHAINS

What's at stake

Agriculture is the most important source of food for human sustenance and approximately 95% of food can trace its origins, directly or indirectly, to the soil.¹⁰⁹

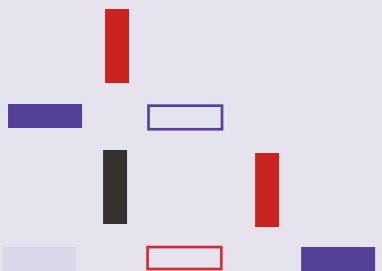
The EU's food supply chain is considered to be a reliable source of a large variety of high-quality and safe foods. However, the agricultural system that underpins this supply chain is complex and vulnerable to environmental and social conditions. The adverse effects of climate change, drought and pollution are already impacting agricultural yield and these effects will be accentuated by the effects of

modern agricultural practices that have delivered benefits at the expense of longer-term environmental impacts on biodiversity and soil health, resulting in farming practices that are neither sustainable nor environmentally friendly. Annual monoculture crops are now produced on bare soils with everything else eliminated with industrial efficiency, mostly with chemicals. This impacts not only wildlife, but also increases our reliance on a narrow group of crops: there are more than 50,000 edible plants in the world, 15 of these provide 90% of the world's food energy intake.¹¹⁰



IVAN STEFANIC

EIC Programme Manager responsible for food chain technologies, novel & sustainable food



Related identified topics in Chapter 1

- + **Next generation aquaculture technologies** - Next generation aquaculture technologies for climate-resilient crops, not yet available through conventional aquaculture.
- + **Mineral fertilizer free crops** - Development of crops that can grow without the need for mineral fertilizers, reducing environmental impact and increasing sustainability.
- + **Novel breeding technologies for climate-resilient crops** - Development of new crop varieties that are more resistant to climate change and pests, ensuring food security in the future.

High potential technologies and the EIC portfolio

The growing portfolio of EIC funded activity in the area 'novel technologies for resilient and sustainable food supply chains' seeks sustainable solutions with the capacity to regenerate agriculture. The core competencies and maturity levels of projects in the portfolio are very different and complementary as summarised below. While much of the activity relates to food production linked to the soil, a growing feature are approaches to decouple food production from the soil and wider environmental conditions.





<p>NO PEST Pathfinder OPEN Novel pesticides: low-impact alternatives to agrochemicals</p>	<p>FUTURE AGRICULTURE Pathfinder OPEN Synthetic photorespiration</p>	<p>CROP4CLIMA Canola and rapeseed to assimilate +60% CO2 Requiring -20% of water</p>
<p>3P TECH Tri-parental plants for high yields & climate-robust crops</p>	<p>SOIL MONITOR Mini sensors against the over fertilisation of soils</p>	<p>LIVENSEMAP Real-time plant nutrient-sensing for smart mapping of fertiliser needs.</p>
<p>MUSHLABS Fermentation of edible mushroom roots to create tasty and sustainable food</p>	<p>ROBI AI adviser for agronomy and food safety</p>	<p>FL'OUR PLANET Fermentation of food side-streams into food ingredients</p>
<p>HAYTECH-AI Data analytics and fermentation control to increase dairy farm milk yield</p>	<p>TRAIT4.0 Increasing crop resilience with AI Technology</p>	<p>AGROBIOGEL Water and fertiliser storage and, slow-release products</p>
<p>TILKAL Blockchain-based supply chain traceability & transparency platform</p>	<p>ECOLACTIPACK A material to unlock plastic-free paper packaging for food</p>	<p>BIOSOLAR LEAF Biomimetic technology for large-scale microalgae cultivation</p>
<p>GREEN-DROP Accelerator Big data for efficient irrigation & fertilisation</p>	<p>GASABATE N-PLUS Accelerator Additive technology to prevent GHG emissions</p>	<p>BIOWEEDCONTROL Accelerator Weed control via a semi-permeable layer within the soil matrix</p>
<p>AGROSTORE Accelerator Replacing chemical fungicides with plant-based solutions</p>	<p>SMART NITRO FARM Accelerator On-farm fertiliser production by plasma treatment of livestock slurry</p>	<p>NURSPRAY Accelerator Crop treatment against climate stress (drought and heat)</p>
<p>Algaenite (ex CYANOBACTERIA) Accelerator Using Cyanobacteria for making Bio Ammonia (organic fertiliser)</p>	<p>ALAV Accelerator An autonomous lightweight agricultural vehicle, eliminating the degradation of soils</p>	<p>ANTOFERINE Accelerator Antifungal products developed for pre- and post-harvest</p>
<p>OptiSignFood Fast Track to Innovation Data Science and AI-assisted holistic software to digitally design food products</p>	<p>SAPHER Fast Track to Innovation Sensing platform for allergens in the food industry</p>	<p>MEAT4ALL Fast Track to Innovation Competitive, sustainable, and consumer-oriented cultivated meat</p>
<p>PHOTO-SENS Fast Track to Innovation The platform for salmon pathogen detection</p>	<p>SUSTAINABLE MANURE Fast Track to Innovation Fertilisers from the air by plasma treatment</p>	<p>PHAGOVET Fast Track to Innovation Controlling Salmonella and Escherichia coli in poultry production</p>
<p>CHILLBACT Fast Track to Innovation Decontamination with ice</p>	<p>PHAGEFIRE Fast Track to Innovation A solution to control fire blight disease in pome fruit crops</p>	<p>ECOEXTRACT Fast Track to Innovation Biobased plant oil and protein extraction system</p>

Overview of the current EIC portfolio (EIC Pathfinder projects are marked in purple, EIC Transition in black and EIC Accelerator and Fast Track to Innovation in red)

Recent activity including an EIC Accelerator Challenge competition under EIC Work Programme 2023 will look to support this trend and ensure a critical mass of activity, with a focus on further developments in:

DECOUPLING FOOD PRODUCTION FROM THE SOIL

Taking into consideration how slowly we make progress in preserving and restoring biodiversity and soil health, it is reasonable to work on solutions that decouple food production from the soil. Foods from cellular agriculture involving bacteria, yeasts, algae, and fungi have made impressive progress recently, and the EIC has a considerable number of projects in that field, including MUSHLABS,¹¹¹ which work on fermentation of edible mushroom roots to create nutritious, appetising and sustainable foods.

Other projects such as FL'OUR PLANET¹¹² works on the fermentation of food side-streams into food ingredients, BIOSOLAR LEAF¹¹³ works on biomimetic technology for large-scale microalgae cultivation. However, precision fermentation and algae based novel aquaculture technologies such as these have not reached their full potential. Global market forecasts point to a more than x20 increase in investment in proteins from precision fermentation by 2030¹¹⁴ and given the strength of the European research base and start-ups, there is significant potential for investment and growth in the coming years.

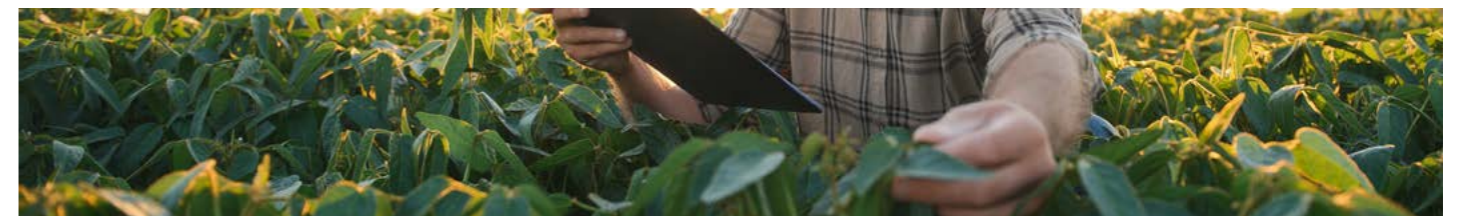
NOVEL CROPS

Future crops will have to be highly resilient and productive to increase yield in unfavourable environmental conditions. Additionally, they could serve as more efficient carbon sinks to mitigate climate change.

the project will improve and bring to commercial use, a disruptive synthetic metabolic pathway, the TaCo pathway, which turns photorespiration into a CO2-fixing instead of a CO2-releasing process, leading to increased net carbon-uptake under agronomical standards and drought field conditions. Another very promising technology for creation of novel crops is tri-parental technology. The 3P-TECH consortium is following this pathway under their EIC Transition funded project to create climate-robust crops for high yields, sugar beet at first, with possible implementation on additional crops.¹¹⁶

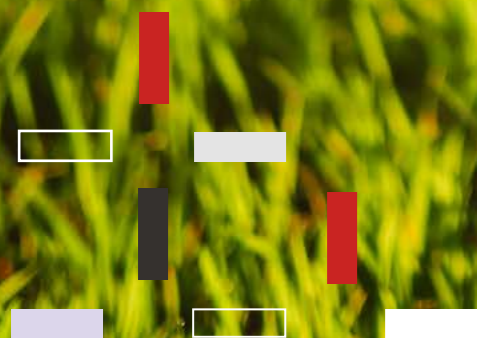
The EIC funded FUTURE AGRICULTURE consortium has successfully taken forward an early stage EIC Pathfinder research project involving entirely novel CO2-neutral or CO2-positive photorespiration based on a novel enzyme to develop a commercialisation path for their most promising synthetic pathways under an EIC Transition funded project, Crop4Clima.¹¹⁵ This project aims to develop first-of-a-kind canola and rapeseed lines to assimilate 60% more CO2 through photorespiration, requiring 20% less water, improving biomass/ha while still maintaining high oil content values as required for canola derived products. To reach such a product,

The process of identifying and developing such novel breeding technologies for climate-resilient major crops could also be shortened and reinforced by employing AI based solutions in the future.



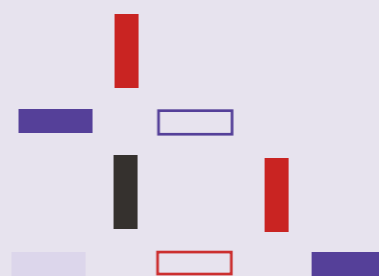
Conclusion

While discussing the role of radical innovation in agriculture and the food supply chain, we must be aware of the complexity and interdependencies within subsystems that may impact positively or otherwise in the longer term. Neither a single research institution, SME, or consortium can address the multitude of issues affecting the sector, but by taking a portfolio approach, the EIC will look to support complementary and compatible solutions with a common focus on making agriculture sustainable and regenerative, focusing on improving the production of food under a range of conditions and improving nutrition, while reducing environmental impacts and increasing biodiversity.



IORDANIS ARZIMANOGLOU

EIC Programme Manager responsible for health and biotechnology



CURRENT TRENDS IN PRECISION ONCOLOGY

What's at stake

Current global cancer trends involving fast-paced enabling technologies are expected to change how cancer treatment and drug discovery research will be applied and conducted, ultimately leading to precision oncology. Scientific breakthroughs are essential

for driving progress in the fight against cancer. Clinical validation of the innovation or research is equally important, to translate those discoveries into meaningful progress, such as life-saving treatments, maximising quality of life for those living with the disease.



Related identified topics in Chapter 1

- Biomarkers for early cancer detection: Spatial omics is the only method with validation of spatial aspects. Applications for precision oncology include: 1) Early diagnosis of cancer, 2) Identifying spatial and functional networks in omics
- + Biomarkers for early cancer detection: Spatial omics is the only method with validation of spatial aspects. Applications for precision oncology include: 1) Early diagnosis of cancer, 2) Identifying spatial and functional networks in omics
- + Biomarkers for early cancer detection: Spatial omics is the only method with validation of spatial aspects. Applications for precision oncology include: 1) Early diagnosis of cancer, 2) Identifying spatial and functional networks in omics

High potential technologies and the EIC portfolio

Selected global cancer trends and technological approaches paving the way to precision oncology include:



LIQUID BIOPSY-BASED BIOMARKERS FOR EARLY AND MORE ACCURATE CANCER DETECTION

More accurate detection of various types of cancer at an early stage and with high accuracy - by using circulating tumour DNA and analysing circulating biomarkers - remains an area with immense potential. The EIC portfolio includes several projects focused on early and

more accurate detection of cancer with Pathfinder projects CIRCULAR VISION,¹¹⁷ BIOCELLPHE,¹¹⁸ VersiLib¹¹⁹ and Accelerator projects ColoDix,¹²⁰ Lung EpiCheck,¹²¹ ProSCAN.¹²²

LIQUID BIOPSY-BASED AND MULTI-OMICS-BASED BIOMARKERS TO GUIDE CANCER TREATMENT AND DETECT RECURRENCE AND IN DRUG DEVELOPMENT

Advances in multi-omics platforms and data analysis tools are critical for bringing multi-omics-based biomarkers to the clinic. DNA methylation in circulating tumour DNA in the plasma has been effectively used as a recurrence biomarker, to detect minimal residual disease in patients with colorectal cancer.¹²³ The combination of biomarker data from different omics analysis has the potential to better support physicians

in the development and prescribe individualised treatment plans.

The EIC portfolio includes Accelerator projects AURORAX,¹²⁴ CytoPro,¹²⁵ MicroCaT¹²⁶ and Multiplex8+.¹²⁷ Moreover, this is the focus of the 2022 EIC Challenge-based Accelerator Call focused on Novel biomarker-based assays to guide personalised cancer treatment.

SPATIAL MULTI-OMICS TO PROFILE TUMOUR HETEROGENEITY & MICROENVIRONMENT

Spatial multi-omics allows the profiling of a range of molecules with high spatial resolution directly on the tissue. It is becoming one of the fastest growing areas in the biotech industry with far-reaching implications in cancer, but also across medicine and the life sciences in their entirety.¹²⁸ Spatial omics covers a wide range of spatial approaches including sequencing-based, transcripts-based, imaging of proteins-based and spatial metabolomics. Spatial omics not only offer

spatial information that can produce detailed maps of tumours and other tissues but unlock unprecedented new opportunities for cancer research and therapeutic discovery using clinical specimens. It is worth noting that five US companies have developed technologies that are pushing the boundaries of spatial genomics.¹²⁹

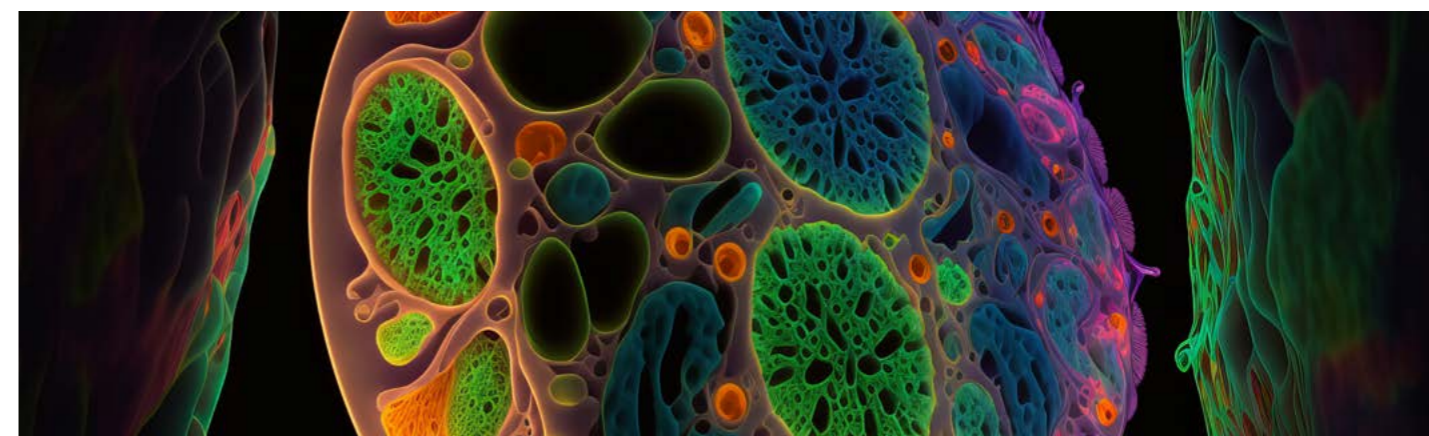
The EIC portfolio includes the Pathfinder projects TROPHY¹³⁰ and PLAST_CELL.¹³¹

CANCER DISEASE MODELLING USING PATIENT-DERIVED ORGANOIDS (PDOs)

Organoids are microscopic self-organising 3D structures that share structural and functional aspects with their in vivo counterpart organs. This versatile technology has led to the development of many novel human cancer models. Tumour samples are now used for the generation of patient-derived organoids (PDOs), i.e. living 3D micro tumours cultured in a gel. When combined with immune cells and fibroblasts, tumour organoids model the cancer microenvironment enabling immune-oncology

applications. Despite recent progress, the development of PDOs has not yet reached its full potential and many challenges exist in the translation of tumour organoid research to clinical decision making.

The EIC Portfolio includes the Pathfinder projects 3DSecret,¹³² Pan3DP,¹³³ NICI¹³⁴ and the Transition project ACHILLEUS.¹³⁵



CANCER TREATMENT WITH DEGRADATION OF DISEASE-CAUSING PROTEINS

Disease-causing protein degradation with small molecules is an emerging technology that has the potential to treat cancer and other diseases in a novel way.¹³⁶ The novelty of this approach relies upon the fact

that it takes advantage of the cell's natural digestive system to degrade disease-causing proteins. The EIC Portfolio does not yet include projects related to this very recent development.

EXOSOME-BASED IMPROVED CANCER DRUG DELIVERY

Newly designed and easily manufactured vesicles that can carry the cancer drug can improve the binding of the drug to targeted markers on the cancer cell surface, leading to a more targeted release of the drug.

The EIC Portfolio includes the Transition projects AcouSome¹³⁷ and MARVEL.¹³⁸

ANTIBODY-DRUG CONJUGATES (ADCs)

ADCs now outnumber traditional monoclonal antibody (mAb)-based therapeutics in the first-in-human cancer studies.

With about 200 active trials of ADCs registered on ClinicalTrials.gov, the global market for ADCs is estimated to reach \$23 billion by 2030, and over 50 ADC-

based M&A and licensing deals having been disclosed since the start of 2022 including the \$43 bn acquisition of Seagen by Pfizer.¹³⁹ ADCs are moving fast to become more mature technologies¹⁴⁰ and are becoming a strategically important therapeutic approach for many cancer companies.

PERSONALISED MRNA-BASED AND OTHER TYPES OF CANCER VACCINES

Future drug development across a wide range of diseases will heavily rely upon personalised mRNA-based therapeutics. According to ClinicalTrials.gov 2021 data, 14 of the 21 (66%) mRNA-based active clinical trials concerned cancer involving at least 10 different cancer indications, which suggests a strong mRNA-based vaccine trend in solid tumours in a tumour type-

agnostic manner, likely to shorten the development cycle of cancer drugs of this type and possibly make them cheaper.

The EIC's portfolio includes the Pathfinder project DESTINATION,¹⁴¹ Transition project TRAFFIKGENE¹⁴² and CancERVacc¹⁴³ under the Accelerator.

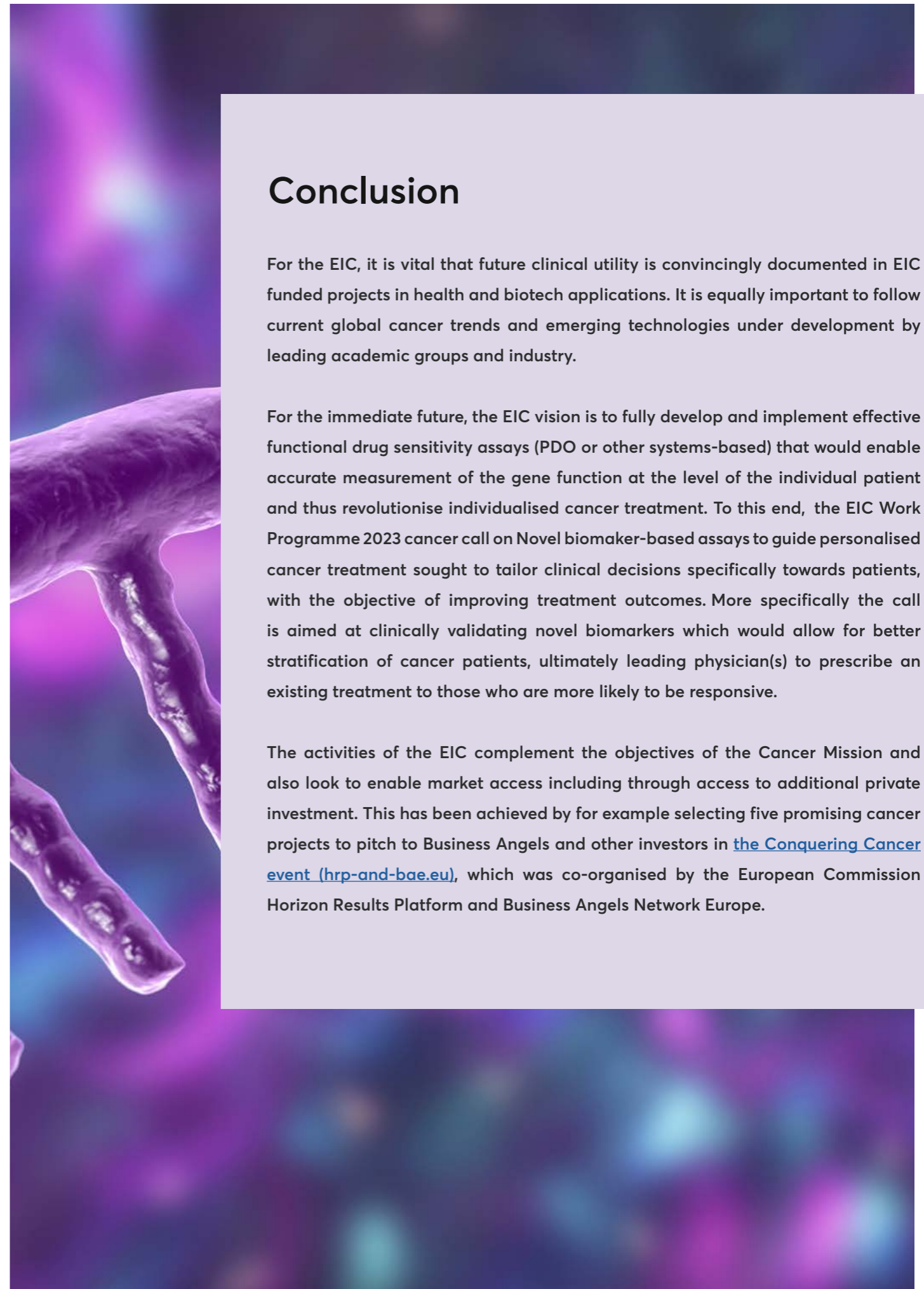


Conclusion

For the EIC, it is vital that future clinical utility is convincingly documented in EIC funded projects in health and biotech applications. It is equally important to follow current global cancer trends and emerging technologies under development by leading academic groups and industry.

For the immediate future, the EIC vision is to fully develop and implement effective functional drug sensitivity assays (PDO or other systems-based) that would enable accurate measurement of the gene function at the level of the individual patient and thus revolutionise individualised cancer treatment. To this end, the EIC Work Programme 2023 cancer call on Novel biomarker-based assays to guide personalised cancer treatment sought to tailor clinical decisions specifically towards patients, with the objective of improving treatment outcomes. More specifically the call is aimed at clinically validating novel biomarkers which would allow for better stratification of cancer patients, ultimately leading physician(s) to prescribe an existing treatment to those who are more likely to be responsive.

The activities of the EIC complement the objectives of the Cancer Mission and also look to enable market access including through access to additional private investment. This has been achieved by for example selecting five promising cancer projects to pitch to Business Angels and other investors in [the Conquering Cancer event \(hrp-and-bae.eu\)](https://hrp-and-bae.eu), which was co-organised by the European Commission Horizon Results Platform and Business Angels Network Europe.



THE HYBRID FUTURE OF MEDICAL TECHNOLOGY: MANUFACTURING FULL BODY PARTS FOR THERAPEUTIC REPLACEMENT

What's at stake

Today's medical technologies such as pace-makers, deep brain stimulators, orthopaedic implants, shunts, and stents are non-biological constructs. However, an emerging opportunity, and global trend partly reflected in the EIC's portfolio is its hybrid future with the convergence of biological components produced in-vitro and non-biological hardware.

The promise of producing any type of cell in a dish, as needed to create a full organ, which in turn includes many different types of cells, can trace its origins to Shinya Yamanaka's discovery that mature cells can be reprogrammed to become pluripotent, for which he received the Nobel prize in Medicine in 2012.

Induced Pluripotent Stem Cell (iPS) obtained from, for example, a skin sample provided by a patient, will be used to create aggregates physiologically and anatomically identical to those of the patient's tissue. This bioengineered tissue will be fully compatible and ideal for implantation in this patient. A shift to such personalised biological

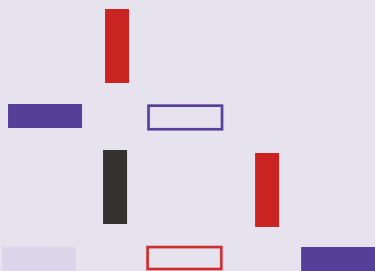
constructs could thus allow repair through reconstruction or full replacement of damaged tissue with new cell aggregates, indistinguishable from the original. An optimal medical tech solution such as this could be applicable to virtually all diseases including traumatic brain injury, spinal cord injury, heart failure, kidney disease, diabetes, oncological conditions (e.g., replacing full organs with primary tumours or metastasis), neurodegeneration, etc.

To date, significant leaps have been achieved by combining microfabrication, sensors, chemistry, electronics and big data processing, including AI with technologies for rapid DNA sequencing such as Next Generation Sequencing (NGS), for gene expression mapping (e.g., RNA-sequencing), for epigenomic mapping (e.g. CHIP-sequencing) and others. Yet in-vitro production of full organs or implantation-ready complex parts of organs remains a long-term goal, and even more so when targeting complex organs such as the brain or the human eye.



ENRIC CLAVEROL

EIC Programme Manager responsible for medical technologies and medical devices



Related identified topics in Chapter 1

- + Metabolic MRI
- Superhuman robot enabled surgery
- + Ultra-small and efficient implantable devices
- + Personalised (including 3d printed) patient-derived tissue production/ organ production

High potential technologies and the EIC portfolio

The promise of a personalised hybrid medtech requires developments across the fields listed below and their subsequent integration, and the EIC has a broad portfolio of activity in each of these domains.



CHAPTER 2 / HEALTH

3D PRINTING OF CELLS

Researchers are currently exploring new approaches to automate the construction of in-vitro tissue by positioning cells layer-by-layer, cell-by-cell, voxel-by-voxel. A subset of EIC projects address 3D printing of cells to recreate the 3D cytoarchitecture (cell position) of real tissue.

ORGAN-ON-CHIP

This approach focuses on scaling and automating other aspects of cell engineering by creating devices with many cell-culture microwells, sensors and actuators, capable of effectively running many thousands of experiments in parallel. Miniaturisation and multiplexing are critical in this area to produce sufficient tissue of the required quality.

NOVEL IMAGING TECHNOLOGIES

Metabolic MRI systems can image cell development within developing cell clusters. The information provided by this new generation of MRI technologies (alongside ultrasound, GHZ, and others) go beyond the

purely anatomical data offered by traditional imaging technologies. This allows cell chemistry to be monitored as it changes over time, e.g. as tumours develop or as cells are reprogrammed to create in-vitro organs.

AI AND BIG DATA ANALYSIS

Artificial Intelligence and big data analysis by machine learning is an increasingly common feature in medtech including the EIC portfolio. Automated image analysis in oncology enables fast and quantitative measurement of suspicious image features; real-time EEG processing for Brain-Computer-Interfaces or epilepsy enables brain signals to be interpreted to predict an upcoming seizure;

and the prediction of neo-antigens from tumour DNA sequence enables predictions on the responsiveness of a patient to specific treatments based on DNA mutations. AI can power and accelerate to discovery of techniques to create more realistic bioengineered tissue for transplantation.



MEDICAL ROBOTICS

Robots in the operating room offer motion precision and speed and will increasingly participate in decision-making enabled by AI. This knowledge can also be used outside the operating-room to achieve unprecedented automation and speed in the discovery

of reprogramming cocktails as needed to create in-vitro organs, with robotic architectures autonomously designing and executing complete experiments with precision.

Conclusion

The major technological challenge, and innovation opportunity, is the acceleration of the process of discovery of the techniques to transform the iPS cells into the desired cell types, with the appropriate developmental stage and 3D aggregate architecture to become a full bioengineered organ. The family of technologies and instruments under development in the EIC portfolio have the potential to accelerate the creation of such patient-ready tissue.

- 1 [About TIM | Knowledge for policy \(europa.eu\)](#)
- 2 [PATSTAT | Epo.org](#)
- 3 [Scopus - Document search](#)
- 4 Eulaerts O., Grabowska M., Perani S., Fragkiskos S. (2023) Anticipation and Monitoring of Emerging Technologies and Disruptive Innovation: Data mining and analytics for the European Innovation Council. Limited distribution.
- 5 Farinha, J., Vesnic-Alujevic, L., Pólvora, A., (2023) Scanning Deep Tech Horizons: Participatory Collection and Assessment of Signals and Trends, Publications Office of the European Union, Luxembourg, doi:10.2760/48442, JRC134369. <https://publications.jrc.ec.europa.eu/repository/handle/JRC134369>
- 6 Farinha, J., Vesnic-Alujevic, L., Alvarenga, A., Pólvora, A., (2023) Everybody is Looking into the Future! A Literature Review of Reports on Emerging Technologies and Disruptive Innovation, Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/144730, JRC134319. <https://publications.jrc.ec.europa.eu/repository/handle/JRC134319>
- 7 [Introduction to the Quantum Flagship | Quantum Flagship \(qt.eu\)](#)
- 8 [High Performance Computer – Quantum Simulator hybrid | HPCQS](#)
- 9 [European Chips Act \(europa.eu\)](#)
- 10 [Protein-based next generation electronics | PRINGLE | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 11 [Proto-Opto-Electro-Mechanical Hybrid Systems for Generation-Next Bionic Devices | PROGENY | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 12 [3D Biofabricated high-perfoRmance dna-carbon nanotube dligital electroniCKS | 3D-BRICKS | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 13 [Functional & Dynamic 3D Nano- MicroDevices by Direct Multi-Photon Lithography | 5D NanoPrinting | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 14 [Dissipationless topological channels for information transfer and quantum metrology | TOCHA | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 15 [Ferroelectric Vertical Low energy Low latency low volume Modules fOr Neural network Transformers In 3D | FVLLMONTI | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 16 [Origami electronics for three dimensional integration of computational devices | ORIGENAL | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 17 [Space Environment Statistics - Space Debris User Portal \(esa.int\)](#)
- 18 Euroconsult: 2022 Space logistics satellite market report
- 19 NASA ODP0 2011
- 20 [otps - cost_and_benefit_analysis_of_orbital_debris_remediation_-_final.pdf \(nasa.gov\)](#)
- 21 [Electrodynamic Tether Technology for Passive Consumable-less Deorbit Kit | E.T.PACK | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 22 [Development and analysis of novel mission scenarios based on Atmosphere-Breathing Electric Propulsion \(ABEP\) | SpringerLink](#)
- 23 [DISCOVERER – DISruptive teChnOlogies for VERy low Earth oRbit platforms | DISCOVERER | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 24 [Gama launches its Gama Alpha solar sail mission \(sail-world.com\)](#)
- 25 [ESA - Show Me Your Wings: Successful In-flight Demonstration of the ADEO Braking Sail](#)
- 26 [SUNERGY | Fossil-free fuels for a climate-neutral Europe - SUNERGY \(sunergy-initiative.eu\)](#)
- 27 [An Artificial Leaf: a photo-electro-catalytic cell from earth-abundant materials for sustainable solar production of CO2-based chemicals and fuels | A-LEAF | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 28 [Diamond materials for the photocatalytic conversion of CO2 to fine chemicals and fuels using visible light | DIACAT | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 29 [Soap Film based Artificial Photosynthesis | SoFIA | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 30 [Light assisted solar fuel production by artificial CO2 Reduction and water Oxidation | LICROX | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 31 We focus on so-called Renewable Fuels (and chemicals) of Non-Biologic Origin (RFNBOs), i.e. the necessary carbon-source does not originate from biomass. Biofuels (made from biomass fermentation) are not considered here.
- 32 Picture source: <https://www.pnas.org/doi/full/10.1073/pnas.1604811113>; Image courtesy of Dave Cutler.
- 33 <https://cordis.europa.eu/project/id/970564>
- 34 <https://cordis.europa.eu/project/id/101010276>
- 35 [Lab-to-tech transition of the current best low temperature electrolyser technology for CO2 reduction to CO using solar energy | SolarCO2Value | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 36 <https://cordis.europa.eu/project/id/899576>
- 37 42 U.S. Code § 13506 – Definitions
- 38 Advanced Materials Initiative - AMI2030, Strategic Materials Agenda, 2023
- 39 Net zero industry act, COM (2023) 68
- 40 Critical Raw Materials Resilience: Charting a Path towards greater Security and Sustainability, COM (2020) 474
- 41 Critical materials for the energy transition, IRENA, 2021
- 42 EMIRI Technology Roadmap, Sept. 2019.
- 43 The European Green deal, COM (2019) 640.
- 44 F. Dolci, et al., Clean Energy Technology Observatory: Water Electrolysis and Hydrogen in the European Union – 2022 Status Report on Technology Development, Trends, Value Chains and Markets, Publications Office of the European Union, Luxembourg, 2022, JRC130683.
- 45 C. Minke, et al., Is iridium demand a potential bottleneck in the realization of large-scale PEM water electrolysis? Int. J. Hydrogen Energy, 2021, 46, 23581-23590.
- 46 EPO and IRENA (2022), Patent insight report. Innovation trends in electrolysers for hydrogen production, EPO, Vienna.
- 47 IRENA (2020), Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal, International Renewable Energy Agency, Abu Dhabi.
- 48 Q. Wang, et al., Applications and recent advances of rare earth in solid oxide fuel cells, Journal of Rare Earths, 2022, 40, 11, 1668-81.
- 49 A. Ludwig, Discovery of new materials using combinatorial synthesis and high-throughput characterization of thin-film materials libraries combined with computational methods, npj Computational Materials (2019) 70
- 50 L. Himanen et al., Data-Driven Materials Science: Status, Challenges, and Perspectives, Adv. Sci. 2019, 6, 1900808.
- 51 Caldeira, et al., Safe and sustainable by design Chemicals and materials, Framework for the definition of criteria and evaluation procedure for chemicals and materials, Publications office of the European Union, Luxembourg (2022), JRC 128591.
- 52 Z. Ghahramani et al., Probabilistic machine learning and artificial intelligence, Nature, 2015, 521, 452–459.
- 53 S.G. Louie, et al., Discovering and understanding materials through computation, Nature Materials, 2021, 20, 728–735
- 54 D. Raabe, et al., Accelerating the design of compositionally complex materials via physics-informed artificial intelligence, Nature Computational

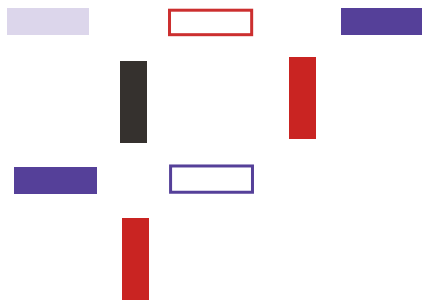
- 55 Science 2023, 3, 198-209.
- 56 P. Friederich, et al., Machine-learned potentials for next-generation matter simulations, Nature Materials, 2021, 20, 750-761.
- 57 J. Fish, et al., Mesoscopic and multiscale modelling in materials, Nature Materials 2021, 20, 774–786.
- 58 M. Jordan et al., Machine learning: Trends, perspectives, and prospects, Science 2015, 349, 255–260.
- 59 Z. Ghahramani et al., Probabilistic machine learning and artificial intelligence, Nature 2015, 521, 452–459.
- 60 E. Muratov et al., QSAR without borders, Chem. Soc. Rev. 2020, 49, 3525–3564.
- 61 D.P. Tabor et al., Accelerating the discovery of materials for clean energy in the era of smart automation, Nat. Rev. Mater. 2018, 3, 5–20.
- 62 K.T. Butler et al., Machine learning for molecular and materials science, Nature 2018, 559, 547–555.
- 63 L. Himanen et al., Data-Driven Materials Science: Status, Challenges, and Perspectives. Adv. Sci. 2019, 6, 1900808.
- 64 G. Gu et al., Machine learning for renewable energy materials. J. Mater. Chem. A 2019, 7, 17096–17117.
- 65 C. Chen et al., A Critical Review of Machine Learning of Energy Materials, Adv. Energy Mater. 2020, 10, 1903242.
- 66 T. Toyao et al., Machine Learning for Catalysis Informatics: Recent Applications and Prospects, ACS Catal. 2020, 10, 2260–2297.
- 67 J. Behler et al., First Principles Neural Network Potentials for Reactive Simulations of Large Molecular and Condensed Systems, Angew. Chem., Int. Ed. 2017, 56, 12828–12840.
- 68 Z.W. Ulissi et al., To address surface reaction network complexity using scaling relations machine learning and DFT calculations, Nat. Commun. 2017, 8, 14621.
- 69 M.A. Mosquera et al., Wave Functions, Density Functionals, and Artificial Intelligence for Materials and Energy Research: Future Prospects and Challenges, ACS Energy Lett. 2018, 3, 155–162.
- 70 N.J. O’Connor et al., Interaction trends between single metal atoms and oxide supports identified with density functional theory and statistical learning, Nat. Catal. 2018, 1, 531–539.
- 71 S. Chmiela et al., Towards exact molecular dynamics simulations with machine-learned force fields, Nat. Commun. 2018, 9, 3887.
- 72 Y. Zhang et al., Machine learning in electronic-quantum-matter imaging experiments, Nature 2019, 570, 484–490.
- 73 V.L. Deringer et al., Machine Learning Interatomic Potentials as Emerging Tools for Materials Science, Adv. Mater. 2019, 31, 1902765.
- 74 K.T. Schütt et al. Unifying machine learning and quantum chemistry with a deep neural network for molecular wavefunctions, Nat. Commun. 2019, 10, 5024.
- 75 G.P.P. Pun et al., Physically informed artificial neural networks for atomistic modeling of materials, Nat. Commun. 2019, 10, 2339.
- 76 S. Schumacher et al., High-throughput discovery of hydrogen evolution electrocatalysts in the complex solid solution system Co–Cr–Fe–Mo–Ni, J. Mater. Chem. A, 2022, 10, 9981–9987.
- 77 S. Moradi et al., High-Throughput Synthesis of Thin Films for the Discovery of Energy Materials: A Perspective, ACS Mater. Au, 2022, 2, 516–524
- 78 P. Friederich, et al., Machine-learned potentials for next-generation matter simulations, Nature Materials, 2021, 20, 750-761.
- 79 Why The Building Sector? – Architecture 2030
- 80 [Grand Challenges | Breakthrough Energy](#)
- 81 [Clayment - Clay cement for massive CO2 reduction | Clayment - Clay cement for massive CO2 reduction | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 82 European Commission, Joint Research Centre (<https://data.europa.eu/doi/10.2760/174037>)
- 83 [GCCA \(Global Cement and Concrete Association\)](#)
- 84 [Bio-Inspired Hierarchical MetaMaterials | BOHEME | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 85 [Analysis, Design, And Manufacturing using Microstructures | ADAM^2 | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 86 [Efficient manufacturing technology for complex architecture | Svelte | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 87 [Robotic Production of EPS Formwork for cost-effective Concrete Stairs | SMARTSTAIR | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 88 [Reducing wind energy costs with a stronger, taller wind turbine towers made from wood modules | Modvion | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 89 [Construction transition pathway \(europa.eu\)](#)
- 90 [About concrete \(solidlife.eu\)](#)
- 91 [Eco-efficient cements: Potential economically viable solutions for a low-CO2 cement-based materials industry - ScienceDirect](#)
- 92 Tafadzwa Mabhaudhi, Aidan Senzanje, Albert Modi, Graham Jewitt, Festo Massawe, Water - Energy - Food Nexus Narratives and Resource Securities, Elsevier, 2022, <https://doi.org/10.1016/B978-0-323-91223-5.01001-7>.
- 93 IEA (2023), Tracking Clean Energy Progress 2023, IEA, Paris <https://www.iea.org/reports/tracking-clean-energy-progress-2023>
- 94 IEA, Primary chemical production process energy consumption and intensity in the Sustainable Development Scenario, 2015-2030, IEA, Paris <https://www.iea.org/data-and-statistics/charts/primary-chemical-production-process-energy-consumption-and-intensity-in-the-sustainable-development-scenario-2015-2030>, IEA.
- 95 NATURE CLIMATE CHANGE | VOL 11 | JUNE 2021 | 543–550 |
- 96 Nature Climate Change | Volume 13 | April 2023 | 324–333
- 97 Tesla Masterplan part 3, Sustainable energy for all on Earth, https://www.tesla.com/ns_videos/Tesla-Master-Plan-Part-3.pdf
- 98 Anton Firth, Bo Zhang, Aidong Yang, Quantification of global waste heat and its environmental effects, Applied Energy, Volume 235, 2019, <https://doi.org/10.1016/j.apenergy.2018.10.102>.
- 99 [Scalable, modular, high temperature, cost-efficient thermal energy and power storage and conversion system made of upcycled industrial by-products | KRAFTBLOCK | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 100 [Increased energy efficiency, flexibility and reduction of green-house gases using thermal battery | HEAT2VALUE | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 101 [Delivering Clean, Affordable, and Safe Nuclear Energy with the Compact Molten Salt Reactor | SEAWEI | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 102 [CO2 based Utility-Scale Long Duration Energy Storage | CO2 Battery | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 103 [A Ferrosilicon Latent Heat Thermophotovoltaic Battery | THERMOBAT | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 104 [Reducing natural gas needs and carbon emissions in industrial usage and transforming industry towards hydrogen with HERC, a novel plasma-assisted combustion \(PAC\) technology | herc accelerating industrial co2 neutrality | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 105 [The Envola storage heat pump enables the world's first highly energy-efficient heating, cooling and ventilation system significantly reducing energy consumption and greenhouse gas emissions in Europe. | Envola storage heat pump - a new product category | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 106 [Stirling heat pump for high temperature industrial use | Highlift | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 107 [Centric Reciprocating Compressor | CRC | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 108 [AgroBiogel International Scale-up | Agrobiogel | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 109 [Ecofining™: turning organic waste into biofuel | Eni](#)
- 110 [Healthy soils are the basis for healthy food production | FAO](#)

- 110 [Food Staple \(nationalgeographic.org\)](#)
- 111 [Using biotechnology to create the next generation of sustainable foods from the roots of mushrooms | Mushlabs | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 112 [Valorisation of food production side-streams as multifunctional ingredients by an innovative fermentation process. | F'Our Planet | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 113 [Disrupting the food ingredient and protein markets: a breakthrough technology for large-scale microalgae cultivation. | Biosolar Leaf | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 114 [Precision Fermentation Ingredients Market Trends, Drivers, and Opportunities | MarketsandMarkets](#)
- 115 [Resilient and environmentally sustainable engineered crops to address climate change | Crop4Clima | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 116 [3P-Tec - Three-parent breeding technology for plants of the future | 3P-Tec | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 117 [Circular DNA in diagnosis and disease models | CIRCULAR VISION | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 118 [Ultrasensitive BIoSensing platform for multiplex CELLular protein PHEnotyping at single-cell level | BIOCELLPHE | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 119 [Versatile Amplification Method for Single-Molecule Detection in Liquid Biopsy | VerSiLiB | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 120 [Disruptive and high accuracy test for early colorectal cancer detection in blood | ColoDix | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 121 [Blood Samples and DNA-an Innovative Technique for Lung Cancer Diagnostics | Lung EpiCheck | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 122 [Prostate cancer diagnostics using a non-invasive test based on innovative glycan-based scanning | ProSCAN | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 123 [Minimal Residual Disease Detection using a Plasma-only Circulating Tumor DNA Assay in Patients with Colorectal Cancer - PubMed \(nih.gov\)](#)
- 124 [Advancing cancer detection through metabolism-based diagnostics | AURORAX | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 125 [A breakthrough cancer diagnostic instrument to save 3000 years of human lives annually and up | CytoPro | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 126 [Micro-tumor Guided Cancer Therapy Selection MicroCaT | MicroCaT | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 127 [A highly accurate breast cancer diagnostic test for effective personalized treatment and assessment of therapy response. | Multiplex8+ | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 128 [home.liebertpub.com/genbio/overview](#)
- 129 [Five Up-and-Coming Firms in Spatial Genomics | Inside Precision Medicine](#)
- 130 [ulTRafast hOlograPHic FTIR microscopy | TROPHY | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 131 [A multiplexed biomimetic imaging platform for assessing single cell plasticity \(Plastomics\) and scoring of tumour malignancy | PLAST_CELL | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 132 [3D SECRET](#)
- 133 [home.liebertpub.com/genbio/overview](#)
- 134 [Non-Invasive Chemistry Imaging in the whole human body | NICI | Project | Fact sheet | H2020 | CORDIS | European Commission \(europa.eu\)](#)
- 135 [Next-Generation Drug Discovery Platform for Targeting Cancer Stem Cell Pathways | ACHILLEUS | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 136 [Targeted Protein Degradation: A Promising Option for Cancer Drug Developers \(genengnews.com\)](#)
- 137 [Acoustofluidic thin-film actuated chip for exosome separation from blood | AcouSome | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)
- 138 [Project - MARVEL-FET : MARVEL-FET](#)
- 139 [Personalized RNA neoantigen vaccines stimulate T cells in pancreatic cancer | Nature](#)
- 140 [BioCentury - ADCs overtake mAbs in AACR's first-in-human abstracts](#)
- 141 [BioCentury - ADCs overtake mAbs in AACR's first-in-human abstracts](#)
- 142 [BioCentury - ADCs overtake mAbs in AACR's first-in-human abstracts](#)
- 143 [Targeting Cancer with ERV Vaccines | CancERVacc | Project | Fact sheet | HORIZON | CORDIS | European Commission \(europa.eu\)](#)

Images

- https://stock.adobe.com/be_fr/images/the-human-finger-delicately-touches-the-finger-of-a-robot-s-metallic-finger-concept-of-harmonious-coexistence-of-humans-and-ai-technology/622965092
- https://stock.adobe.com/be_fr/images/a-stack-of-various-rectangular-blocks-isolated-in-style-forms-a-spatial-structure-the-design-showcasing-clean-geometric-shapes-conveys-concepts-of-architecture-creativity-and-proportion/639489807
- https://stock.adobe.com/be_fr/images/3d-cubes-on-a-grey-surface-rendered-in-modern-style-create-an-abstract-geometric-pattern-their-blue-reflections-and-simple-design-give-a-futuristic-and-creative-touch-to-the-digital-architecture/639490881
- <https://elements.envato.com/male-laboratory-worker-in-whitecoat-studying-detai-DRACAWP>
- https://stock.adobe.com/be_fr/images/digital-surveillance-extreme-close-up-of-robotic-or-bionic-eye-with-advanced-circuitry/627756988
- https://stock.adobe.com/be_fr/images/a-stack-of-various-rectangular-blocks-isolated-in-style-forms-a-spatial-structure-the-design-showcasing-clean-geometric-shapes-conveys-concepts-of-architecture-creativity-and-proportion/639489807
- <https://elements.envato.com/modern-data-servers-glass-security-panels-technolo-Q7QGJV6>
- https://stock.adobe.com/be_fr/images/ai-machine-learning-hands-of-robot-and-human-touching-on-big-data-network-connection-background-science-and-artificial-intelligence-technology-innovation-and-futuristic/323829966
- <https://elements.envato.com/architect-planning-new-construction-project-FUQST7Z>
- https://stock.adobe.com/be_fr/images/biophilic-architecture-design-with-lush-vegetation-and-greenery-building-providing-connection-to-nature-for-its-inhabitants-reducing-the-carbon-footprint-and-promoting-sustainability-generative-ai/569890878
- <https://elements.envato.com/hydrogen-fuel-storage-and-solar-panel-with-wind-tu-XQGSZTY>

- https://stock.adobe.com/be_fr/images/intelligent-vehicle-concept-autonomous-electric-shuttle-bus-self-driving-through-city-s-green-road-generative-ai/568021993
- <https://elements.envato.com/young-male-doctor-specialised-in-brain-tumor-check-VQL4RTD>
- https://stock.adobe.com/be_fr/images/visual-representation-of-exosomes-in-3d-generative-ai/596517376
- https://stock.adobe.com/be_fr/images/human-multicolored-iris-of-the-eye-animation-concept-rainbow-lines-after-a-flash-scatter-out-of-a-bright-binary-circle-and-forming-volumetric-a-human-eye-iris-and-pupil-3d-rendering-background-4k/612500470
- <https://thenounproject.com/icon/quantum-computer-4320269/>
- https://stock.adobe.com/be_fr/images/quantum-computer/618298224
- https://stock.adobe.com/be_fr/images/merging-of-ai-and-quantum-computing-for-powerful-data-processing-background-with-empty-space-for-text-generative-ai/601607813
- <https://thenounproject.com/icon/energy-1709679/>
- https://stock.adobe.com/be_fr/images/concept-of-green-technology-green-recycle-sign-on-circuit-board-technology-innovations-environment-green-technology-computer-chip-green-computing-green-technology-green-it-csr-and-it-ethics/574261429
- https://stock.adobe.com/be_fr/images/tree-on-an-electronic-circuit-board-future-of-agriculture-boosting-agricultural-productivity-with-chip-and-computer-tech-generative-ai/624358081
- https://stock.adobe.com/be_fr/images/tree-growing-on-digital-plant-pot-eco-technology-and-technology-convergence-green-computing-green-technology-green-it/631321265
- https://stock.adobe.com/be_fr/images/african-american-scientist-works-in-a-modern-scientific-laboratory-for-the-research-and-development-of-microelectronics-and-processors-manufacturing-worker-uses-computer-technology-and-equipment/465936721
- <https://thenounproject.com/icon/space-1075966/>
- <https://elements.envato.com/night-landscape-with-milky-way-starry-sky-universe-PY5QNGY>
- <https://elements.envato.com/3d-illustration-of-satellite-orbiting-the-earth-P2X8FTJ>
- <https://thenounproject.com/icon/microbe-3500734/> & <https://thenounproject.com/icon/renewable-energy-5435071/>
- <https://elements.envato.com/sunset-in-the-fields-with-vineyards-PX5XC7G>
- https://stock.adobe.com/be_fr/images/dawn-of-new-renewable-energy-technologies-modern-aesthetic-and-efficient-dark-solar-panel-panels-a-modular-battery-energy-storage-system-and-a-wind-turbine-system-in-warm-light-3d-rendering/248626760
- <https://elements.envato.com/modern-bio-complex-renewable-energy-from-biomass-in-DXGHERS>
- <https://thenounproject.com/icon/green-energy-transition-5907459/>
- <https://elements.envato.com/big-and-blue-solar-panels-as-zero-emission-energy-ZTTZ5QD>
- <https://elements.envato.com/hydrogen-storage-with-wind-turbines-hydrogen-renew-3MU8PQP>
- https://stock.adobe.com/be_fr/images/sustainable-green-building-eco-friendly-building-sustainable-glass-office-building-with-tree-for-reducing-carbon-dioxide-office-with-green-environment-corporate-building-reduce-co2-generative-ai/616412474
- https://stock.adobe.com/be_en/images/from-carbon-neutral-to-negative-hand-flips-cubes-and-changes-words-carbon-neutral-to-carbon-negative-beautiful-white-background-copy-space-business-ecological-and-carbon-negative-concept/398942289
- <https://elements.envato.com/green-building-organic-building-materials-AKAHMHS>
- <https://elements.envato.com/sustainable-green-building-eco-friendly-building-su-RJ3TS8P>
- <https://thenounproject.com/icon/fertilizer-4169308/>
- https://stock.adobe.com/be_fr/images/environment-target-of-green-business-business-development-strategies-with-environmental-conservation-green-community-new-green-business-plan/562325650
- <https://elements.envato.com/geothermal-power-station-in-iceland-in-summer-4BQZC6A>
- https://stock.adobe.com/be_en/images/save-planet-in-hands-concept-day-earth-save-the-world-save-environment-eco-friendly-green-company-culture-concept-carbon-neutral-and-net-zero-target-sustainable-environment-and-generative-ai/608204628
- <https://thenounproject.com/icon/fertilizer-5363655/>
- <https://elements.envato.com/greenhouse-with-negative-co2-footprint-3PTSvQ8>
- <https://elements.envato.com/man-and-woman-cultivating-organic-crops-looking-fo-23MCF9F>
- <https://elements.envato.com/farmer-agronomist-in-soybean-field-checking-crops--89754JL>
- <https://elements.envato.com/farmer-check-his-crop-plant-in-the-field-farmer-ex-NBBMPFY>
- <https://elements.envato.com/doctor-and-female-patient-in-the-room-of-computed--DNEYWQF>
- <https://thenounproject.com/icon/medical-1070131/>
- https://stock.adobe.com/be_en/images/scientist-holds-blood-sample-for-liquid-biopsy-test-to-detect-cancer-cells-or-dna-fragments-with-patient-bed-background/542613343
- https://stock.adobe.com/be_en/images/organoid-brain-cells-science-elaboration/567760125
- https://stock.adobe.com/be_en/images/pharmaceutical-manufacture-background-with-glass-bottles-with-clear-liquid-on-automatic-conveyor-line-covid-19-mrna-vaccine-production-platform/627445496
- https://stock.adobe.com/be_en/images/molecule-of-mrna-3d-illustration/532133575
- <https://thenounproject.com/icon/mri-4304932/>
- https://stock.adobe.com/be_en/images/molecule-of-dna/74928548
- https://stock.adobe.com/be_en/images/medical-technology-doctor-use-ai-robots-for-diagnosis-care-and-increasing-accuracy-patient-treatment-in-future-medical-research-and-development-innovation-technology-to-improve-patient-health/612191457
- https://stock.adobe.com/be_en/images/doctor-diagnose-and-checking-brain-testing-result-with-computer-and-ai-robotic-on-virtual-interface-in-laboratory-innovative-technology-in-science-and-medicine/573385753



BACKING VISIONARY ENTREPRENEURS

European
Innovation
Council



eic.ec.europa.eu
@EUeic

