Missions for European research beyond 2020

Suggestions by the Helmholtz Association

The Helmholtz Association, Germany's largest research organisation, is a strong supporter of European research cooperation. We are convinced that many big challenges for today's and tomorrow's society can only be solved by joint action on a European scale, and that common ambitious and motivating goals can inspire both scientists and the public. This is why we support identifying missions able to address major challenges and make the enormous impact of European research tangible to citizens.

In this spirit, we have identified 3 plus 11 proposals for missions which we are convinced would have the potential to bring important benefits to citizens. The suggestions show the broad spectrum of the societal missions addressed by the Helmholtz Association.

The Missions

Further missions from the six Helmholtz research fields:

Research Field "Energy"

Mission "Affordable, sustainable and clean energy supply"

The idea

There is an urgent need to increase the efficiency and reduce the costs of clean energy technologies and to enable access to affordable and sustainable energy throughout the world. This is the only way to make carbon-free, clean energy sources attractive and thereby to drastically reduce and eventually zero the worldwide use of fossil fuels within the coming decades. For Europe this is also an opportunity to take the industrial lead in the energy field and remain worldwide competitive. But to reach this goal as soon as possible proper coordination and concentration of resources is mandatory.

A research flagship, having a focus on lowering Europe's dependency on fossil fuels, could develop new materials, methods and applications, which then could form the base for future price competitive clean energy technologies. On top of the research flagship a mission is needed that helps to bring the new technologies onto the market by funding additional higher TRL and supporting their marketing.

In the wake of the COP21 Europe intends to support developing countries on their way to sustainable energy supplies. Efforts to make clean energies more competitive will have a large impact for developing countries as well. A suitable collaboration with developing countries should be part of this mission.

EU added value

- Basic right for all European citizens to access renewable energy sources at affordable costs
- Realization of the *Energy Union*

Setting a direction

- Consolidation of efforts in Europe as Energy Union beyond 2020
- Circular Economy Strategy of the European Commission

- Direct relevance to UN Sustainable Development Goal:
  - Goal 7 "Affordable and clean energy"

  There is further relevance of the proposed mission to
  - Goal 11 "Sustainable cities and communities"
  - Goal 13 "Climate Action"

Clear focus on research and innovation

- Scale-up for technologies, including the reduction of materials consumption
- Implementation of the Circular Economy Strategy at all stages
- Coordinated and focused contributions to energy production, energy conversion, energy storage, and energy distribution (energy systems) by member state research organisations.

Citizen priorities and final user relevance

- Access to renewable energy sources at affordable costs
- Clean mobility options
- Innovation Laboratories for citizen-inspired technology development (demand pull AND technology push)
- Education and training

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

- Transformation of business models for energy suppliers
- Public-co-inventors through user-inspired technology development
- New importance for European / international energy legislation

Stimulate efforts and investments at national and regional levels

- Development of national energy laws in European Member States
- Joint realization of technology plants through several European Member States will be supported. The SETPLAN implementation plan will be supported and will have higher chances of success.

European partners

- Members of the European Energy Research Alliance: 250 leading energy research organisations with more than 30,000 researchers.
- Non-EERA research organisation with relevant contributions for implementing the mission
- Industries participating in the different European Technology and Innovation Platforms of the SETPLAN.
- Industry associations like Energy Materials Industrial Research Initiative (EMIRI), European Association for Storage of Energy (EASE)and others.
- Member States active in the SETPLAN and willing to make the next steps needed to consolidate the European Energy Union and to develop their national energy law

Suggestion by Forschungszentrum Jülich, Helmholtz-Zentrum Berlin, Karlsruhe Institute of Technology (KIT) and IMEC (Belgium)

Research Field "Key Technologies"

Mission "Decode the essence of information processing"

The idea

In order to tackle the grand challenges of today's and tomorrow's society, future technological systems must be more powerful and intrinsically safer as well as much more energy efficient than current hardware systems. Therefore, we have to develop new and in part revolutionary data processing concepts and completely new materials and components. We have to conduct research targeting the missing link between research on basic principles of information processing and a successful implementation of such knowledge for novel technologies. The aim is to unravel how information is processed in nature in order to understand the very essence of the concept of information by connecting both inanimate matter and biological systems including the human brain and to adopt these to develop new principles for the next generation of computing systems. Of special relevance are quantum computing that uses previously unused physical effects, and neuromorphic computing that aims at exploiting insights from biological information processing. The brain is an organ of extreme complexity and by itself creates information from data and derives ways to translate it to action. Its organization may serve as a blueprint for developing new physics-based solutions such as neuromorphic devices or neural networks. Decoding its principles, strengths and limitations is a prerequisite not only for designing innovative technologies but also for studying cognition and action, behaviour and learning, communication and social being, both in healthy subjects and patients.

EU added value

Scientific and economic leadership in the fields of novel computing concepts (brain-inspired hard- and software, neuromorphic and quantum computing, machine and deep learning)

Setting a direction

This mission has direct and indirect lasting effects on several EU policy priorities and UN Sustainable Development Goals. First and foremost, this mission fosters the enabling of the digital transformation in the EU. By developing new and innovative hardware and software solutions for new devices and innovative information processing methods, existing barriers can be overcome in order to make the internet a safe place. This mission aims to develop more energy efficient hardware and thus will contribute to the climate goals of EU and UN. Indirectly, this mission will bring benefit to initiatives which aim to end hunger, ensure healthy lives and promote well-being, ensure access to water and sanitation for all, ensure access to affordable, reliable, sustainable and modern energy, make cities inclusive, safe, resilient and sustainable, sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss by offering more efficient, powerful and intelligent information processing methods, such as data processing concepts or neuromorphic devise.

Enable funding for basic and applied research in the mentioned scientific fields, ensure further support for corresponding FET-flagship projects that are vital for European scientific cooperation, capacity and community building.

Clear focus on research and innovation

Cf. research agenda of the HBP and Quantum Flagship, foster cooperation and involvement of suitable European industrial partners and enable stronger entrepreneurship.

Citizen priorities and final user relevance

The prospect of brain-inspired, neuromorphic computing as well as the development of new technologies for the realisation of quantum computing devices in Europe will lead to major advantages in global scientific and economic competitiveness leading to the creation of public welfare and prosperity. Society needs new tools and

methods to master enormous challenges and global problems related to a growing world population and even greater need for a balance of ecological and economical sustainability. Furthermore, decoding the human brain will be the basis also for understanding pathologies and is thus a prerequisite for new therapies for brain-related and neurological diseases.

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

Public investments (Member States, EU) will trigger successive private investments since the need for applications in the mentioned fields is based on scientific findings and developments. New economic sectors and services will be created to implement new methods and technologies.

Stimulate efforts and investments at national and regional levels

Ideally, a European research and innovation strategy will be supported by all Member States according to their existing scientific competencies and main focuses. A cluster-like European structure around the centres of excellence will attract qualified personnel and further economic activities around it. This is a profound motivation for the Member States and their corresponding regions to create open and competitive environments for further private investments.

European partners

Germany, France, Italy, Spain, Switzerland, Sweden, Norway, Austria, Netherlands, Belgium, Poland, Luxembourg, Finland

Research Field "Health"

Mission "A European initiative to turn cancer into a chronic disease"

The idea

Joining forces in Europe to fight cancer: the right therapy for the right patient at the right time

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EU added value

- **Reduce burden on European healthcare systems** by strengthening cancer prevention and screening programs as well as diagnosis, treatment, and cancer care in order to improve disease outcomes and prevention
- **Improve quality of life for EU citizens** through personalised cancer medicine, improved access to high-quality health care, reduced mortality and morbidity rates, and quantitively and qualitatively enhanced survivorship
- **Reduce socioeconomic burden of cancer**, such as lost work time (health is wealth!)
- **Creation of EU-wide platform and infrastructure in translational cancer medicine** to ensure pan-European development and harmonization of protocols for data collection and cancer healthcare, platforms for data sharing and exchange, platforms for clinical studies with adequately sized patient cohorts, development of network of European-wide Comprehensive Cancer Centers
- **Creation of a platform for industrial collaborations** in pharmaceutics, biotechnology, and medical technology to develop innovative therapies on a previously unknown scale

Setting a direction

Relevance of mission to EU policy priorities and UN Sustainable Development Goals:

- **Innovation Union** – especially delivering on the European Research Area, promoting excellence in education and skills development, spreading the benefits of innovation across the Union, reforming research and innovation systems
- **Open Innovation, Open Science, Open to the World**
- **UN Sustainable Development Goals No. 3** "Ensure healthy lives and promote well-being for all at all ages" and **No. 10** "Reduce inequality within and among all countries" by improving access to and effectiveness of health care

Clear focus on research and innovation

Establish a platform for pan-European cancer research of excellence

- Development of innovative strategies for personalized prevention, screening, diagnosis, treatment and care of tumour diseases
- Enabling clinical research studies using patient cohorts across Europe by sharing research and clinical data among European Cancer Centers
- Offering a unique platform for industrial partnerships to develop innovative cancer diagnosis and treatment modalities

Citizen priorities and final user relevance

- Prevention and improved therapy of cancer leading to reduced cancer mortality rates, increased survival rates and improved quality of life.
- Accelerated transfer from laboratory discoveries to diagnostics and treatments that meet the needs of patients and that health care systems can afford.

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

- Creating network of comprehensive cancer centres to join together research and medical care at all levels throughout Europe
- Creating platforms for innovative, targeted clinical trials based on principles of personalised cancer medicine
- Creating platforms for joining up efforts of different stakeholders (research, clinic, patient groups, regulatory agencies, industry, SMEs, education and training, outreach into society) to improve efficiency of research, access to health care, quality of life
- Creating data-sharing platforms (including clinical, pathological, diagnostic imaging, biological, and genomic data in compliance with national regulations) as a foundation for diagnostics, therapy-monitoring, epidemiological studies, and outcomes research
- Creating ecosystem of innovation

Stimulate efforts and investments at national and regional levels

- Balance between top-down and bottom-up efforts is essential
- Adequate funding and instruments for basic research as the engine of innovation
- Collaborative research funding instruments in FP9 that are of the right dimension (in terms of size and funding duration) to effectively promote translational research and clinical studies
- Establishment of a “European Clinical Research Fund” in collaboration with industry and SMEs to guarantee adequate funding for patient cohorts at European level
- Creation of ERC-Nets or co-funded European Joint Programs in translational cancer research
- Use of European Structural Funds to promote development of comprehensive cancer centers in EU countries that are less well developed in this area

European partners

- European Cancer Centers already organised in the legal entity **Cancer Core Europe**:
  German Cancer Research Center DKFZ and its Comprehensive Cancer Center NCT, Heidelberg; Gustave Roussy Cancer Campus, Paris, France; Cambridge Cancer Center, UK; Karolinska Institutet, Stockholm, Sweden; The Netherlands Cancer Institute, Amsterdam; Vall d’Hebron Insitute of Oncology, Barcelona, Spain
- Interaction/Integration with Cancer Prevention Europe (European centers of excellence in prevention research)
- Additional European Cancer Centers of excellence

Research Field "Energy"

1. Mission "Pan European Carbon-Neutral Energy System Design and Operation"

The idea

In order to achieve the ambitious goals with respect to CO2 emissions Europe needs to establish a new energy system that increasingly needs to address Pan-European systemic aspects including all components and stakeholders like producers, conversion systems, storage systems, transport systems, and consumers of multimodal forms of energy (e.g. electricity, gas, heat, fuels) in order to be successful.

The specifically systemic approach of this mission addresses the interaction of these individual components in a system from both the technical and the economic point of view. In current and future scenarios, the above individual components are coupled physically and by information technologies with the need to consider:

- *added value chains for various multimodal forms of energy: generation, conversion, storage, transport, and use;*
- *timelines for the generation of scenarios: today, tomorrow (until 2050), and on the longer term (after 2050);*
- *interactions with users and their behaviours: society, economy, physical environment, materials, and technologies development.*

Management, control and optimisation of the entire system as well as of individual sub-systems will decisively determine stability and availability (robustness & resilience), economic efficiency and ecology. For this purpose, new grid structures covering various forms of energy will be developed. Both the European and global context will be considered and the relationship of centralised and decentralised components will be resolved. In this context, the reorganisation of the energy markets will also be addressed.

The integration of the energy system in a sustainable circular economy is an important subset of the larger challenge: the dynamic management of resources including energy, materials and the natural environment. All these natural and industrially processed resources are connected into a multidimensional system of networks, storage and conversion processes. With respect to materials, the basic industrial sectors metallurgy, cement, and petro-chemistry, which use highly complex processing, storage and transport networks, are of particular importance. The final goal, a viable, stable, and resource efficient energy system, cannot be described by singular objectives, such as low-energy consumption, grid stability or low resource intensity, since all of these goals compete with each other and, ultimately, are connected via the systems entropy.

Moreover, implementation of the necessary European energy turn in 2050 needs to be able to answer the question of how can the energy system be redesigned according to a carbon neutral system being based on renewable sources. In this light, the European geography and its respective yield of renewable energy have to be considered in order to form a Pan-European system.

EU added value

A reliable, secure, economically and ecologically system which respects the geographical of all European countries aiming at carbon emission neutrality. A larger geopolitical independence from non-EU countries.

Setting a direction

- Consolidation of efforts in Europe as Energy Union beyond 2020
- Circular Economy Strategy of the European Commission
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- Direct relevance to UN Sustainable Development Goal:
    - Goal 7 "Affordable and clean energy"
    - Goal 9 "Industry Innovation and Infrastructure"
    - Goal 11 "Sustainable cities and communities"
    - Goal 12 "Responsible Consumption and Production"

- Goal 13 “Climate Action”
- Goal 17 “Partnership for the Goals”

Clear focus on research and innovation

Interactions within the energy system are represented by models, simulated in a variety of scenarios, and verified by real data sets. Modelling from the component level to the process level to the energy system level will lead to in-depth knowledge and applicable tools for:

- integrated systems management for various energy sources,
- interaction of centralised and decentralised structures,
- energy-intensive and resource-intensive industries as flexible suppliers of grid services,
- sector coupling,
- long-term scenarios,
- IT architecture development,
- high-resolution modelling of the energy system / energy market

Citizen priorities and final user relevance

- Affordable energy based on renewables
- Robust energy supply for everybody
- Clean mobility options for urban areas as well as for long-distance travel and transportation
- Education and training

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

- Virtual power plants in rural areas
- Efficient technologies for energy distribution including new power electronics and superconducting components
- New technologies for implementing large-capacity energy storage
- New IT-grids and respective technologies

Stimulate efforts and investments at national and regional levels

- Legislation of new markets and business models of decentralized systems
- New grid topologies and respective grid investments
- New storage capacity
- Reorganization of the energy harvesting technologies following the yield (“PV in the South, wind turbines in the North”)

European partners

- 250 leading energy research organisations with more than 30,000 researchers and members of the European Energy Research Alliance. EERA Joint Programmes (e.g. Energy Systems Integration, Smart Grids, Smart Cities)
- Non-EERA research organisation with relevant contributions for implementing the mission
- Industries participating in the different European Technology and Innovation Platforms of the SETPLAN (e.g. The European Innovation Partnership on Smart Cities and Communities marketplace, Smart Networks for Energy Transition)
- European Association for Storage of Energy (EASE) and others.
- Member States active in the SETPLAN and willing to make the next steps needed to consolidate the European Energy Union

Suggestion by German Aerospace Center (DLR), Forschungszentrum Jülich, Helmholtz-Zentrum Berlin and Karlsruhe Institute of Technology (KIT)

Research Field "Earth and Environment"

2. Mission "Blue Ocean: Providing the Healthy Ocean we need for the Future we want"

The idea

Improving human ocean interactions: Reduce ocean pressures to secure prosperity.

Obtain a comprehensive, solution-oriented understanding of human-ocean interactions by science and innovation actions in key areas of integrative ocean science. Pursue transdisciplinary science and synthesis by strong engagement of science with non-academic stakeholders (citizens, policy-makers, and practitioners) and society at large to provide the knowledge we need to inform human development to sustain ocean services and human prosperity and well-being for future generations. Address ocean-relevant targets in the full set of SDGs

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EU added value

- Define Europe's contribution to the SDG14 targets and a prosperous ocean state and sustainable economy.
- Put Europe in the global lead for ocean integrated research and services
- Realize significant contributions to the UNESCO Decade of Ocean Research
- Realize the Galway Statement on Atlantic Ocean Cooperation that was signed in 2013 by the EU, Canada and the US, and the Belem statement signed in 2017 by the EU, Brazil and South Africa to forge Transatlantic Ocean Research Alliances to enhance collaboration to better understand the Atlantic Ocean and sustainably manage and use its resources.

Setting a direction

- Contribution to SDG 14 "Conserve and sustainably use the oceans, seas and marine resources for sustainable development" from the European perspective
- - Support the scientific foundational knowledge for the Common Fisheries Policy. The Marine Framework Directive, Climate adaptation and mitigation measures in the marine realm and to secure a long term prosperous blue/green economy.
- - Build capacity in Europe and Africa on marine observations, information sharing, marine forecasting and warning, assessments and ocean governance.

Clear focus on research and innovation

- Implement the European contribution to the Global Ocean Observing System as outlined by the Framework of Ocean Observing and promoted by the AtlantOS and related H2020 projects.
- Advance Ocean Science Technology, including data and information technologies, by innovation actions and partnerships between industry and science.
- Build a truly integrative ocean system model system that can support science and operations by using innovative methods and networked computing capabilities.
- Grow the Ocean Open Science Cloud by networking the Data centers such as EmodNet and the Copernicus Services CMEMS.
- Interlace the sustainability concept and the SDG targets into maritime technology and industrial innovation processes (e.g. aquaculture, seafloor mining, offshore constructions, fisheries, biotechnologies, tourism industry and other sectors)
- Improve European, Regional and Global Ocean Governance by science, capacity building and innovative and flexible governing frameworks.
- Goal: having a long-lasting and sustainable contribution to realising societal, economic and scientific benefits arising from this integrated approach, with implementation extending beyond the project's lifetime. Advances will be achieved by improving the value for money, extent, completeness, quality and ease of

access to European Coasts and Ocean data required by industries, product supplying agencies, scientists and citizens.

Key areas of action

- **Coastal transition Zones under Natural and human Pressure**
  How vulnerable is the land-ocean interface to anthropogenic and natural pressures?
  Past, present and future; Impact of sea level change, natural hazards, pollution and invasive species on the North Sea and Arctic coasts
  How can climate services help coasts and cities to adapt to and mitigate climate change and contribute to solutions for the water-food-energy nexus?
- **Sustainable adaptation measures**
  How can we develop sustainable adaptation measures, which can serve multiple developmental goals and minimize trade-offs
- **Offshore industrialization**
  How can we assess industrialization impacts on complex coastal systems under changing climate?
- **Moving coastlines and matter transports**
  Understanding natural dynamics and coastal protection on basin scale
- **Environmental Pollutants**
  Impacts of natural and anthropogenic drivers on fate and transport of pollutants, considering physical, biological and chemical drivers
- **Marine and Polar life: sustaining Biodiversity, Biotic interactions, Biogeochemical functions**
  What is the role of marine and polar life in the Earth‘s biogeochemical cycles and ecosystem functions?
  From organisms to communities to ecosystems: Responses to natural and man-made dynamics and their impacts on biodiversity
- **The restless seafloor - threats and opportunities**
  What is the past, present and future state of the pan-European seafloor in and beyond the EEZ; how are high risk (geodynamics) and high pressure (human impact) areas identified and monitored

Citizen priorities and final user relevance

Providing for healthy seas

- The ocean covers more than 70% of Earth’s surface and hosts our largest ecosystem, exerting a major influence on the global climate and hosting both living and non-living resources that are essential to human society. Worldwide the population has doubled over the last 50 years and continues to grow. Already today coastal areas (below 100 m altitude) are the most densely populated on Earth. Currently, more than 40% of the population is located in this area, benefiting from a range of vital ocean services that support human prosperity. The relationship between humans and the ocean is, however, not only one of prosperity and well-being. The ocean is also a source of natural and man-made environmental threats to an ever more interconnected and technological society. Anthropogenic pressures on the ocean threatening its productivity, resilience, and biological diversity include climate change, non-sustainable resource extraction, land-based pollution and habitat degradation. However, the rapid warming and oxygen depletion along with other pressures will change important ocean functions. Extreme heat waves and pollution can trigger harmful algal blooms and can cause pathogenicity in marine microbes. Seafloor dynamics and ocean extreme events such as floods are risks to human settlements on the pan-European coastlines and beyond. Pressures on ocean life and the coastal transition zone will continue to grow unless concerted efforts are made on a global scale. However, the existing ocean governance system is unable to support such efforts being weak, fragmented, and in urgent need of reform. The United Nations 2030 Development Agenda, with its 17 Sustainable Development Goals (SDGs), has for the first time recognized the crucial role of the ocean (SDG 14), and the contribution that the ocean makes to the 2030 Development Agenda as a whole. These ambitious goals can only be achieved through innovative, integrative, and solution-oriented research.

Managing global challenges of an increasing world population

- The ocean provides food security for many poor coastal communities, provides jobs, energy and raw materials, enables global trade and cultural services, and offers opportunities for recreation. Many of its

values represent the future prosperity of mankind, and long-term targets are needed to sustain healthy oceans and ocean-based economies. This needs substantial innovation in ocean uses, and an improved knowledge on consequences of human activities for the oceans, starting with industrial processes, material footprint in production, to tourism and human behaviour.

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

- Ocean Observing,
- Ocean Modelling and Predictions
- Ocean Information and Scenarios
- Ocean Conservation
- Ocean Governance
- Ocean services for society (technology and knowledge transfer)

- Dialog towards a vision for our future ocean and how to get there assuming sustainable development (no one, no region, no ecosystem should be left behind!)
- All require shared investments, innovation and new forms of collaborations. The ocean community has already build forward looking activities in this space. Has an active JPI Ocean, several EU institutions and networks that provide the engagement and connectivity between the diverse actors.

Stimulate efforts and investments at national and regional levels

- Develop science-based options for the sustainable use of the ocean with new technologies and information systems.
- Tackle the great questions of the future of marine research at the highest level and to provide knowledge for politics, business and civil society.
- Optimize the use of research infrastructures: operate and develop high-performance infrastructures at universities; ensure adequate funding and sufficient specialized staff.
- Making Substantial Progress in Modeling and Trend Analysis by Building a Common, Open Data and Information System for German Marine Research: Increasing Accessibility to Marine Research Data by Linking Databases (Currently, only about 25% of data is from ships via data portals available); strengthen advanced data analysis; set up a common data portal and support it in the long term.
- Development of innovative marine environmental monitoring technologies: increasingly developing and deploying research robots and autonomous environmental monitoring systems as technology drivers and pioneers in the sustainable management of marine resources.
- Innovate the collaboration of science and other societal stakeholders in developing best practices and case studies for securing healthy seas.

International and European partners

International partners:

- UN, IOC, IPCC, IPBES, GEOSS, OOI

European partners:

- Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans)
- Euro-Argo ERIC
- European Global Ocean Observing System
- Copernicus Marine Environmental Monitoring Service (CMEMS)
- European Marine Observation and Data Network (EMODnet)
- ESA Ocean Missions
- EurOcean – The European Centre for information on Marine Science and Technology
- European Marine Board
- WCRP-CORDEX (Med-Cordex and EURO-CORDEX)

International and European partners (continued)

Key European Ocean Laboratories

- Ifremer, CNRS, IRD (France)
- GEOMAR, AWI, HZG (Germany)
- U Bergen (Norway)
- Institute of Marine Research (Norway)
- The Marine Institute Galway (Ireland)
- NOC Southampton (England)
- CMCC (Italy)
  Etc.

Several NGOs

- OCEANA Europe
- WWF EU
- Oceano Azul Foundation
- ICES

Research Field "Earth and Environment"

3. Mission "Securing Resources, Functions and Services of Future Land and Freshwater Ecosystems"

EU added value

Implementing European Legislation, Economies of scale (Nature-based Solutions), Promotion of best practice, Benchmarking for decision making

Setting a direction

National, European and Global commitments including Food 2030 and the Sustainable Development Goals under the Agenda 2030: SDG-2 Zero Hunger, SDG-6 Clean Water and Sanitation, SDG-13 Climate Action, SDG-14 Life below Water and SDG-15 Life on Land

Clear focus on research and innovation

- **How to use, maintain and restore ecosystems, their functions and services in a sustainable way?**
  Safeguarding ecosystem services grouped into: Provisioning, such as the production of food and drinking water, regulating, such as climate and soil fertility; supporting, such as pollination, nutrient and carbon cycles and cultural, such as recreational services.

- **How to ensure water security for humans and the environment in the 21st century?**
  Science - based knowledge on how the quantity, quality and ecological functions of the groundwater and surface waters are affected by natural and human impacts. Based on this we have to identify pathways for a sustainable water management that can be implemented at regional scales in a global context.

- **How to develop chemicals in a way that they no longer pose a threat to human health or the environment?**
  A constantly growing and diversifying global chemical lifestyle critically threats our environment and humans through the increasing interference with the water cycle, the growing demand for agricultural land or the worldwide growth in prosperity and demand for natural resources. Risk assessment of chemicals in the future must be an integrated assessment that combines ecotoxicology with human toxicology and effect with exposure based approaches.

Citizen priorities and final user relevance

Facing a broad range of priorities, such as degradation and loss of natural capital and the ecosystem services it provides (clean air, water and soil and food and other resources), climate change and an alarming increase of natural disaster risks and related human health issues

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

- Resource efficient, competitive and greener economy
- Reduction of fossil resource use
- Safeguard and enhance the natural capital of Europe
- Reduction of Europeans Global Footprint
- Cooperation with Industries, Agriculture, Forestry, the public sector and NGO`s

Stimulate efforts and investments at national and regional levels

- Development of new products and “know how”
- Innovations by Nature-based Solutions
- New land and resource management
- Innovations for a more effective investments in resources and environmental management
- Innovations for an advanced governance and policy implementation

European partners

European Commission, European Environmental Agency (EEA), European NGOs, eLTER-Network Europe, PEER (Partnership for European Environmental Research)

Research Field "Earth and Environment"

4. Mission "Sustainable livelihood in a changing climate"

EU added value

- Taking international leadership in climate research
- Provide EU citizens with time critical information
- Support the development of *"mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on [...] local and marginalized communities"* (SDG 13, Target 13 B)

Setting a direction

- Contribution to IPCC, COP 21
- Contribution to SDG 13 "Climate action", especially to the following targets:
    - 13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
    - 13.2 Integrate climate change measures into national policies, strategies and planning
    - 13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning

Clear focus on research and innovation

Take the link between observations, models and society to the next level by establishing workflows along the following chain: Observations → process understanding → prognosis → action.

Develop a global observing system that meets the different needs of an increasingly diverse range of stakeholders.

Develop the next generation of modular Earth system models that provide step changes in their ability to simulate climate, that are capable of including all relevant Earth system compartments (e.g. physics, biology and the human dimension), that are seamless across space and time scales, that include components that allow to ingest observational data (data assimilation), and that can make efficient use of the new generation of exascale high-performance computing systems.

Improve our understanding of the processes governing climate and anthropogenic climate change to generate the knowledge base needed to ensure accelerated progress in providing solutions to climate change-related grand challenges.

Produce much enhanced climate change projections including much more reliable uncertainty estimates with special emphasis on

- Extreme events (e.g. heat waves and hydro-meteorological extremes),
- Regional and global sea level rise,
- Representation of socio-economic processes,
- Representation of biological processes on land and in the ocean,
- Advanced Earth System Models, integration of yet unconsidered processes
- Climate impact models for complex systems

Development of regional/local scale climate and environmental services and solutions taking into account user driven demands and resolving cross-sectorial interactions and trade-offs.

Develop dynamical vulnerability and risk assessments to support adaptation and ensure local resilience to climate change, thus avoid migration.

Citizen priorities and final user relevance

- Building reliance to changes in extreme weather and climate change and developing prosperity of human systems in a changing climate
- Protect critical infrastructure and evolve flexible solutions taking mitigation and adaptation into account

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

- Climate services for society (technology and knowledge transfer)
- A Dialog towards a vision for a healthy Earth (sustainable livelihoods) and how to get there assuming sustainable development (no one, no region, no ecosystem should be left behind!)

Stimulate efforts and investments at national and regional levels

- Ensure preparedness of citizens to regional manifestations of climate changes, including extreme events.
- Ensure capacity development in regional under climate change, combine local traditional knowledge from the challenges of the future

European partners

- Research organisations (e.g. Helmholtz Association, Max-Planck Society, Centre National de la Recherche Scientific, National Centre for Atmospheric Sciences).
- Universities
- Research Platforms and Programmes (e.g. European Climate Research Alliance (ECRA), World Climate Research Programme (WCRP), World Weather Research Programme (WWRP), European Polar Board)
- Operational forecasting centres (e.g. ECMWF, DWD, KNMI, SMHI, MET-Offices, BSC, CMCC)
- High-performance computing centres (e.g. Jülich Supercomputing Centre (JSC), Deutsches Klimarechenzentrum (DKRZ), Barcelona Supercomputing Centre (MSC), PRACE)
- Local communities (e.g. C40 cities)
- Policy makers (e.g. EEA)
- Businesses (e.g. insurance companies, DELTARES)

Research Field "Health"

5. Mission "EUDiaCure - Unified European Action for a Diabetes-Free Europe"

EU added value

In the current atmosphere, and what might be called frenzy of "big data," enormous resources are being invested into what are often scientific fishing expeditions without a clear goal of transformative socioeconomic impact in reach. In contrast, **EUDiaCure** offers a targeted and scientifically-based approach to address a major public health problem. Modeled after the successfully validated and uniquely translational concept of the German National Diabetes Center, **EUDiaCure is designed to remove the burden of Diabetes from the European community.** Around **60 million men, women and children** suffer from diabetes in Europe, and its complications and comorbidities include heart attack, stroke and cancer. By 2030 this number will increase by around 60% to almost 100 Million Europeans suffering from this devastating disease complex.

Eradication of diabetes can and will ultimately happen. However, at the current pace of research progress, Europe will reach this point decades after the disease epidemic will have caused a socio-economic breakdown of unprecedented scale. That scenario will be driven to considerable extent by the irreversible long-term complications of diabetes; i.e., cardio-vascular disease, blindness, kidney failure and cancer among others. Even more alarming are recent discoveries documenting that the urgency of this situation will be amplified by epigenetic programming that will render coming generations to become more susceptible to develop diabetes.

The only way to avoid such a scenario is to act now and to act together. **EUDiaCure** will place Europe in the unique position of being able to thwart this narrowing time window in less than two decades with the potential of removing this scourge from the European population. The **EUDiaCure** program is modeled on the unique example of the German Diabetes Center that has been successfully bundling national efforts toward preventing and curing diabetes since 2009. Building on these and numerous other existing strengths that have emerged from a considerable number of successful Horizon 2020 diabetes/obesity/metabolism programs, **EUDiaCure** will synergistically bundle the most promising efforts across Europe to maximally **accelerate the race toward a diabetes-free European society.**

Setting a direction

Given the magnitude of the challenge and the urgency of the situation, coupled with the current momentum and international leadership EU countries have developed in the area of translational biomedicine, a committed investment into **EUDiaCure** is positioned to become the single **most important and promising European flagship** effort. With its uncompromising commitment to a unified integrative effort across boundaries, disciplines and countries, **EUDiaCure's** transformative potential for the health of our aging society will set a world-wide example beyond biomedicine.

Clear focus on research and innovation

In a unique effort, in less than a decade Germany has successfully built an unprecedented nation-wide effort with the goal to rid society of diabetes. Led by the Helmholtz Diabetes Center, the National German Diabetes Centre was initiated in 2009 by Helmholtz Center Munich, and it has already successfully bundled, re-organized and enhanced basic and translational diabetes research across Germany. Today, this operation represents the largest integrated diabetes research center worldwide and has achieved remarkable success including advancing several novel therapeutic concepts to clinical-stage testing. Outstanding diabetes research activities can also be seen in other European Member States. Unfortunately, until now Europe has fallen short of jointly leveraging national efforts into one **synergistic pan-European operation**, an effort which would undoubtedly multiply its potential to turn numerous promising research breakthroughs into one diabetes-free Europe. In times of **Big Data** and **Digitalization**, great opportunities will arise by combining the national efforts on the European scale, but only if scientific fishing expeditions are replaced by focused translational efforts building on existing momentum to solve defined major health threats. The point is that now is the time to bring European

efforts together to reach the **ultimate goal of a diabetes-free Europe**. Because of the fact that in a very short time the German research coalition has already generated a series of translational breakthroughs toward that goal, the likelihood of success is high. The unique example of this powerful national effort and the lessons learned while building it provide only a glimpse of what will be possible once 28 nations integrate their leading translational activities into one joint research force. Propelled forward by the **momentum developed in successful EU Horizon 2020 programs targeting metabolic diseases**, the final time window offering to leverage these investments offers a unique chance for a historic European achievement. **EUDiaCure** as a pan-European "mission to mars" program would not have had the right tools even a decade ago. But today, it can **utilize novel metabolic precision-medicine strategies, digitalized clinical big data as well as emerging tools including interventional chromatin remodeling, human gene editing, stem cell-based cell replacement and regeneration therapy, artificial intelligence-based data analysis and next generation immunotherapy**. Building upon the national mega-cohorts and European efforts currently assessing more than 10 million European citizens, individual molecular- and phenotypic profiles in combination with lifestyle behaviors and environmental metadata will be collected in a joint European diabetes database as part of **EUDiaCure**. Working together, this first major pan-European disease eradication effort will set new standards beyond its concrete goal of a diabetes-free Europe.

Citizen priorities and final user relevance

EUDiaCure will strictly follow the priorities of the Europe for Citizens program. Equal access, cross border and local dimension intercultural dialogue and promotion of volunteering will be essential to reach the **transformative dimension of this pan-European project**. A joint European data base will enable researchers to reach out to people at risk and those who are already metabolic disease patients. The use of social and other new media to reach the wider European population, will be enabled by a joint European data base and ensure the outcome of the **EUDiaCure** to be relevant for all European citizens, and not just a selected rare cohort. The final user relevance cannot be underestimated: Executing the program will lead to a better health status of hundreds of millions of European citizens suffering from the disease, its prequelae such as obesity and prediabetes, its comorbidities such as heart attack, stroke and cancer and its complications such as kidney failure, limb amputation or blindness. Importantly, the **precision prevention program** that is part of **EUDiaCure** will provide European citizens at risk with personalized and evidence-based advice to prevent them from entering the disease state.

Type 1 and type 2 diabetes, together with their co-morbidities, are impairing health and well-being over decades and are causing a sequelae of complications with terrifying socioeconomic impact on our health care system. Effective prevention and treatment is needed to ensure a life free of diabetes for European citizens, and ultimately decrease mortality rates from its long-term complications, thereby bridging over to – and generating an example for - other major human disease entities.

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

National mega cohorts have been built across Europe over the last two decades. They now represent major national assets and offer an unprecedented treasure of European population data. They will function as the cornerstone for personalized risk stratification of European populations and as such will inform **EUDiaCure** every step of the way toward a Diabetes-free Europe. In parallel, **novel biotechnology tools and next generation imaging technology** have been discovered and developed in leading European Research Centres (Helmholtz, Inserm, CNRS, ETH, Max-Planck Society, etc) which are now applied toward metabolic disease research (e.g. Helmholtz Pioneer Campus) offering considerable acceleration of research and development in the diabetes field, which until recently had been unthinkable.

Stimulate efforts and investments at national and regional levels

EUDiaCure is designed to involve matching funds on a national level, aiming to mirror the successful example of the German Diabetes Centre on a much larger and further improved scale. In addition, **EUDiaCure** will include public-private partnerships in key areas of technical innovation (Biotech), large clinical trials and drug development (pharmaceutical industry).

European partners

EUDiaCure will integrate all leading European Diabetes and Metabolic Disease Research including the following selected examples:

- Germany – Helmholtz Center Munich (HDC, HPC); German Centre for Diabetes Research, Max Planck, Elite Universities
- France – CNRS/INSERM Lille, Paris
- Switzerland – EPFL/ETH
- Denmark – Danish Metabolism Research Center and Stem Cell Center
- Spain – Santiago Di Compostela, CNIO Madrid
- Sweden – Universities Malmö & Uppsala, Karolinska Institutet
- UK/Cambridge – Metabolism Research Center
- UK/Oxford University
- Belgium – Leuven University
- Polen - Warsaw University
- Italy – Torino, Naples and Rome

Research Field "Health"

6. Mission "Reduction of Antimicrobial Resistance (AMR)"

EU added value

Reducing the burden of diseases on society caused by antimicrobial resistance (AMR), especially with regard to health care–associated infection with multi-resistant bacterial pathogens

Setting a direction

- G7 Science Academies' Statement 2015: "Infectious Diseases and Antimicrobial Resistance: Threats and Necessary Actions"
- European Commission, Antimicrobial resistance, http://ec.europa.eu/dgs/health_food-safety/amr/index_en.htm
- World Health Organization (WHO) (2014), Antimicrobial Resistance: Global Report on Surveillance (ISBN 978 92 4 156474 8)
- EU new One Health Action Plan against Antimicrobial Resistance, http://ec.europa.eu/health/amr/action_eu_en

Clear focus on research and innovation

Research towards identifying and developing novel antibiotics and pathoblockers with innovative mode of action

Citizen priorities and final user relevance

Long term availability of treatments for infections caused by multiresistant pathogens

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

Stakeholders such as Innovative Medicines Initiative (IMI, especially the ENABLE programme), Global Union for Antibiotics Research and Development (GUARD), Global Antibiotic Research and Development Partnership (GARDP), Joint Programming Initiative Antimicrobial Resistance (JPIAMR), but also pharmaceutical industry

Stimulate efforts and investments at national and regional levels

- Public private partnerships to develop antibiotics and antimicrobial therapies
- Increased funding for drug research in academia, especially with translational focus (e.g. the German Centre for Infection Research (DZIF)).
- Cooperations between academia and pharmaceutical industry
- Investments by chancellor Merkel (500 million €) in the field of infectious disease research with focus on antimicrobial resistance

European partners

GARDP, Drugs for Neglected Diseases Initiative (DNDi), Joint Programming Initiative on Antimicrobial Resistance (JPIAMR) with its proposed Virtual Research Institute (JPIAMR-VRI)

Research Field "Aeronautics, Space and Transport"

7. Mission "European Aviation Goes Electric"

EU added value

Challenge: Electrification of transport becomes more and more adopted by manufacturers and citizens. There are multiple reasons why aviation is lagging behind in this development. This ranges from propulsion challenges to impacts on airport infrastructures and from aircraft configuration changes to electro-magnetic problems. This complex set of challenges require a radical new approach to overcome. The traditional large aircraft manufacturers cannot resolve this problem by themselves.

Europe's drive to be leading in sustainable development fits with the European industries ambition to develop the next generation of emission free and silent aircraft tailored for European use (short to medium range, up to 100 passengers). The European Union could give the development a big boost by developing a mission to build a full scale demonstrator that shows the way forward. By showing that it is possible, the European citizens can see what our aviation sector is capable of and at the same time lead the way towards smart and sustainable transport.

Setting a direction

Reduction of noise and emission, decarbonisation of Air Transport, Energy Union

Clear focus on research and innovation

- Designing for extreme efficiency to be able to handle the battery weight that needs to be taken along. Areas affected are aerodynamics, structures, propulsion, materials and many others.
- Development of novel propulsion systems. Electric aircraft could make use of propellers or distributed propulsion. They need to be designed to be silent and still give an acceptable cruising speed to the aircraft.
- The electrical power needed will be in the order of several MegaWatts. This will require an electric system using kiloVolts. Incorporation and collaboration with battery experts is required to select the best type of battery. A complementary issue to be resolved deals with electro-magnetic interference challenges with the onboard navigation and communication equipment.
- Developing an (electrical) infrastructure on airports for fast charging and/or exchanging energy packs.

Citizen priorities and final user relevance

European citizens can see what our aviation sector is capable of and at the same time lead the way towards smart and sustainable transport

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

The entire R&I scene in aviation but also in energy technology will need to contribute

Stimulate efforts and investments at national and regional levels

Links will be established on the basis of existing cooperation e.g. European Aerospace Cluster Partnership (EACP) or the MoUs established by Clean Sky with aviation regions

European partners

Manufacturing industry, supply chain/SME, research organisations, universities, airlines, airports, energy supply, renewable energy stakeholders

Research Field "Aeronautics, Space and Transport"

8. Mission "A better connected Europe"

The idea

4 hrs door-to-door on intra-European travel within central Europe and 5 hrs including the periphery of the EU for 90% of travellers by 2040'

EU added value

From a European citizens perspective, the current transport system for intra-European travel is very complex. Planning and executing all segments of a door-to-door journey is a cumbersome and time-consuming process often based on insufficient and biased information. Although a truly intermodal transport system has long been on the agenda, progress towards it is slow and well behind expectations. This causes significant inefficiencies, long travel-times and a situation, where the passenger (in most cases) bears the risk for disruptions or delays and is on his own reconfiguring affected journeys.

The proposed mission is about reducing door-to-door journey times and increasing passenger satisfaction by the creation of a truly passenger-centric transport system, which is highly integrated, intermodal and transparent to the customer and delivers a step-change in predictability.

The transport system has shown high inertia to changes and European-wide standardisation as it consists of hundreds of different stakeholders and has many regional facets. But in the near future disruptive developments like connected and autonomous vehicles (land-based and airborne) or new applications of IT (e.g. big data, IoT, blockchain, machine learning) will trigger significant changes. These technologies show unprecedented potential for a much better aligned, intermodal and passenger-centric transport system in Europe for people and freight.

Innovative means of transport under development offer the potential for a reduction of travel times mostly in the regional and urban areas to the long-distance hubs (railway stations, airports, cargo hubs) with vastly reduced environmental impact (noise, pollution). The time required and buffers applied for changing transport modes can be shortened significantly by better information and coordination, higher predictability and on-time-performance. Processes at the hubs can be accelerated, streamlined and made more customer-centric by new IT-technologies. Having a single ticket for the whole journey would also cut times and increase passenger satisfaction.

The metric to monitor the implementation of the results and its progress is the time it takes for passengers travel from door-to-door. According to the H2020 DATASET2050 project, only 15% of the passengers are currently capable to end their door-to-door journey within 4 hours. From a different point of view, the current metric of door-to-door travelling time for the 90% of the travellers is 7,5h. So the envisioned mobility performance goal is very ambitious, but also appears to be achievable. This would boost EU growth, enhance EU cohesion, competitiveness and prosperity, and provide a vastly improved customer travel experience in terms of time and comfort.

Setting a direction

Sustainable mobility of passengers and goods as basis for European economy and competitiveness, investment in jobs and growth

Clear focus on research and innovation

- Explore & develop novel transportation concepts (e.g. autonomous vehicles, urban air mobility, hyperloop etc.) and their effect on mobility performance & behavior
- Explore feasibility & accelerate implementation of new IT-technologies and concepts (AI / big data, block chain, digital identities, passenger and freight trajectories etc.) in transport to improve mobility performance, passenger-centricity and informed mobility choices

- Improve current levels of efficiency and predictability on each of the transport modes involved enhancing coordination for a more efficient operation
- Enhance the coordination & cooperation between the different transport modes promoting multimodality and intermodality in an EU-wide transport system that places the passenger at the heart of European mobility
- Develop a regulatory framework supporting implementation with regards to passenger rights, safety and security, environmental impact and accessibility

Under the FP9 framework, Research and Innovation and Actions will be needed to progress beyond the state of the art in the previously identified sections. Also, Coordination and Support Actions will be key to foster coordination across transport modes and its related stakeholders, understand passenger expectations and needs, identified potential barriers, propose potential solutions to be further analyzed, etc. Critical to the success of this mission is a close coordination among many diverse stakeholders who should consider this collaboration paradigm as the path to enable a new passenger-centric mobility system that will benefit EU citizens and economy.

The mechanisms to foster the implementation of the different solutions would be very diverse, according to the different nature of these outcomes: new or enhanced multimodal infrastructures, IT mobility platforms, innovative vehicles, improved operations to increase efficiency, etc. Each of these results would need different funding mechanisms (both public and private). Due to the importance of coordination, a Mobility PPP or JTI would be extremely beneficial.

Citizen priorities and final user relevance

The proposed mission is about reducing door-to-door journey times and increasing passenger satisfaction by the creation of a truly passenger-centric transport system, which is highly integrated, intermodal and transparent to the customer and delivers a step-change in predictability

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

Industry, research organisations, regulators, SMEs, universities from the entire transport sector in Europe

Stimulate efforts and investments at national and regional levels

Demonstration need to be implemented on national and regional level

European partners

Industry, research organisations, regulators, SMEs, universities from the entire transport sector in Europe

Research Field "Matter"

9. Mission "Identify Dark Matter!"

The idea

Identify Dark Matter! This mysterious form of matter shows up only in gravitation and it makes up for 85% of the total matter in the Universe. What is it?

One of the biggest and most fascinating open questions in modern science is related to identify the nature of dark matter in the Universe, an issue which galvanizes both citizen scientists as well as researchers in cosmology and particle physics. This mysterious form of matter so far has only been revealed by its interaction via gravitation. This has allowed astronomers to map the dark matter in the Universe and to reveal that it makes up to 85% of the total matter content. Dark matter influences the evolution of large-scales structures such as galaxy clusters, as well as galaxies, and even our own solar systems, which moves at velocities much larger than expected from normal matter such as stars formed by atoms. There is a variety of novel elementary particles which have been proposed as origin of dark matter, ranging from very light particles, which are expected to be about a billion times lighter than electrons, up to the leading dark matter candidate, so-called Weakly Interacting Massive Particles (WIMPs), which would have masses comparable to single atoms, or even more massive. Here we propose an ultimate search for WIMPs within the EU. The holy Grail in the search for these novel particles is to identify them via their interaction with normal matter, such as in a collision process with an atomic nucleus. Due to the very feeble interactions of Dark matter particles with normal matter this requires to set up very large dark matter detectors, typically on the ton-scale. These detectors have to be very sensitive to the exceedingly small signals from an interaction. The leading technology in dark matter (WIMP) identification is based on liquid noble detectors, which have to be housed in large underground laboratories to shield against cosmic radiation. In this class of experiments, the heavy noble gas element xenon has the best properties to detect dark matter. Accordingly, xenon-based experiments have outperformed other experiments based on different target & detection materials. To act as detector, a large amount of xenon has to be liquefied and purified to extreme levels so that dark matter interactions can be detected without distorting signals. Here we propose to build an exceedingly large xenon-based detector as flagship mission of European Research, a 50 t dark matter detector, the DARWIN (DARk matter WImp search with liquid xenoN) observatory. Its overwhelmingly large target mass, which is equivalent to the world supply of one calendar year, makes DARWIN the ultimate stage in the search for dark matter on earth. DARWIN will push forward to a sensitivity regime, where interactions of astrophysical neutrinos constitute an ultimate background barrier. Here we specifically will target also the procurement of such a huge amount of xenon. Xenon is the rarest natural non-radioactive element on earth with a content of 87 ppb (parts per billion) in air. The world-wide demand on xenon is steadily growing, coming from diverse areas such as lighting, the satellite industry, PDP backlighting, laser mixtures, and research, from dark matter to semiconductors to serving as anesthesia. To enable dark matter research with DARWIN, European industry has to implement novel technologies to drastically increase the available xenon.

EU added value

The Dark Matter search experiment DARWIN is technologically very challenging: it requires 50 tons of ultra-pur liquid Xenon. The core of the international collaboration would be European.

Setting a direction

Relevant UN goals are #9 (industry, innovation and infrastructure), #12 (responsible production) in our technology part, and #4 (quality education) in our science mission part, among many others.

Clear focus on research and innovation

Technology phase: new procurement technologies for 50 tons of xenon (or more) on short time scales; science phase: construct and operate DARWIN based on R&D works at many European academic institutions. Start construction around 2025.

Citizen priorities and final user relevance:

The public interest in this kind of basic science – elementary particles and the Universe at large – is huge. We will capture the interest of young scientists at an early stage. The cooperation between academia and industry will be boosted.

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

DARWIN will have to be co-founded and co-funded by institutions across the world – mostly from Europe – that work in academia, technology and industry. Challenges include low-temperature technology, precision measurements, large data volumes & analysis algorithms and physics interpretation with astronomy and particle physics.

Stimulate efforts and investments at national and regional levels

DARWIN will have to be co-founded and co-funded by institutions across the world – mostly from Europe. It will constitute a vivid network in science and technology.

European partners

Our European partners will include leading companies and xenon supplies in the EU, as well as many high-tech industrial partners in the areas of light sensors, electronics, big data and high voltage, among others. In the science part of DARWIN we will collaborate with a large number (20) of academic partners in the EU, forming a large research network targeted at identifying dark matter in the universe.

Research Field "Key Technologies"

10. Mission "Use our data for our purposes"

The idea

In science, economy, healthcare, and society from communication to consumer behaviour, Europe is witnessing a massive increase in data generation due to the digital transformation in all sectors in the coming years. The processing of large amounts of data from diverse sources by industry and the state, but also by entities from civil society and private individuals will open up totally new possibilities to benefit from our data. To keep pace with digitalization in almost every aspect of modern society and the demands of future humanity our digital world requires new information technologies and data processing methods.

Innovative methods to analyze scientific data are central to success within a wide variety of use cases. Scientific Deep Learning (SDL) emerged as a promising disruptive approach, allowing knowledge discovery from large data sets in an unprecedented effectiveness and efficiency. SDL is particularly relevant in research areas, which are not accessible through modeling and simulation, and thus complementary to classical approaches. Research regarding deep learning will enable innovative methods and techniques in order to 'learn from data' and to be prepared for the ever increasing number of scientific datasets and datasets in general. SDL has already shown its potential to gain new insights, and to generalize problem representations across datasets from a multitude of disciplines, leading to new breakthroughs in science and applications for industry and society.

The mission addresses the enormous methodological, technical, organizational, and sociological challenges which modern science and engineering face in the next era of digital transformation, mastering increasingly complex problems of research, economy, and society by means of simulation and data analytics. Besides the required fundamental research in the area of ***simulation and data science, scientific deep learning, co-design of leading-edge hardware and software technology*** *are essential. Furthermore, this high ambition entails unprecedented* ***security and trust challenges****, and it requires finding answers to corresponding* ***socio-technical matters*** *in question.*

In all areas of our life, data generation increases and the digital transformation is taking place. This mission has to foster interdisciplinary, cross-cultural and transdisciplinary research projects that yield both, generic and specific science-based solutions to face tomorrow's challenges of society and humanity. Examples are personalized medicine or climate forecast combined with energy generation from renewable energy sources.

EU added value

The digital transformation and data generation have no limits and no barriers – it is essential for each of us. Social, economic, but also political sovereignty in the digital world is vital for each member state. But each individual member state is not big enough to reach critical mass for successful transformation and only a common digital Europe can create a framework for our new digital world and Europe's place in it.

Setting a direction

This mission aims at tackling the digital transformation and new ways of data generation and processing, which are essential to face and support many of the goals defined in the new sustainable development agenda of the United Nations. For example, this mission can help to reach the climate goals of EU and UN. Indirect, this mission will bring benefit to missions, which want to end hunger, ensure healthy lives and promote well-being, ensure access to water and sanitation for all, ensure access to affordable, reliable, sustainable and modern energy, make cities inclusive, safe, resilient and sustainable, sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss by offering more efficient, and powerful simulation and data analysis tools, solving security and trust challenges, and tackle socio-technical matters related to the digital transformation.

Clear focus on research and innovation

This mission has a clear focus on research and development and the provision of scientific infrastructure. Supercomputers and Big Data Systems based on current as well as novel technologies are crucial for the development of new methods for simulation and data science. Scientific infrastructure will be accessible and made available for users from other research centres or universities, and other public and private partners and industries. Hardware and software development in turn will bring new generations of even more powerful and secure infrastructure. The digital transformation is not only a technical issue, but refers to societal transformation as well. Therefore interdisciplinary research on these socio-technical changes must be a key element.

Citizen priorities and final user relevance

Use our data for our civil purposes from a citizen's perspective: personalized medicine, smart data for industry, climate research, energy efficiency are only a few examples that can bring great benefits for society trough new and innovative simulation and data science technologies. Especially in such a highly innovative and technological field, it is advisable to develop and follow common paths and to define common standards, in order to raise the full potential of a common approach compared to individual and independent developments. In particular with regard to the analysis of data, it is assumed to be of great practical importance to pursue a common approach.

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

With the fulfilment of this mission, several further investments can be leveraged. Simulation and data science is a highly interdisciplinary research field. New investments in this field will trigger successive innovations and investments that will be based on new methods, algorithms, technologies and ideas gained via this mission. This should be orientated towards the idea of responsible research and innovation.

Stimulate efforts and investments at national and regional levels

It will be of great interest to each member state to participate in the transformation based on digitalisation in order to be part of the new digital world and benefit from the arising new possibilities.

European partners

All European Member States

Research Field "Key Technologies"

11. Mission "Materials for sustainable markets, growth and citizens' wellbeing"

The idea

Design of Functional Materials for Technology and Life

New materials and material systems directly or indirectly enable the majority of technical innovations. Materials research is thus key to fundamental technological progress today and prosperity tomorrow, leveraging strong global competition for achieving critical breakthroughs for new materials and the improvement of existing materials concepts. Beyond a broad range of challenging scientific and technical issues, the increasing rate of demands for newly designed, more efficient, smarter, and lower cost materials result in four overarching challenges, which must be solved on high international standards: ***computational design, information-driven interface design, combining biological with artificial materials, and scale bridging manufacturing****. Addressing these four overarching challenges, this mission contributes to the grand challenge of the digitalization of materials science* ***yielding materials for sustainable markets, growth and citizens' wellbeing****.*

This mission aims to foster an innovative approach that substantially incorporates efficient simulation techniques, powerful computer architectures, and data integration as efficient tools to save time and costs in materials development and design. At the same time, materials with particularly high potential must be of great interest to be converted into discrete, specific applications. Not only materials properties, such as the electronic structures of molecules have to be considered, but also the performance of materials or materials systems in the context of the manufacturing processes, the end product and its life cycle. The long-term resulting enabling of inverse engineering, the rational derivation of material properties based on the required product properties including its sustainability (life cycle) in the market, must also be addressed in this mission.

Materials research builds on many disciplines, materials science, physics, chemistry, and biology, which all strongly interact with each other with the development of more complex systems in particular. This mission is designed to be carried out in a coordinated interdisciplinary effort.

The mission addresses the whole value chain from basic research to final product or problem solution by the consistent integration of experiment, data analysis, modeling, and simulation in the sense of the continuous digitalization of materials discovery, design and production.

EU added value

The mission will integrate material scientists, their competences, and high-level research tools from Europe in order to develop and integrate information-based techniques in the material design, development, and processing as a major asset for future breakthroughs.

In the face of intense international pressure due to new developments, a competitive advantage of EU research can be reached by drastically reducing the long time-period between generic new developments and specific applications. This can only be achieved through the close interaction between digitalization and computer simulation

Setting a direction

By directly or indirectly enabling technical innovations with new materials and material systems, this mission:

1) Addresses the EU policy priorities of innovation, competitiveness for more growth and jobs, strengthening the industrial base, as well as digitalization and single market.
2) Contributes to solving challenges connected with UN SDG's
   - 3 (good health and well-being) by developing novel concepts, models, and instruments for biotechnological applications and regenerative therapies

- 7 (affordable and clean energy) by the development of new materials and concepts for energy-saving and pollutant-reducing separation and purification technologies or materials for new energy storage concepts
- 9 (industry, innovation and infrastructure) by developing innovative materials, materials systems and processes for multiple applications (e.g. new lightweight materials and their partial functionalization)
- 12 (responsible consumption and production) by developing innovative, energy-saving production and processing methods

Clear focus on research and innovation

The objective of this mission is to implement an innovative approach that substantially incorporates efficient simulation techniques, powerful computer architectures, and data integration as efficient tools to save time and costs in materials development and design. The spectrum of materials systems under consideration will cover quantum materials and molecular systems, active and responsive materials systems, photonic materials, materials for energy, smart bioactive materials, and structural materials systems.

- Computational design and digitalized material properties and behavior become a real important need for future “smart factories” in the frame of Industry 4.0 concepts
- Information-driven interface design, in particular of nanomaterials, biomaterials, and advanced engineering materials, offers great potential in future technological applications by tuning the materials properties beyond the design of bulk microstructures via the functionalization of surfaces and control of interfaces
- The development of novel concepts, models, and instruments combining biological with artificial materials will address the scientific challenges concerned specifically with the interfaces between materials design, biology, and chemistry for controlling cellular behavior for biotechnological applications and in regenerative therapies
- In order to cope with the high level of complexity, advances in materials development will be driven forward by the advancement of characterization and simulation techniques and their coupling over many scales via sophisticated methods of information processing
- The aim is to develop solutions to secure an economically, ecologically and socially sustainable & reliable supply of energy including safe disposal and treatment of wastes, residues and emissions. One important goal is to replace fossil fuels and

Citizen priorities and final user relevance

- Design of new materials is a main prerequisite to keep the pace in developing new technologies for information, health care, transportation and clean energy.
- The possibility of flexible surface and interface functionalization with on-demand tailored properties opens a new way to increase the added value and to customize the products in the frame of Industry 4.0 concepts
- An in-depth understanding of the reaction of the biological system, its interaction with the artificial materials and their degeneration, and finally, their distribution and impact on the human body will help to meet the dramatically increasing need for smart biomedical implants and devices
- The advancement of up-scaling and (additive) processing technologies will guarantee the reliable production of sufficient amounts of novel material and (architectured) components or devices with tailored property profiles

Transformative, leveraging investments by different actors (innovators, researchers, public authorities, citizens)

This mission will give rise to investments by different actors by:

- enabling inverse engineering on the long term, that is, the rational derivation of material properties based on the required product properties including its sustainability (life cycle) in the market
- Converting developments with particularly high potential into discrete, specific applications

Stimulate efforts and investments at national and regional levels

- The development of new materials and materials systems has the potential to stimulate multiple efforts, especially through cooperation (e.g., with universities, public authorities or industry)

European partners

Germany, France, Spain, Greece, Portugal, Netherlands, Norway, Sweden, Denmark, Poland, Belgium, Switzerland, Czech Republic

(Potentially all European Member States)

BRIEF PORTRAIT OF THE HELMHOLTZ ASSOCIATION

The Helmholtz Association contributes to solving major challenges facing society, science and the economy with top scientific achievements in six research fields: Energy; Earth and Environment; Health; Key Technologies; Matter; and Aeronautics, Space and Transport. With some 38,000 employees in 18 research centres and an annual budget of more than €4 billion, the Helmholtz Association is Germany's largest scientific organisation. Its work follows in the tradition of the great natural scientist Hermann von Helmholtz (1821-1894).

Please direct further questions and comments to

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