GEOLOGICAL SERVICE FOR EUROPE

STRATEGIC RESEARCH & INNOVATION AGENDA

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By EuroGeoSurveys, the Geological Surveys of Europe

The geoscience community of the Geological Surveys from 37 European countries, that provide public Earth science knowledge to support the EU's competitiveness, social well-being, environmental management and international commitments.

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FOREWORD

Geological Surveys in Europe have changed with time, as has the challenge of remaining relevant to today's society. Facing major current environmental issues related to the geosciences including climate change, pollution, environmental degradation, and resource depletion requires a societal transformation based on advanced scientific understanding. The Geological Surveys in Europe provide new and relevant knowledge and information needed to support policy development and its implementation to find solutions for environmental challenges. This advance of information and knowledge in geosciences is transferred to national and European policymakers, international forums and the general and nonspecific public to promote significant changes in the consumption and management of georesources (soil, water, energy, raw materials, space).

To be prepared for the European societies' future and to better serve the European Union's competitiveness, social well- being, environmental management, and international commitments, EuroGeoSurveys, the Geological Surveys of Europe, presents its Strategic Research and Innovation Agenda. This document forms the basis and input for the Geological Surveys of Europe's research goals and objectives and their position in the Horizon Europe Framework Programme for Research and Innovation 2021-2027. This multi-annual roadmap outlines how jointly, the Geological Surveys of Europe can play a key role in integrating the EU's ambitious targets for building a resilient society with a prosperous economic growth. Our main objective will be the implementation of innovative solutions based on research and innovation for natural resource security (land and soil, water, energy and raw materials) and management (energy storage, mitigation of the impacts of natural and anthropogenic hazards) towards ensuring environmental sustainability and social well-being and progress in the digital era.

How can these solutions be achieved? Linking research with the societal challenges is the best approach for Europe to advance. The linkage and optimal balance between basic and applied research is required to deal with the global challenges and the overhanging European priorities (e.g., resource-efficient, competitive low-carbon economy, protecting and enhancing natural capital; strengthening environmental governance…) based on digital and open data and information for informed decision-making. These concerns cannot be addressed successfully without a robust program of research and innovation across the full spectrum of subsurface geological information. Cross-country geological data, information, knowledge and expertise are needed to address the challenges raised above at pan-European scale. There is clear and urgent need for a common Geological Service for Europe to align national strategies with EU action plans for effective policy- and decision making, and strategic planning related to the subsurface geological information.

This document presents the research priorities and scientific topics of the Geological Surveys of Europe that will result in common projects with the ambition towards a Geological Service for Europe. The relevant scientific topics present in this document are strategic and with added value for the progress of the EU Member States and its international commitments and targets.

This document development is supported by the well-established and extensive network of the Geological Surveys of Europe including 38 European Geological Surveys, that are public organizations providing a Geoscience knowledge base.

01

Introduction

The European Commission remains committed to the United Nations' 2030 Agenda. The European Union (EU) made a positive and constructive contribution to the development of this Agenda of unprecedented scope and significance, with human well-being and a healthy planet at its core. Under the leadership of President von der Leyen, the Commission has presented an ambitious policy programme in the EU. The President's political guidelines and the Commission's annual work programmes integrate the Sustainable Development Goals (SDGs) of the 2030 Agenda into all the **European Commission priorities**, proposals, policies and strategies. Hence, the 17 SDGs lie at the heart of the policymaking on internal and external action across all sectors in the EU (Figure 1) considering different national realities, capacities and respecting national policies and priorities.

The implementation of the United Nations' 2030 Agenda is crucial to strengthen resilience action plans for people, planet and prosperity and to cope with the global challenges that threaten the present and future generations (i.e. sustainable consumption and production, sustainably management of natural resources), while preparing the world for the twin green and digital transitions, in a balanced and integrated manner. Europe will not achieve its 2030 goals without urgent actions during the next 10 years to address the overconsumption of natural resources, the alarming rate of biodiversity loss and increasing impacts of climate change according to the European environment state and outlook 2020 (SOER 2020) report.

Figure 1. The 17 Sustainable Development Goals grouped by the European Commission Priorities

Underlying the recent EU policy focus on achieving sustainable development in its three dimensions: economic, social and environmental, the European Commission has set out guidance for the implementation of the 2021 Annual Sustainable Growth Strategy (ASGS). The four dimensions of environmental sustainability, productivity, fairness and macroeconomic stability remain its guiding principles, with initiatives such as the European Pillar of Social Rights, the Green deal or the National Energy and Climate Plans.

Additionally, the 6 European Commission's priorities include the European Green Deal, a Digital Future, and an economy that works for people.

The main objectives of the European Green Deal include the EU commitment to reduce emissions by 50-55% by 2030 and become net carbon-neutral by 2050; the Water and Marine Strategy Framework Directives, the Farm-to-Fork Strategy, and the revised EU Adaptation Strategy; supporting the Sendai Framework for Disaster Risk Reduction (2015-2030), the land/sea degradation neutrality, and the UN Sustainable Development Goals. The implementation of these action plans requires profound changes in thinking, in economic and social structures and in consumption and production patterns that will involve experts who provide knowhow and knowledge to support decision making and policymaking.

The geoscientific community is looking for clear and reliable information and solutions for the exploitation of natural resources in a smarter way, with adequate management methods to minimize long-lasting consequences for the provision of natural and strategic resources such as raw materials, fresh water, energy and soil and ecosystem services (sustainable development) and in order not to increase health hazards and risks of natural disasters. To benefit from natural resources while sustaining the life on Earth, it is required to combine scientific knowledge, creativity, and innovation to drive transformation in all sectors of society. The **Geological Surveys of Europe** has the challenging task to help balance the opposing demands of 'exploitation' and 'stewardship' of our planet. Recognizing the subsurface as an "under-arching" domain critical to the prosperity of society in Europe, the Geological Surveys of Europe hold the key to subsurface planning, exploration, exploitation, monitoring and remediation to address today's and future challenges supporting an internationally competitive Europe.

We propose a comprehensive research and innovation programme, established under common challenges at national, European and global scale. This Strategic Research and Innovation Agenda seeks to provide a long-term vision and comprehensive programme of activities that constitute the overarching scientific framework of the Geological Surveys of Europe. It contributes to a number of key areas in line with the European Commission priorities and SDGs that require urgent action (Table 1):

→ **Resourcing Europe**: conservation and management of natural and strategic resources

→ **Energy transition and decarbonisation**: climate change and clean energy

→ **Enhancing safety, security and wellbeing for EU citizens**: public health and smart cities

→ **Europe's Digital Twin**: collection and provision of geoscience data & knowledge, digital transition and open science

Our aim is to increase the effectiveness and impact of EU development action plans and contribute to define and implement sound policies and realise down-to-Earth solutions, based on shared analysis, common strategies, joint programming, joint action and improved reporting at pan-European scale.

We also recognize the need to support strengthening data collection and capacity building in EU Member States, to develop geoscientific knowledge, skills, technology and innovations. We commit to define and address scientifically the huge gaps in data collection, to better inform the scientific community, stakeholders, policymakers and the general public, in particular for those objectives below which are threatened by missing basic data and information about the subsurface, essentially in terms of 2D–3D geological datasets and models. A collaborative and rigorous research and innovation effort driven by the Geological Surveys of Europe is our key principle that is promoted by a strong network of experts, who facilitate exchange of knowledge, proficiency, good practices and lessons learned from a multitude of perspectives and sectors of geosciences, to contribute to life-long learning with permanent open access to up-to-date, high-quality data and information to sustain EU policy and decision making.

Table 1. Description of the objectives of the Geological Surveys of Europe in line with EU Policy Priorities and the Sustainable Development Goals.

GEOLOGICAL SURVEYS OF EUROPE OBJECTIVES	EU POLICY PRIORITIES	SUSTAINABLE DEVELOPMENT GOALS	DESCRIPTION
Resourcing Europe	• Digital and Industry: Circular Industries • Climate, Energy and Mobility: Energy Supply, Energy Storage		Reliable and unhindered access to certain raw materials is a growing concern within the EU and across the globe. To address this challenge, the European Commission has created a list of **critical raw materials** (CRMs) for the EU. One of the objectives of this list is **to stimulate the production of CRMs by enhancing new mining and recycling activities in the EU.**
Energy transition & decarbonisation	• Climate, Energy and Mobility: Energy Supply, Communities and Cities, Energy Storage • Digital and Industry: Low-Carbon and Clean Industries		The ESTMAP 'Energy Storage Mapping and Planning' project provides an overview of available sites that could host **energy storage facilities and integrates this information with advanced planning of the European energy system.** This contributes directly to the European Commission's goal to provide **clean, secure and affordable energy for all EU citizens.**
Enhancing safety, security & wellbeing	• Health: Environmental health determinants • Inclusive and Secure Society: Cultural Heritage, Disaster Resilient Societies • Digital and Industry: Space • Climate, Energy and Mobility: Climate Solutions; Communities and Cities • Food and Natural Resources: Environmental Observation, Sea and Oceans		Roadmap to a Resource Efficient Europe (EC, 2011) has as a goal that **water abstraction should stay below 20% of available renewable freshwater** resources. However, so far it had not been possible to correctly estimate the water extraction and water scarcity correctly due to the lack of good data for groundwater.
Europe's Digital Twin	• Research Infrastructures • Digital and Industry: Key Digital Technologies; AI and Robotics; Advanced Computing		Digital twins have typically been applied to human-made infrastructure, Building Information Models (BIM) being a typical example. Subsurface Digital twins can be employed at scales ranging e.g. from individual buildings to continental or even global. These digital twin models will be an ensemble of 4D geospatial data (including sensor networks, parameters and properties), models and visualisations. In many European regions, however, appropiate data collections for the classical 2D- and 3D approach of geological datasets and models have still to be set up.

02 THE EU CONTEXT

The Geological Surveys of Europe actively contribute to the European Commission priorities for 2019-24 :

I

EUROPEAN GREEN DEAL

Europe aims to be the first climate-neutral continent by becoming a modern, resource-efficient economy. The European Green Deal provides an action plan to boost the efficient use of resources by moving to a clean, circular economy restore biodiversity and cut pollution. The plan outlines investments needed and financing tools available. It explains how to ensure a just and inclusive transition. The EU aims to be climate neutral in 2050 by proposing a European Climate Law to turn this political commitment into a legal obligation. Reaching this target will require actions by all sectors including investing in environmentally-friendly technologies supporting industry to innovate rolling out cleaner, cheaper and healthier forms of private and public transport decarbonising the energy sector and ensuring buildings are more energy efficient.

CONTRIBUTIONS TO THE EUROPEAN GREEN DEAL		
	CLEAN ENERGY	Intermittent renewables such as solar and wind are challenging because they disrupt the conventional methods for planning the daily operation of the electric grid. We can increase our energy storage capabilities through the advancement in battery technologies, but especially new and proven technologies for **large-scale, subsurface, renewable energy storage (hydrogen, green gas, compressed air)** deliver the capacity (power and duration) needed for integration of high shares of intermittent renewables.
	SUSTAINABLE INDUSTRY	Decarbonising electricity generation requires expansion in renewables, many of which require **critical raw materials and metals** to manufacture. Europe is currently a net importer, but actually has **underexplored local mineral resources** or possibilities for seabed mining, which would diversify sourcing and allow mineral extraction in a sustainable and ethical way according to EU laws.
	BUILDING & RENOVATING	At European level 47% of final energy consumption is absorbed today for heating and cooling of buildings, **geothermal energy** has the potential to be a key driver in decarbonizing the way we climatize our houses.
	CLIMATE ACTION	Fully switching to renewables would reduce CO_2 emissions. However, this will be more challenging in certain industry sectors. Also the ultimate aim is not only to be carbon neutral, but carbon negative, capturing excess CO_2 that is already in our atmosphere. This will require **underground carbon capture and storage (CCS)**.
	BIODIVERSITY	Complex interconnectivity between the atmosphere, hydrosphere and geosphere means that environmental management cannot be restricted to artificial environmental boundaries. Groundwater has been an historical buffer against climate variability. Our and nature's **dependence on groundwater resources** is likely to increase as water supplies are further stressed by population increase and climate change.
	ELIMINATING POLLUTION	Whilst current European legislation may have substantially reduced many polluting activities, a legacy of **contamination can remain in soil and (ground)water** for tens, hundreds, or even thousands of years. And new contaminants such as antibiotics and plastics are appearing in even the most untouched places. Constant environmental monitoring, identification of contagions and measures of remediation will have to remain in place and constantly updated and improved.

II

EUROPE FIT FOR THE DIGITAL AGE

The EU's digital strategy will empower people with a new generation of technologies. The Digital Europe programme has the aim to reinforce both EU critical digital capacities by focussing on the key areas of artificial intelligence (AI), cybersecurity, advanced computing, data infrastructure, governance and processing, and their deployment and best use for critical sectors like energy and environment, manufacturing, agriculture and health. This also includes a European data strategy which aims to create a genuine single market for data, where private and public entities can fully control the use of the data they generate and where both businesses and the public sector have easy access to a large pool of high quality data. One element of this high value **European Green Deal Data Space is the EGDI or EuroGeoSurveys' European Geological Data Infrastructure** This digital infrastructure aims to exploit the major potential of data in support of the European Green Deal priorities. Two main initiatives of EU policy will contribute to this work: Destination Earth and the local data ecosystem for climate-neutral and smart communities.

The objective of **Destination Earth (DestinE)** is to deliver a dynamic, interactive, computing and data intensive "**Digital Twin of the Earth**": a digital, multi-dimensional replica of a physical entity, the Earth (system), which would enable different user groups (public, scientific, private) to interact at various scales with vast amounts of natural and socio-economic information.

The ambition of the Geological Surveys of Europe is focussing particularly on creating a **digital twin of Europe's subsurface**, which entails much bigger challenges than its surface counterpart which, however, displays an indispensable starting point in 3D-modelling. This subsurface component of the digital twin, in the shape of geological map data sets relevant in scale and quality for applied applications, is still far from being completed in many European regions. This is why a realistic approach towards a digital twin of Europe's subsurface will also include efforts to fill this huge data gap. Smaller, but more detailed subsurface digital twin versions will be developed simultaneously and be of great support to the many actions taken by European cities and in line with the initiative of **local data ecosystem for climate-neutral and smart communities**.

Open science is a policy priority for the European Commission and the standard method of working under its research and innovation funding programmes as it improves the quality, efficiency and responsiveness of research. When researchers share knowledge and data as early as possible in the research process with all relevant actors it helps diffuse the latest knowledge. And when partners from across academia, industry, public authorities and citizen groups are invited to participate in the research and innovation process, creativity and trust in science increases. The **European Open Science Cloud** will enable researchers across disciplines and countries to store, curate and share data. The effective linking of open science practices to innovation and business models requires careful consideration of issues such as Intellectual Property Rights (IPR), licensing agreements, interoperability and reuse of data and it recognises and rewards the participation of citizens and end users.

III

AN ECONOMY THAT WORKS FOR PEOPLE

The EU must create a more attractive investment environment to stimulate the economic growth, especially for new generations. A strong European economy relies amongst others on a strong and high-performing industry. Built on a large single market, Europe is the global leader in many industries, especially in high value-added, low-carbon and sophisticated products and services. The economic significance of non-energy mineral resources and their exploitation is enormous: Sectors such as the construction, chemicals, automotive, aerospace, machinery and equipment industry, which provide a total value added of €1,324 billion and employment for some 30 million people, all depend on access to raw materials. A sustainable supply of raw materials to the EU – for its industry and society as a whole – is therefore strategically important (e.g. FP7 fact sheet on raw materials, 2013). Europe is using 23% of the world's mine production of metals and minerals but only produces 2-3% itself. Similarly, only around 9% of the global production of critical raw materials (CRM) is provided by European countries. Hence, Europe is vulnerable to scarcity and supply shortage and there is a need for increased exploration activity and the development of world leading mining operations and processing capabilities.

IV

STRONGER EUROPE IN THE WORLD

The EU will strengthen its voice in the world by championing multilateralism and a rules-based global order. The scale and ambition of the new Agenda requires a revitalized Global Partnership to ensure its implementation. The international stakeholders of the Geological Surveys of Europe will allow the partnership to tackle together global societal challenges and at the same time have access to the world's best talents, expertise and resource. This will enhance the supply and demand of innovative solutions. In this sense international cooperation will allow to compare approaches, test solutions, exploit results, exchange experiences and support transfer of knowledge across continents and regions. An examples of existing EGS international activities is with the Organisation of African Geological Surveys (OAGS), with whom there is already a strong collaboration through the PanAfGeo project financed by the European Commission.

V

HORIZON EUROPE

The Strategic Plan for the European Union Framework Programme for Research and Innovation 2021 – 2027, Horizon Europe, will be based on two legal acts: one laying down its structure, rules for participation and dissemination, the other containing the Specific Programme that sets out thematic clusters and the broad lines of action for future research and innovation activities. Horizon Europe will be structured in three pillars, supported by activities aimed at widening participation and strengthening the European Research Area (Figure 2):

→ Pillar I, Excellent Science will reinforce EU scientific leadership through the European Research Council (ERC), Marie Skłodowska-Curie Actions and Research Infrastructures.

→ Pillar II, Global Challenges and European Industrial Competitiveness will take forward the societal challenges and enabling and industrial technologies to better address EU and global policy priorities and accelerate industrial transformation. Pillar II includes six broad thematic “clusters” of activities.

→ Pillar III, Innovative Europe, focuses on stimulating, nurturing, and deploying disruptive and market-creating innovations, and on enhancing European ecosystems conducive to innovation, including the new European Innovation Council.

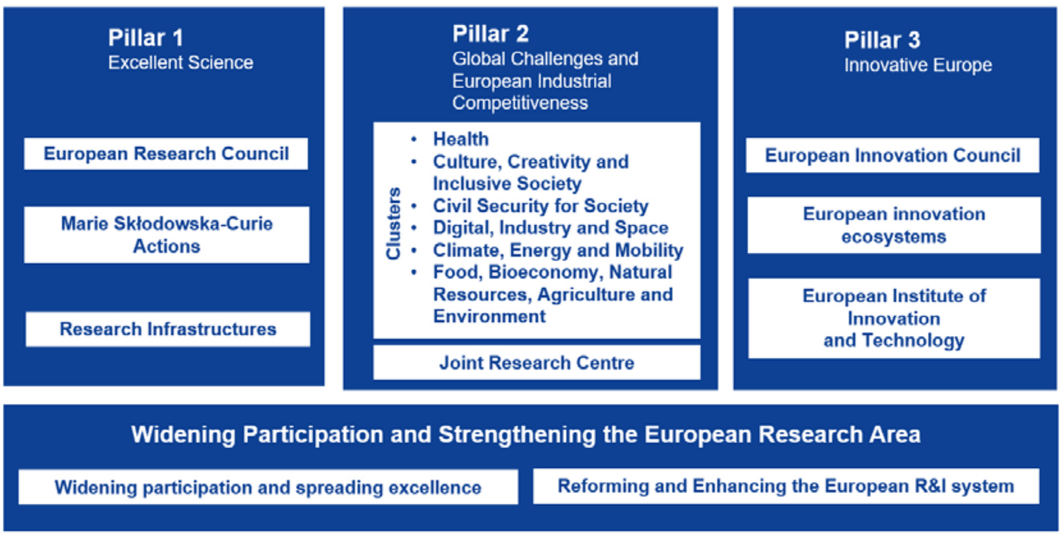


Figure 2. The 3 Pillars of Horizon Europe

The research and innovation policy priorities that will be considered during the implementation of Horizon Europe are:

→ **Cluster 1**, ‘Health’, aims to promote and protect human health and well-being, prevent diseases and decrease the burden of diseases and disabilities on people and communities, support the transformation of health care systems in their efforts towards fair access to innovative, sustainable and high-quality health care for everyone, and foster an innovative, sustainable and globally competitive European health industry. Research and innovation actions under this cluster will be key to address the health-related challenges and drivers delivering new knowledge and capabilities, improving our understanding of health and diseases, developing innovative methodological and technological solutions to better manage health and diseases, and designing sustainable approaches for the digital transformation and delivery of integrated and person-centred health and care services supported by needs-driven innovation and reliable supply chains in Europe.

→ **Cluster 2**, 'Culture, Creativity and Inclusive Society' aims to meet EU goals and priorities on enhancing democratic governance and citizens participation, and on the safeguarding and promotion of cultural heritage, and to respond to multifaceted social, economic, technological and cultural transformations. Activities will contribute to expanding civic engagement, boosting transparency, accountability, inclusiveness and legitimacy of governance, improving levels of trust and tackling political extremism. Activities within the Cluster will also promote better access and engagement with cultural heritage and improve its protection, enhancement and restoration. Research and innovation will support sustainable growth and job creation through contributing to a European industrial policy for the cultural and creative industries. At the same time, actions will help tackle social, economic and political inequalities, support human capital development and contribute to a comprehensive European strategy for inclusive growth. This also involves understanding and responding to the impacts of technological advancements and economic interconnectedness with a view to social resilience. Finally, the Cluster will support EU migration and mobility policies, both internal and external, while aiming to promote integration.

→ **Cluster 3**, 'Civil security for Society', aims to contribute to protecting the EU and its citizens from the threats posed by crime and terrorism (including in the cyber environment) and from the impacts of natural and man-made disasters. As shown in Eurobarometer surveys, security is one of the main concerns of EU citizens and is therefore among the top priorities for the Commission. Modern security threats are evolving rapidly, and technological and societal changes are creating unprecedented complexity, but so also are 6 opportunities for addressing them more efficiently. In this regard, security research provides the resources to be able to adequately counter current threats, by enabling the availability of state of the art equipment and knowledge. Furthermore, by working to anticipate future threats, security research develops today the capabilities that will be needed in the future.

→ **Cluster 4**, 'Digital, Industry and Space' will advance key enabling, digital and space technologies, underpinning the transformation of our economy and society, support the digitisation and transformation of European industry and contribute to securing global industrial leadership and autonomy in terms of technologies and resources. Furthermore, activities with the Cluster will contribute to growing a low-carbon, circular and clean industry respecting planetary boundaries and to fostering inclusiveness in the form of high-quality jobs and societal engagement in the use of technologies. Thereby it will contribute to addressing the challenges European industry is facing, such as its reliance on imported key technologies and raw materials, the scarcity of resources including energy, as well as skills mismatches and ethical considerations relating to technological progress.

→ **Cluster 5**, 'Climate, Energy and Mobility', aims to fight climate change while improving the competitiveness of the energy and transport industries as well as the quality of the services that these sectors bring to society. This entails establishing a better understanding of the causes, evolution, risks, impacts and opportunities of climate change, as well as making energy and mobility systems more climate- and environment-friendly, smarter, safer, and more resilient, inclusive, competitive and efficient. Actions of this Cluster will contribute to the technological, economic and societal transformations required to achieve climate neutrality and to ensure a socially fair transition, as outlined in the Commission's long-term strategy (adopted in November 2018).

→ **Cluster 6**, 'Food, Bioeconomy, Natural Resources, Agriculture and Environment' will advance knowledge, expand capacities and deliver innovative solutions to accelerate the transition towards the sustainable management of natural resources (such as biodiversity, water and soils). This will include measures for: climate adaptation and climate neutrality of sustainable primary production (agriculture, forestry, fisheries and aquaculture), value chains, food systems and bio-based industries; optimising ecosystem services including for climate mitigation; reversing biodiversity decline; and reducing environmental degradation and pollution. Activities will benefit people and society by promoting safe and healthy food as well as human well-being, including through a better understanding of consumer behaviour. Furthermore, activities will help to develop vibrant rural and coastal areas and to establish governance models for the transition towards sustainability. To this end, actions under this Cluster will lead and support the switch to a competitive, more circular and bio-based, climate-neutral, resilient and environmentally-friendly economy in compliance with the Paris Agreement on Climate Change and the United Nations Sustainable Development Goals.

03 THE GLOBAL CONTEXT

I

UN SUSTAINABLE DEVELOPMENT GOALS

The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in September 2015, represents an ambitious new blueprint to respond to global trends and challenges. The core of the 2030 Agenda are the 17 Sustainable Development Goals (SDGs) and associated targets, which run to 2030. For the first time, the Sustainable Development Goals are universally applicable to all countries and the EU is committed to be a frontrunner in implementing them. The ambition of these Goals and targets envisages a world free of poverty, hunger, disease where human habitats are safe, resilient and sustainable and where there is universal access to affordable, reliable and sustainable energy and natural resources. Global health threats are more frequent and intense including natural disasters. Natural resource depletion and adverse impacts of environmental degradation, including desertification, drought, land degradation, freshwater scarcity and loss of biodiversity, add to and exacerbate the list of challenges which humanity faces. Climate change is one of the greatest challenges of our time and its adverse impacts undermine the ability of all countries to achieve sustainable development. Increases in global temperature, sea level rise, ocean acidification and other climate change impacts are seriously affecting coastal areas and low-lying coastal countries, including many least developed countries and small island developing States.

II

PARIS AGREEMENT

The UNEP Emissions Gap Report states that between 2020 and 2030 an annual global decrease of 7% in CO_2 emission is needed to achieve the 1.5 degrees target. In order to meet CO_2 reduction commitments agreed at the Paris climate change conference in 2015, countries will need to reduce carbon-emitting sources of energy and increase lower-carbon energy. These will go some way to limiting global warming to 2 degrees, and aim to reduce the increase to closer to 1.5 degrees. As the latter may require zero emissions during part of the next few decades, new approaches to energy production are required; although it is acknowledged that reliance on fossil fuels is likely to continue during this energy transition.

Nonetheless, greenhouse gas emissions have risen at a rate of 1.5 per cent per year in the last decade, stabilizing only briefly between 2014 and 2016. The total greenhouse gas emissions, including from land-use change, reached a record high in 2018.

There is an international recognition that Carbon Capture and Storage (CCS) and geothermal energy are needed to meet the global climate ambitions of the Paris Agreement. The Intergovernmental Panel on Climate Change (IPCC) further reinforced this fact in its 2018 Special Report on Global Warming of 1.5°C by highlighting that we must get to net-zero emissions by 2050 and that it is crucial to deploy all clean technologies including CCS and geothermal energy to meet this goal. The latest statistics shows that the penetration of renewable energy varies across sectors, with renewable energy reaching 30.8% in the electricity sector, but only 19.5% in the heating and cooling sector, and 7.6% in the transport sector. The pace of increase in the share of renewable energy has also slowed since 2014. While the EU is on track to meet its 2020 targets for renewable energy, efforts should be stepped up to ensure that 2030 targets are met. Research and innovation will be key drivers for this.

III

SENDAI FRAMEWORK FOR DISASTER RISK REDUCTION

UN World Conference on
Disaster Risk Reduction
2015 Sendai Japan

Global trends, including population growth, unsustainable urbanisation and poor land management, ecosystem degradation and climate change, have led to an increase in the frequency, intensity and impact of disasters over the last decades. At the international level, work on disaster risk management is drawn together under the Sendai Framework for Disaster Risk Reduction 2015-2030, adopted by United Nations (UN) Member States at the Third UN World Conference on Disaster Risk Reduction in March 2015 and endorsed by the UN General Assembly. The Sendai Framework is the basis for a disaster risk-informed and resilient sustainable development agenda. The Sendai Framework is a voluntary instrument providing a new global approach to disaster risk management policy and operations. This framework aims to prevent new and reduce existing disaster risks, through an all-of-society and all-hazards risk approach across economic, social, and environmental policy areas, with a view to reduce vulnerability and increase resilience. The geological scientific community have an understanding of the Earth, its physical structure, and the processes by which it is constantly being shaped, which are of particular relevance within the Sendai Framework.

The Sendai Framework for Disaster Risk Reduction 2015-2030 outlines seven clear targets and four priorities for action to prevent new and reduce existing disaster risks: (i) Understanding disaster risk; (ii) Strengthening disaster risk governance to manage disaster risk; (iii) Investing in disaster reduction for resilience and; (iv) Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

The European Union has played a leading role in the negotiations of the new Framework and many of the Sendai recommendations are based on existing EU disaster risk management policies and programmes, including most of the ongoing civil protection, development cooperation and humanitarian aid actions. There are also several links to other EU policies, including climate change adaptation, critical infrastructure protection, flood risk management, water and biodiversity protection, research and innovation and global health security, food and nutrition security.

04 RESEARCH, DEVELOPMENT & INNOVATION CHALLENGES

I

A DYNAMIC STRATEGIC RESEARCH & INNOVATION AGENDA

The Geological Surveys of Europe respond cooperatively to the priorities for Europe (Figure 1) that emerge from the societal challenges for more sustainable and resilient societies and to support the transition towards a green and digital future.

The Strategic Research and Innovation Agenda (SRIA) describes the long-term strategy and programme for the Geological Surveys of Europe. In this document the Geological Surveys of Europe present their priorities in research and innovation and the scientific topics for the implementation of the next generation of pan-European research infrastructures.

The Geological Surveys of Europe envisage this strategic agenda in research and innovation as the ambition of building a Geological Service for Europe, by sharing a joint vision and programme in geosciences that should move it from being a common project to a long-lasting institution in the near future. This SRIA acts as a stepstone in the establishment of a pan-European research and innovation structure. The European Geological Surveys will be able to contribute, together with the Member States and other stakeholders, to a constructive dialogue on the scientific topics and where to put efforts in the research and innovation agenda, as well as to the specific initiatives which are required to move the implementation of a pan-European research and innovation infrastructure forward.

II

FOSTERING IMPLEMENTATION

The guiding principles for the Strategic Research and Innovation Agenda implementation are:

→ Joint Programming to put together national Geological Surveys research efforts to make better use of Europe's research and development resources and deal with common European challenges more effectively by combining a strategic framework defined in this document.

→ Building up the transfer of skills, knowledge, and resources to advance research and innovation in geosciences and to create the required R&I infrastructure to move forward the implementation of a pan European research and innovation.

→ Joint investments in research and innovation developing the current European infrastructure for R&I projects, innovation actions and alignment of national projects.

→ Science-policy cooperation and collaboration throughout initiatives, activities and instruments.

→ Strategic partnerships with European (and international) networks to support the development, transfer and/or implementation of innovative initiatives in geosciences promoting cooperation and exchanges of experience and lessons learned.

→ Promoting the sharing of knowledge and data by developing existing scientific data infrastructures and promoting effective communication, dissemination, and exploitation activities to develop an inclusive open science ecosystem in Europe.

The strategic planning process will also include close coordination and synergy with the following initiatives:

III

EUROPEAN PARTNERSHIPS UNDER HORIZON EUROPE

European Partnerships bring the European Commission and private and/or public partners together to address some of Europe's most pressing challenges through concerted research and innovation initiatives. They are a key implementation tool of Horizon Europe, and contribute significantly to achieving the EU's political priorities. By bringing private and public partners together, European Partnerships help to avoid the duplication of investments and contribute to reducing the fragmentation of the research and innovation landscape in the EU. The aim of European partnerships with EU and associated countries, the private sector, foundations and other stakeholders is to deliver on global challenges and modernise industry. The partnership candidates are collected across 5 areas:

health digital,
2/ industry and space climate,
3/ energy and mobility,
4/ food, bioeconomy, natural resources, agriculture and environment
5/ partnerships across themes.

IV

EIT INITIATIVES

The European Institute of Innovation & Technology (EIT) Knowledge and Innovation Communities are pan-European partnerships that strengthen cooperation among businesses (including SMEs), higher education institutions and research organisations and universities. EIT Knowledge and Innovation Communities aim to find solutions to major societal challenges in areas with high innovation potential. There are currently eight Innovation Communities and each focuses on a different societal challenge:

EIT Climate-KIC: Drivers of climate innovation in Europe and beyond
EIT Digital: For a strong, digital Europe
EIT Food: EIT Food connects businesses, research centres, universities and consumers.
EIT Health: Together for healthy lives in Europe
EIT InnoEnergy: Pioneering change in sustainable energy
EIT Manufacturing: Strengthening and increasing the competitiveness of Europe's manufacturing
EIT Raw Materials: Developing raw materials into a major strength for Europe
EIT Urban Mobility: Smart, green and integrated transport

V

HORIZON EUROPE R&I PROJECT PROPOSAL CALLS

Horizon Europe is the framework programme (2021 – 2027) that will succeed Horizon 2020. Horizon Europe will incorporate research and innovation missions to increase the effectiveness of funding by pursuing clearly defined targets. A mission is a portfolio of actions across disciplines intended to achieve a bold and inspirational and measurable goal within a set timeframe, with impact for society and policy making as well as relevance for a significant part of the European population and wide range of European citizens.

Specific missions will be programmed within the Global Challenges and European Industrial Competitiveness pillar (Figure X). This mission-oriented approach will focus on 5 mission areas, each with a dedicated mission board and assembly. The identified missions are

1/ Adaptation to climate change including societal transformation: a mission in this area will help maximise the impact of the EU's support to research and innovation and demonstrate its relevance for society and citizens. Its focus will be on solutions and preparedness for the impact of climate change to protect lives and assets. It will include behavioural changes and social aspects by addressing new communities beyond usual stakeholders, which help lead to a societal transformation.;

2/ Cancer: if no further action is taken, the number of people newly diagnosed with cancer every year in Europe will increase from the current 3.5 million to more than 4.3 million by 2035. A mission in this area will help set common goals aiming to reverse these frightening trends in cancer;

3/ Climate-neutral and smart cities: more than half of the world's population now lives in urban areas. This is expected to reach 80% by 2050. Cities and metropolitan areas are centres of economic activity, knowledge generation, innovation and new technologies. A mission in this area will help us meet the goals and targets set out by international policy frameworks such as the COP21 Paris Agreement, the UN's Sustainable Development Goals (notably SDG11), the Urban Agenda for the EU and the Habitat III New Urban Agenda as cities play a key role in all of them;

4/ Healthy oceans, seas, coastal and inland waters: Healthy oceans, seas, coastal and inland waters are vital for our societies and the future of our planet. A mission will be a powerful tool to raise awareness among citizens of the importance of healthy oceans, seas, coastal and inland waters, and help develop solutions on a range of issues;

5/ Soil health and food: land and soil are essential for life on Earth. They supply the food we grow and eat, as well as other goods such as feed, textiles, or wood. A mission in the area of soil health and food will provide a powerful tool to raise awareness on the importance of soils, engage with citizens, create knowledge and develop solutions for restoring soil health and soil functions. This will allow full use of the potential of soil to mitigate the effects of climate change.

05 SYNERGIES & COLLABORATION

I

EUROPEAN PARTNERSHIPS

- Clean Energy Transition Partnership
- Water4All Partnership
- Clean Hydrogen
- Agriculture of Data
- Industrial Battery Value Chain
- Carbon Neutral and Circular Industry
- Sustainable, Smart and Inclusive Cities and Communities
- European Open Science Cloud
- EIT KICs

SUBJECT	IDENTIFIED PARTNERSHIPS UNDER HORIZON EUROPE	PROGRAMMES, PROJECTS AND COLLABORATIONS
Resourcing Europe		
Raw materials inventory, classification, undiscovered deposits, potential of secondary resources, marine resources	28. Batteries: Towards a competitive European industrial battery value chain 47. EIT Raw Materials-KIC	GeoERA projects: FRAME, EuroLithos, MINDeSEA, MINTELL4EU, GARAH Raw Materials Initiative EIP on RM EIT Raw Materials, ERMA ETP-SMR UNCE on UNFC/UNSRM EMODNET-Geology COST- CRM_EXTREM / ITHACA EPOS ERIC SCALE SCRREEN
Climate Change & Decarbonisation		
Energy storage	17. Carbon Neutral and Circular Industry 23. Clean Hydrogen 30. Clean Energy Transition 41. EIT Climate-KIC	ESTMAP HEATSTORE HYPOS H2 UGS
Geothermal energy	17. Carbon Neutral and Circular Industry 30. Clean Energy Transition 41. EIT Climate	GeoERA projects: MUSE, Hotlime, 3DGEO-EU GeoPlasma-CE DarlingE MINERA GeoMol Transenergy

CC(U)S	17. Carbon Neutral and Circular Industry 30. Clean Energy Transition 41. EIT Climate	CO2STOP ENOS GeoCapacity CO2 GEONET CCS Demonstration Network GCCSI UltimateCO2
Safety, Security & Wellbeing		
Water Resources, Climate Change, Biosphere, Biodiversity, Ecosystems	38. Water4All: Water security for the planet	FOREGS GEMAS PanGeo
Geo-environmental pressure in Urban Areas	29. Sustainable, Smart and Inclusive Cities and Communities 30. Clean Energy Transition	EuroGEOSS E-SHAPE EU COST Action Sub-Urban
Climate hazards; induced hazards, geo-hazards	41. EIT Climate-KIC	GeoERA HIKE
The subsurface in Europe's Digital Twin		
Data capture, storage, analysis, infrastructure, visualisation		Infrastructure: EPOS Information system: RMIS Data network: EMODnet

II

PARTNERS & STAKEHOLDERS

In light of the 2030 Agenda, inclusive multi-stakeholder partnerships are perceived and promoted as key instruments for achieving the Sustainable Development Goals: partnership platforms are surfacing and new instruments are being set-up.

The challenges faced by modern economies urgently call for new forms of collective action between public and private stakeholders, to better integrate social challenges into research and innovation. A new approach is necessary to solve problems where social and technological progress co-evolves to generate social and public value. Most societal challenges are multidisciplinary in nature, thus dialogue between the different sectors in sciences is fundamental in this process.

Today's social challenges are numerous, complex, and urgent, from ageing societies, climate change, to energy efficiency and security. There is a wide consensus that the disconnection between economic growth and wellbeing is increasing. It is important that the EU Member States develop strategies that are underpinned by cross-border collaboration. In this way, the Geological Surveys of Europe will ensure shared expertise and information available to EU decision makers for sustainable use and management of natural ecosystems, based on full support at the national level and active collaboration with other scientific disciplines.
Some examples of relevant stakeholder groups include:

The European Energy Research Alliance (EERA) is the largest energy research community in Europe. It is a membership-based, non-profit association and brings together 250 universities and public research centres in 30 countries. EERA's joint research programmes cover the whole range of low-carbon technologies as well as systemic and cross-cutting topics.

The European Marine Observation and Data Network (EMODnet) is a network of organisations supported by the EU's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards and make that information freely available as interoperable data layers and data products.

The European Network for Research in Geo-Energy (ENeRG) created by European organisations involved in research and technology development (RTD) focused on fossil energy sources, especially oil and gas. It was formed to promote European RTD capability in the service of Europe's geo-energy exploration and production industry and its associated service and supply sector. The focus has been evolving towards all technologies for enabling energy transition and climate change mitigation: geothermal energy, CO_2 geological storage, underground energy storage, etc.

IMA-Europe is an umbrella organisation which brings together a number of European associations specific to individual minerals as Calcium Carbonates (GCC/PCC), Dolomite, Andalusite, Bentonite, Borates, Diatomite, Feldspar, Kaolin, Lime, Mica, Plastic Clays, Sepiolite, Silica, Talc, Vermiculite.

III

INTERNATIONAL COOPERATION

In line with the strategy for EU international cooperation in research and innovation (COM(2012)497), international cooperation is encouraged for adapting the upscaling approaches for restoration demonstrated for use in European conditions and applying them to harness transformative change internationally. In light of the SDGs, combing local research and practice with global learning and exchange is needed to benefit from different perspectives and diverse experiences. The international stakeholders already engaged with the Geological Surveys of Europe will allow them to tackle global societal challenges together and at the same time have access to the world's best talents, expertise and resource. This will enhance the supply and demand of innovative solutions. In this sense international cooperation will allow to compare approaches, test solutions, exploit results, exchange experiences and needs and support transfer of knowledge across continents and regions. Examples of international stakeholders of the Geological Surveys of Europe are the Organisation of African Geological Surveys (OAGS), with whom there is already a strong collaboration through the PanAfGeo project co-financed by the European Commission, and the Association of Ibero-American Geological and Mining Surveys (ASGMI). Other international organisations such as for example the IEA Greenhouse Gas R&D Programme, International Union of Geological Sciences (IUGS), International Union of Geodesy and Geophysics (IUGG), Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP) and Commission for the Geological Map Of The World (CGMW) will be important stakeholders who will have a high interest in different activities of this SRIA. International organisations such as UNECE, UNEP, UNESCO, IAEA and others are important groups with a wide platform to disseminate important R&I developments and evidence-based policy support.

06 THE FOUR GOALS OF THE GEOLOGICAL SURVEYS OF EUROPE

The 2020 Work Programme of the European Commission will turn the Political Guidelines of President von der Leyen "A union that strives for more – my agenda for Europe" into tangible benefits for European world leadership towards a healthy planet and a climate-neutral economy.

The driving force behind this first Work Programme is to successfully grasp the opportunities that the twin ecological and digital transitions will bring. The Geological Surveys of Europe would like to contribute to this vision and agenda which focuses on the actual planet itself: The Earth beneath our feet. The subsurface holds indispensable resources for European industries and options to decarbonise our economy, but also requires careful management to help preserve Europe's natural environment, including resources of clean water, which are prerequisites for a healthy and safe living environment for Europe's citizens and ecosystems services. We propose to achieve our targets by delivering a comprehensive programme of potential research and innovation actions shaped around the following four overarching goals, driven by common challenges that are facing our nations, our continent and our world:

1/ resourcing Europe

2/ supporting decarbonisation and mitigating climate change

3/ enhancing safety, security and wellbeing for EU citizens

4/ developing the subsurface part of Europe's Digital Twin.

We believe it is key to address the subsurface component of the European Green Deal challenges in an integrated, cross-challenge programme. The availability and accessibility of subsurface resources – whether this is geothermal heat, pore space, minerals, building resources, or clean soils, seas and groundwater – is determined by a complex interplay of a wide range of geological factors. The same goes for the positive and negative impacts that the exploitation of such resources may have on our living environment. A common thread in our research will therefore be innovation in the ways in which subsurface information is generated, conceptualised, organised, visualised, delivered and translated to the needs of a wide range of audiences. Such underlying methodologies are specifically addressed in the fourth challenge: the subsurface in Europe's digital twin.

I

GOAL 1 – RESOURCING EUROPE

Minerals are essential for modern living and vital for Europe's transition to carbon neutrality. Raw materials are indispensable ingredients for engineering, health solutions and for the preservation of our cultural heritage. Mining and quarrying are still the primary methods of their extraction. The main constraints to sustainability in the mineral resource sector derive from the ever-increasing demand for mined resources, the consumption of resources (mostly energy and water) needed to extract rocks and minerals and process metals, the increasing pollution generated by the extraction process and still limited circular use of resources. These aspects drive our research priorities and adds to strengthen a robust European economy. COVID-19 also brought the supply chain resilience to the awareness of society at large. This and the European Green Deal will be a driver that calls for a greater share of mineral raw materials to be mined and processed in Europe.

RESEARCH PRIORITIES

- Raw materials for the transition to carbon neutrality
- Sustainable & resilient mineral supply chain for Europe
- Circular use of resources
- Diversifying sourcing (on- & offshore; in Europe & beyond)
- Responsible mining practices

Research Priorities

Raw materials for the transition to carbon neutrality

The need to meet future energy demands, while striving for a low carbon future, is not immaterial. The technologies assumed to populate the clean energy shift – wind, solar, hydrogen, and electricity systems – are in fact significantly more material intensive in their composition than current traditional fossil-fuel-based energy supply systems[1].

Decarbonising electricity generation requires expansion in renewables, many of which a manufactured using critical raw materials (CRM) and metals. This calls for a sustainable and secure supply of mined materials. Some of the required materials are rather new targets in respect to Europe's long history in mining. Hence, the knowledge of Europe's CRM-inventory mined and in the ground is limited. Our main goal is to identify where those materials are hosted in Europe's continental and oceanic crust as well as in historical mining sites. This is the first step to unlock new European sources and to add to a fair share of responsible sourcing.

Sustainable & resilient mineral supply chain for Europe

No matter how innovative, sustainable and circular our industries will become, they will always rely on resources that, if they cannot be recycled, will either have to be grown or mined. The EU is a world leading producer and exporter of agricultural products (relying in part on the good soil quality guaranteed by (mineral) fertilizers). In contrast, the EU is a net importer of many mineral derived commodities. For most raw materials, particularly those needed for the energy transition – most notably for battery technologies and the e-mobility – for the IT Sector, the digital revolution and defence sectors, the world markets are highly concentrated, i.e. the supply comes from only a few countries. Many of these raw materials are identified by the EU as critical raw materials, not only due to the demand but also due to the shattered value chain in Europe.

The higher demand results in an expansion in frontier terrains. New technologies and innovation such as in the field of Earth Observation (EO), geological mapping, ore deposit research, or exploration of deep and/or complex deposits in Europe, can be exploited for global mineral exploration and geological mapping in virgin or little studied regions and allow for continuous environmental monitoring of ongoing mining activities. Innovation in mineral beneficiation, refining, processing and recovering are key to reconnect the shattered European raw materials value chain. In the increasing high-technology sector, Geological Survey Organisations have their share by developing technologies and being able to test them on site.

1. World bank 2017. The Growing Role of Minerals and Metals for a Low Carbon Future. 112 p

Data collection and harmonisation of those data is a mammoth task, but a **European resource inventory** is paramount for strategy formulation and risk assessment in the European supply chain. Material Flow Analysis, based on inventories and pooled with forecast studies will identify bottle necks, potentially improve recirculation, and help ensure sustainability throughout the value chain. A pan-European resource inventory combined with continued work to better the data, closing data gaps and providing more information will improve awareness of the European resource potential and improve quality of planning to lower the criticality risk. Those reliable information are essential for industry beyond mining.

Circular use of resources

In the context of circular economy, existing mining waste (e.g. historical abandoned mining sites, current waste rocks, tailings and metallurgical residues) have to be recognized as a potential resource for critical and strategic minerals. Mining and metallurgical waste may turn into important raw materials and environmental issues may be mitigated through reprocessing using optimized, environmentally friendly techniques.

The knowledge base, today, on (historical) mining waste is limited. However, new technologies and more advanced techniques allow economically viable mineral extractions from mine waste. This technique is often already common practice in active mines, which reprocess older tailings. Waste sites need to be mapped, characterised and sampled to turn mining and metallurgical waste into useful raw materials.

Diversifying sourcing (on- & offshore; in Europe & beyond)

Frontier terrains are not just confined to regions outside of Europe. As mining in Europe has been on the decline for decades, so has minerals exploration. Therefore, what we know about minerals potential in most of Europe predates current definitions of economic deposits, in terms of grade and depth and also of composition and complexity. The consequence is, perhaps counterintuitively, that Europe is underexplored for mineral resources especially at greater depths, below 100/200 meters.

Mining is not constrained to metals and industrial minerals. The need for natural construction materials, such as natural stone, sand, gravel and crushed rock for European housing and infrastructure, remains high. When locating and extracting resources, be it onshore or offshore, closeness to market is essential in order to minimize CO_2 footprint through transport and to ensure robustness for flood control measures. Construction materials therefore have their own issues in terms of location and land use management, and coexistence with other natural resources and potential coastal impacts and on-stream courses.

Other than that, the possibilities for seabed mining need to be investigated both geologically (how and where do marine mineral deposits form?), environmentally (which impact does extraction have on the ecosystem?) and technologically (how can these be mined?). Important initiatives in this field are already underway, e.g., improvements of the EU Raw Materials Knowledge Base and research into the use of non-invasive exploration methods.

Geological Survey Organisations study these three key questions in national and international waters. Their repeated investigations in the same area provide time series measurements, which are the first step of monitoring and recommendation settings. Combining the knowledge of land-based deposits and the frontier research in the marine is crucial to understand the ore forming processes, to identify new sources and to develop advanced technologies.

Responsible mining

Mineral resource extraction has to be strongly embedded in environmentally and socially responsible natural resource policies and practices, which promote local voices and explore innovations that help deliver a more inclusive and accountable mining sector, sensitive to the environment, biodiversity and to the rights and responsibilities of all stakeholders.

The Geological Survey Organisations are neutral bodies that provide unbiased, reliable science-based information to the public and to policy makers. This information is a vital component for trust building, societal acceptance and for reliable decisions. Moreover, Europe's Geological Surveys have a long-lasting standing in capacity building. Our expertise is essential to improve the raw materials knowledge base in Europe and to build strong, fair and faithful raw material partnerships with raw materials suppling economies.

Research Themes

UNDISCOVERED DEPOSITS

→ Frontier terrains:
- Deep-seated deposits
- Complex ores
- Deep ocean exploration & seabed mining and related environmental investigations
- Modern and advanced technologies (e.g. analytic, geophysical technologies including of Earth Observation for Exploration)

→ Underexplored Europe for minerals, metals & industrial minerals

CIRCULARITY

→ Circularity of historic (European) mine waste/residuals

→ Reuse of abandoned mines for touristic sites and its storage capacity (water or energy storage)

→ Aftercare of abandoned mining sites and quarries for cultural heritage and touristic purposes and protection of biodiversity and valuable habitats

INVENTORY

→ Material Flow Analysis based on European Raw Material inventories

→ Minerals from value chain perspective (i.e. Forecasts)

→ Intelligent decision support

→ Land-sea connection

IMPACTS & HAZARDS

→ Environmentally and socially responsible natural resource policies and practices

→ Environmental evaluation & monitoring of pre-, during & post-mining activities

→ Geohazards assessment & monitoring of pre-, during & post-mining activities

→ Use of Earth Observation for monitoring of entire mine cycle

II

GOAL 2 – ENERGY TRANSITION & DECARBONIZATION

The most challenging and compounded environmental challenge we face today is climate change and its consequences. The energy transition is essentially a huge innovation in all aspects and on all scales, i.e., involving the development of enabling technologies, restructuring of energy production and distribution, and consumer behaviour. Decarbonisation is key.

Geoscience was central to the carbonisation of our environment through the exploration, extraction and use of fossil fuels. The same skills and expertise that helped develop these resources can significantly contribute to decarbonisation solutions. Many of the technologies involved share common scientific, regulatory and technical challenges, which will be a priority to address moving forward.

RESEARCH PRIORITIES

- **No-carbon energy sources**
- **Large-scale energy storage**
- **Reduce GHG emissions**
- **(Subsurface) land-use management & oversight**

Research Priorities

No-Carbon Energy Sources

At European level 47% of final energy consumption is absorbed today for heating and cooling of buildings, geothermal energy has to potential to be a key driver in decarbonizing how we climatize our houses. Geothermal heat is a sustainable, no-carbon energy source that has the potential to supply an energy baseload and even shallow groundwater resources may be used to both heat and cool cities.

Altogether, our current energy system is largely planned and managed in a sectoral approach that will fall short for a more sustainable, multi-sourced energy system. To our community a more integrative and holistic approach implies that the geoscientific information and knowledge that we will deliver need to be presentable and understandable outside the geoscience domain.

In order to make use of the subsurface in the energy transition, it needs to be revisited. It requires exploration for geothermal energy and subsurface storage options, in depth knowledge of where we can source the raw materials needed for wind and solar power generation, batteries for mobile and large-scale energy storage, as well as controlling technologies. The siting of windfarms, especially referring the offshore ones, requires new data and an understanding in geologically relatively unchartered territory.

Large-Scale Energy Storage

Currently most renewable energy is generated at the surface, for example solar, wind and hydrokinetic. Individual countries are in the process of developing large scale renewable capacity by wind and solar power but face the challenge of suffering production gaps due to periods of diminished wind and/or sunshine. These gaps exceed the energy capacity of current batteries or hydro-storage lakes by a factor of several hundreds or thousands. New and proven technologies for large-scale energy storage in the subsurface (hydrogen, green gas, synthetic fuels, compressed air, heat) can deliver the capacity (power and duration) needed for future capacity balancing.

Reduce GHG Emissions

Fully switching to renewables would reduce CO_2 emissions. However, this will be more challenging in certain industry sectors. Also, the ultimate aim is not only to be carbon neutral, but carbon negative, capturing excess CO_2 that is already in our atmosphere. This will require underground carbon capture and storage (CCS).

(Subsurface) Land-Use Management & Oversight

Such new usage of the subsurface introduces a spatial planning aspect for which policies and tools are largely lacking, especially in view of the growing controversy of energy production and mining in general. The latter aspect applies to CO_2 and energy storage as well. In fact, planning conflicts that will inevitably arise when using the subsurface for these new purposes in coordination with land use and exploitation of groundwater, require a 3D planning approach that still needs to be fully conceptualised.

All these new interventions in the subsurface require proper risk and hazard assessments, meticulous monitoring and oversight to ongoing activities to ensure the protection, exploitation and sustainable use of groundwater and surface water resources and prevent risks related to industrial activity such as seismicity, surface deformation, leakage, facility hazards.

Research Themes

ENERGY FOR TODAY & TOMORROW

→ Aftermath of fossil fuel energy system: new use for old data & infrastructures

→ Shallow & deep Earth heat

→ Subsurface energy creation (geothermal) & storage

FEASIBILITY, SUITABILITY & SOCIAL LICENSE TO OPERATE

→ 3D planning for use of subsurface

→ Spatial, environmental, legal and safety restrictions

→ Risk and hazard assessments

→ Monitoring and oversight

REDUCING GHG EMISSIONS

→ Underground carbon capture and storage (CCS)

→ GHG (incl. methane & CO_2) emissions from oceans, soils, …

→ GHG emissions due to subsidence

III

GOAL 3 – SAFETY, SECURITY & WELLBEING

The subsurface plays an important role in our day-to-day life, although it is often literally overlooked. Clean water is a precondition for life, sustaining all humans, ecosystems and biodiversity, and plays a fundamental role in the climate regulation cycle. At the same time there is a 'race for space' in our rapidly urbanizing world. And at the same time, we hope that the piece of land we built on is safe, will not start trembling or have hidden risks underneath.

RESEARCH PRIORITIES

- **Clean water for all**
- **'Race for Space' especially in the urban environment**
- **Preserving biodiversity & geoheritage**
- **Eliminating pollution**
- **Reducing (geo)hazards**

Research Priorities

Clean Water for All

Water is the most important linking pin between the subsurface and the environment. Water needs to be managed internationally: Europe's main rivers and watersheds are larger than its Member States, similarly groundwater flows across European borders. Apart from a resource, it is also a transport agent for pollutants from surface activities such as agriculture and industry to drinking water wells and other pressures.

Driven by the rapid growth of demand for agricultural, industrial and municipal water, annual global groundwater extraction has rapidly increased in recent decades, from 100 km^3 a year in 1950 to the current use of about 800 km^3 a year. Hidden under the ground, groundwater is often considered as an infinite resource. However, groundwater is often extracted faster than the reservoir is replenished by rainfall. Groundwater represents 18 percent of the total water use in Spain, going up to 43 percent in Greece,54 percent in Portugal and more than 95 percent in Slovenia. If we continue to pump as much groundwater in the coming decades as we have done so far, a critical point will be reached in these countries. Climate change may even accelerate this process, as we expect less precipitation, which will further increase the extraction of groundwater and cause dry areas to dry out completely.

Continuous and real-time monitoring of groundwater quantity and quality is needed to fully understand the European hydro(geo)logical context. It will also allow to take data-based decisions to improve the current groundwater status and based on future climate predictions how this positive status can be maintained. It will also allow to track historical and new pollutants present in the water.

‘Race for Space’ in the Urban Environment

The urban environment, where most Europeans live and where artificialization, i.e., human interference with geology, challenges traditional approaches to map and study the subsurface.

There is a serious issue due to the lack of information about the ground beneath our cities and the un-coordinated way in which the subsurface space is managed. Mounting pressures of affordable housing, infrastructure management and environment protection place significant pressure on the finite land resource. Late stage awareness of ground properties and physical constraints to planned development is costly – ground risk is one of main causes of project delay and of insurance claims on completed projects. Underground assets, such as water, sewerage, electricity, gas or communications infrastructure, constitute the foundation of a country’s infrastructure. Unavailable, inadequate or poor quality of underground data results in damages, strikes and accidents during earth excavation leading to high repair and replacement costs, in addition to associated social and environmental costs. Third party damages to utility assets costs the UK alone £150 million per year, while indirect costs are estimated to be 10x of this.

Providing relevant and more accessible geological data to the user at the right time and in the right format is crucial to help save money, improve efficiency in planning and development, in resource extraction (water, geothermal, minerals) and to reduce the impacts of geological hazards. Also, by integrating geological information and smart geo-data monitoring and observation into the concept of the smart city the impacts of for example climate, demographic, resource and waste flows and land-use change in the context of the wider geo-environmental setting will be much better understood.

Preserving Bio- & Geodiversity & Geoheritage

Nobody doubts the importance of biodiversity for human life and the planet in general. Geology has strong ties with biodiversity, in that the nature of the substrate, as usually determined by the nature of the underlying rock, is a key factor in determining the distribution of habitats and species. Geomorphological processes, which shape our mountains, rivers and coasts, also maintain the dynamic habitats and ecosystems on which our biodiversity depends.

Geology is part of the planet's “natural capital”, the stock of global natural assets. These assets provide many benefits for society, often referred to as “ecosystem services”. However, traditionally these have mainly focused on biotic services and have undervalued the abiotic ones. Society benefits from bio- and geodiversity, and of the planet's geoheritage. Conservation of geoheritage is not only important for the preservation of natural areas of planetary importance, but also the public interest in visiting spectacular geological places and the economic benefits this geotourism brings.

Eliminating & Mitigating Pollution

Given that soil contamination is a key issue in planning a healthy home, school, work, and recreational environment, there is an urgent need to know what geochemical elements are present in our urban environment. Whilst current European legislation may have substantially reduced these activities, a legacy of contamination can remain in soil for tens, hundreds, or even thousands of years. In the EU-28, an estimate based on artificial surfaces reveals the possible existence of around 2.8 million sites where polluting activities took/are taking place. However, this is an estimate as while some Member States might already have several decades of experience with identifying contaminated sites, determining the type of pollutants, and taking adequate remediation measures, other Member States are still in the process of identifying sites.

Reducing (Geo)Hazards

Europe may falsely seem to be relatively safe when it comes to geological hazards. However, almost all of Europe is affected by landslides and subsidence. Moreover, seismic and volcanic risks are extremely high in the Mediterranean area. Also, around the North Sea there is increasing evidence of seismic activity in a region that does not have a history of such events, and thus it is not prepared for this kind of hazard. The lack of multi-hazard assessments and adequate hazard maps combined with the lack of pan-European knowledge on geohazards such as landslides or subsidence poses significant risks to European citizens and infrastructures, particularly in urban areas. Also, modification of natural slopes, groundwater flow alterations, underground excavations, or sea land reclamation for urban developments, will increase anthropogenic related geohazards such as slope instabilities, flooding and subsidence due to underground excavation, among others.

Similarly, land subsidence is causing more and more damage every year due to increasing flood damages, casualties and as structural damage and high maintenance costs. The impact on coastal cities and peat areas is increasingly apparent. The total bill worldwide mounts up to many billions of euros annually. It can only rise further in the future with population growth and the intensification of economic activities in delta areas. One of the most striking examples of the devastating impact of subsidence is the city of Venice. The spectacular centrepiece of Venice, Piazza San Marco, now floods more than 60 times a year, up from four times a year in 1900. The subsidence of this city seriously compromises its heritage and its safety in relation to its small elevation above the sea. The increased flooding is often said to be caused by rising sea level due to climate change. However, only 10 cm out of 25 cm during the last 100 years can be linked to changing sea level, the other 15 cm is due to subsidence triggered by groundwater pumping in the nearby industrial area.

Research Themes

WATER

→ Climate change and the water-energy-food-environment-health nexus

→ Groundwater and the biosphere: biodiversity, nature-based solutions and ecosystem services

→ Data and tools for EU and UN policy support

→ Innovative and sustainable solutions to safeguard water resource quantity and quality

URBAN AREA

→ Urbanized catchments

→ Urban subsurface planning

→ Non-technical communication

→ Improved socio-environmental evaluation of urban development: value of subsurface

MONITORING & RISK REDUCTION

- → Multi-hazard assessments
- → Pan-European multi-hazard databases
- → Reference databases of water and soil
- → Pollution mapping and monitoring, also new contaminants

IV

GOAL 4 – EUROPE'S DIGITAL TWIN

The Geological Service for Europe will take optimal advantage of ever-evolving digitalisation by conceptualising the digital subsurface as a component of Europe's digital twin.

RESEARCH PRIORITIES
Data handling: Subsurface information and management
New tools and methodologies for data acquisition
Interoperability of data between different data platforms
Machine learning & Big Data technologies

Research Priorities

Data handling: Subsurface information and management

Still missing standards in geologic nomenclature and suitable data models for 2D to 5D geological information, in which these standards are to be applied, need to be developed. By employing a system of hierarchical nomenclature and tools for automated aggregation of model-information according to zooming ratio, we will move beyond the current European Geological Data Infrastructure and develop new digital, transboundary, geological models and datasets of European regions.

New Tools and Methodologies for Data Acquisition

New tools and methodologies for data acquisition, processing and dissemination have emerged. They have the potential to revolutionize the way in which geological data and knowledge are collected and managed.

Interoperability of Data between Different Data Platforms

Interoperable subsurface data (geological maps, borehole data, mineral resources, geochemical data, groundwater information, etc.) at a pan-European level is still a challenge. However, such data is essential for dealing with resources, climate change, decarbonisation and safety and wellbeing at a European scale. This requires standardization, harmonization, adequate handling of resolution differences, unified modelling techniques and innovation.

Machine Learning & Big Data Technologies

The Big Data technology has a potential for processing of large amounts of unstructured data and giving access to manage big data in geosciences from different sources (sensors, satellites, model-based simulations, etc.). It is closely connected to AI and machine learning.

Research Themes

DATA HANDLING & MODELLING

→ Standardization

→ Technical & scientific harmonization

→ Scalability, resolution differences, dynamic legends

→ Unified modelling techniques and innovation

→ New subsurface datasets & models of European regions

→ Dealing with data uncertainty

→ Connections between different data types (i.e. land-sea, different platforms)

USER EXPERIENCE

→ Co-creation of data services based on user needs

→ Understanding of the user experience

→ Value of data to different users

IT INNOVATION

→ AI

→ Machine learning

→ Data visualization

07 LEVERAGING INTERLINKAGES

In today's world, a pure sectoral approach to societal challenges is unable to grasp the potential synergies and trade-offs between different existing activities to deliver real-world solutions, for example competing uses of water for industry, for domestic use and for the natural ecosystems. The increasing reliance on subsurface resources and uses to achieve a climate-neutral economy highlights that we need to embrace a cross-sectoral, coherent and integrated perspective where these uses can be complementary to each other.

The GeoERA programme takes important steps towards identifying and optimizing interlinkages in subsurface management with intra- and cross-thematic interactions between the 15 projects. Cross-sectoral collaboration is a natural following step when exploring Earth system interlinkage possibilities even further.

As an example, water uses for industrial activities, for societal needs and for natural ecosystems may be first seen as conflicting, but there are ways they can benefit from one another. A primary example model of such close interlinkages is the WEFE (Water-Energy-Food-Ecosystem) Nexus. The Food and Agriculture Organisation of the United Nations (FAO) first coined the water, energy and food security (WEF) nexus to indicate that the actions in any one particular area often can have effects in one or both of the other areas. Recently this nexus concept has been broadened to also include ecosystems. This approach highlights the interdependencies between in this case achieving water, energy and food security for human well-being, while ensuring ecologically sustainable use of globally essential resources.

Such interdependencies exist in all aspects of life. A nexus approach ensures a more integrated and sustainable use of resources that goes beyond traditional silos and that can be applied at different scales.

I

EUROGEOSURVEYS EXPERT GROUPS

EuroGeoSurveys is an outstanding example of cooperation between national institutions, thanks to its ability to synergistically integrate both information and activities of the member's organisations. This has allowed the association to make impressive progresses over the years, permitting geosciences to become a primary subject deserving great attention within the European Union's political agenda.

The EuroGeoSurveys (EGS) Expert Groups are integrated by individual members from 38 European Geological Surveys Organisations. The objective of the Expert Groups is to join forces and cooperate in research and innovation in a broad field of expertise in geosciences. By sharing expertise and experience, the Expert Groups identify knowledge gaps, contribute to improve the operational capacity and economic capabilities of governments, institutions, organizations, businesses, and individuals and define measures and actions. EuroGeoSurveys research covers a wide range of topics through the work of Expert Groups. Each Expert Group is active in the following specific geoscientific fields:

Earth Observation & GeoHazards

Earth Observations from satellites in orbit, high and low altitude aircraft and ground-based observation systems play an increasing role in modern geological measurement, mapping, monitoring and modelling. Earth Observations allow field resources to be targeted efficiently, provide an economic, consistent, synoptic view over large areas and consequently, they offer considerable efficiency, cost and high-quality information.

The mission and vision of Earth Observation and Geohazards Expert Group (EOEG) is twofold: to improve geoscience knowledge (geohazards monitoring, mineral exploration, assessing the impact of mining activity) exploiting the full range of Earth Observation tools (radar, optical, hyperspectral and thermal); and, to evaluate the impact of geohazards in Europe through the harmonization and upgrading of national databases and the application of innovative mapping, monitoring and modelling techniques and methods.

Geochemistry

The chemical composition of near-surface materials (rock, soil, sediment, water) is crucial for the well-being of all life (humans, animals and plants) on Earth which are themselves combinations of the naturally occurring chemical elements.

The quality and survival of life depend upon the availability of chemical elements in the correct proportions and combinations. Natural processes and human activities continuously modify the chemical state of our environment, and therefore, it is important to determine and to monitor the distribution and mobility of chemical elements across the Earth's surface.

The mission of the Geochemistry Expert Group (GEG) is to provide high-quality geochemical data of near-surface materials (rock, soil, sediment, water), to develop harmonised databases for multi-purpose use, to offer independent expert advice to the European Commission, and to supply sound background data to scientists for their research, and to the public, in general, for education and other purposes (e.g., land use planning, agriculture).

GeoEnergy

Security of energy supply is critical to the world economy. The hydrocarbons (oil, gas, coal) are the most important commodity for international trade and are high on the political and social agenda. Fossil fuel is becoming a scarce raw material in the European Union. Energy trade is becoming a stock market business. In order to keep energy affordable, new opportunities need to be developed. Geothermal energy, new exploration methods and a better understanding of the geological processes have resulted in solutions to meet increasing energy demands. The GeoEnergy Expert Group (GEEG) provides impartial, scientifically robust information to advance the understanding of fossil fuel energy and geothermal energy (geoenergy) resources in Europe, to contribute to plans for a secure energy future, to facilitate evaluation and responsible use of energy resources, and to analyse future geoenergy resources of Europe and possibilities of their sustainable use. Geoenergy information provided by GEEG is based on publicly available and accessible information and data, which are of globally comparable standards of excellence for science and expertise.

Geological Mapping and Modelling

The collection and continuous update of continental and marine geological data as well as their interpretation, by establishing geological models (maps, sections and 3D- up to 5D-models) and through expertise, is a vital task of most national (and regional) geological surveys. The Geological Mapping and Modelling Expert Group's (GMMEG) ambition is to share at a European scale the knowledge and expertise of the different national and regional Geological Surveys along with the other public and private sectors active in the field of geosciences, in order to improve the quantity and quality of the geological data, information and knowledge, and hereby develop a world leading European geological information platform (via the EGDI information platform and contributing to the subsurface in "Europe's digital twin") to better serve the needs of society.

International Cooperation and Development Task Force

Geological Surveys have a high potential to provide information, expertise and advice, and this offers unique opportunities for international cooperation and projects. The EuroGeoSurveys Task Force on International Cooperation and Development (ICDTF) was therefore established by EGS to intensify and improve international cooperation. Its mission is to increase the capacity of EGS and its members to establish stable, permanent and effective relationships with Geological Survey organisations and other relevant stakeholders internationally, as well as to capitalise on international cooperation opportunities. The ICDTF ensures that members share their international cooperation expertise and research, and act upon request of the EU institutions by making use of newly opening opportunities.

Marine Geology

Marine geological information and interpretations is fundamental for better use of the marine environment including a variety of topographies and marine biotopes which provide us with a wide range of resources. The coastal zone where human activities have had the most impact on the marine environment as large numbers of people live close to the coast and many of our industries are located close to ports are particularly vulnerable parts for human induced pressures. The Marine Geology Expert Group (MGEG) delivers high-quality information and advice to decision-makers responsible for the European seas. The MGEG emphasis is placed on cross-cutting issues such as sustainable use of natural resources, climate change, habitat mapping, natural hazards and long-term maintenance of databases.

Mineral Resources

The European Union aims to place Europe at the forefront of the raw materials sectors and mitigate related negative environmental and social impacts. Additionally, it aims to reduce the import dependency on raw materials that are considered critical to Europe's industries by improving supply access conditions from EU and other sources and promoting resource efficiency, including recycling, and alternatives in supply through the urban mine and substitution while promoting the concept of a circular economy. The EGS Mineral Resources Expert Group (MREG) is actively involved in contributing to policy- and strategy-making processes aiming to identify, characterize and safeguard a sustainable resource potential, notably on critical and strategic raw materials, through research, development and innovation. The MREG mission is to provide the best available mineral expertise and information based on the combined knowledge of member Geological Surveys, for policy, communication, value chain creation, public awareness and education purposes at European level, focusing mainly on strengthening the position of the European minerals industry towards resource sustainability and competitive growth. To stimulate economic growth and minimising the societal, environmental and political values and developments that place increasing pressure on the availability and exploitation of geological resources.

Spatial Information – INSPIRE

Geoinformation management is a key domain of expertise of geological surveys, in their capacity as information agencies and national data centres. The member organizations of EuroGeoSurveys are the key metadata and data/information providers not only on the subsurface of their individual countries but also at the European scale. EGS has formulated a strategy for establishing a Geological Service for Europe. A central pillar in this strategy expresses the need for pan-European accessible and interoperable geoscientific information, which has been addressed by developing a common sustainable infrastructure, EGDI. The Spatial Information Expert Group (SIEG) provides governance and resources for its continued design and development. It also brings a common platform to share expertise among EGS members and to discuss the science topics relevant to the geoinformation development for the next period. The SIEG vision is to contribute to further development of the infrastructure to reach a highly advanced technological level, providing more products and data as co-developed with and demanded by the user community and to contribute to the definition of the "Subsurface in Europe's Digital Twin". Establishing the connections between the different existing infrastructures will be paramount in achieving interoperability and a step-change in usability and utility. The Spatial Information Expert Group should assess the possibilities of new technologies such as artificial intelligence (AI), big data processing, modelling, and the potential to resolve current challenges related to standardization, knowledge representation, learning, natural language processing, advanced methods of search and mathematical optimization, etc. Greater focus on the latest technologies together with more efficient stakeholder outreach may help to improve visibility and usability of the products as a decision support system.

Water Resources

The Water Resources Expert Group (WREG) mission is to provide scientific information and unbiased advice on water resources. In particular, the focus is on groundwater management and protection in general, and more specifically related to the groundwater aspects of the Water Framework Directive (European Commission, 2000), the Groundwater Directive (European Commission, 2006) and the Common Implementation Strategy (CIS) of both Directives. The WREG vision is to be the most authoritative source of subsurface water resources scientific information and expertise and develop methodologies to understand, evaluate and predict climate change impacts on groundwater resources and interlinked surface waters and ecosystems.

Urban Geology

Cities are complex systems that exist at the interface of natural, built and social environments. The solutions to our urban challenges require interdisciplinary collaboration and integrated approaches. Geological and geotechnical information about the subsurface are of paramount importance and of high socio-economic value for the development of our cities and maintenance of critical infrastructure (e.g. transport tunnels, supply networks and foundations). To achieve the vision of resilient cities, the Urban Geology Expert Group (UGEG) supports Europe's Urban Agenda and urban policies to fulfil the requirements of European Commission Directives and the UN Sustainable Development Goals. The Urban Geology Expert Group provides high-quality scientific information and expertise relevant to the needs of the EU's urban decision-makers and European Institutions in the areas of sustainable urban development, urban resilience, future-proofing of cities, SMART Cities, and safe construction.

Communication Strategy Task Force

The purpose of the Communication Strategy Task Force is to improve the EuroGeoSurveys (EGS) identity and visibility by identifying methods and tools to collect, disseminate, and archive information that is the result of the collective work done by the EGS Members. The Communication Strategy Task Force increases the visibility and knowledge on EuroGeoSurveys and its members and, in particular, its mission, goals, and activities, and to disseminate the results achieved, with the main scope to build stronger relations with the most important public administrations, in the particular European Union institutions, as well as the private sector, and to raise awareness and interest in major mass media.

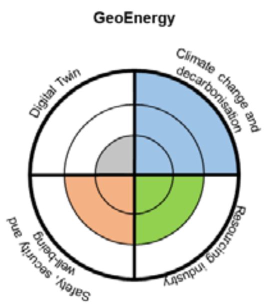
EGS Expert Group	Resourcing Europe	Climate Change & Decarbonization	Safety, Security & Wellbeing	Subsurface in Europe's Digital Twin
Geo-Energy	+	+++	++	+
Groundwater	+	+	+++	+
Minerals	+++	++	+	+
Earth Observation	++	+	+++	++
Information	+	+	+	+++
GeoChem	++	+	+++	+
Urban	+	++	++	++
Marine	++	+++	++	+

Figure 3. Degree of engagement of the Expert Groups at each of the 4 established goals (+ indicates low, ++ medium and +++ high)

Example Mapping science topics to main themes: GeoEnergy

Subthemes
- Pan-EU harmonization > resource portfolio
- Integrating data across research disciplines
- Big data mining, analysis
- Monitoring and geological test beds
- Safeguarding industry data for future generations

Stakeholders
- DG-JRC (collaboration)
- Academia (collaboration)
- Research partners / Surveys / EPOS (collaboration)
- Consultants (defining specifications)
- Industry (data owners)



Subthemes
- Renewables (upscaling geothermal)
- CO2 reduction (implement/upscale CCS)
- Energy security (enable E-Storage)
- Energy efficiency (manage heat/cold shallow)

Stakeholders
- National authorities (Nat. policy agenda)
- EC Green Deal (EC policy agenda)
- DG-ENER (agenda, EC research agenda)
- Local authorities (planning distributed)
- JRC (end-user EC)
- Technology platforms, industry (agenda, tech. lobby)
- Policy advisors (end-users, influencing agenda)

Subthemes
- Induced hazards and impacts (decarb/mining)
- Nuclear waste storage
- Gas hydrates (climate risk)

Stakeholders
- DG-ENV (EC research agenda)
- Nat./Loc. Regulators (policy agenda)
- Advisors/regulators/boards (policy implementation)
- NGO's, citizens, etc. (influencing agenda)

Subthemes
- Critical Strat. Minerals
- Re-use of mines
- Energy minerals

Stakeholders
- DG-GROW / DG-ENER (EC res.agenda)
- Mine operators (planning)
- ...

Example Mapping science topics to main themes: Urban Geology

Digital Twin

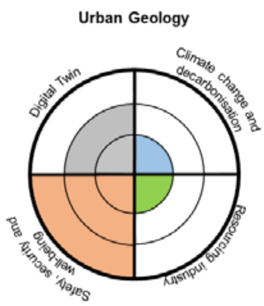
Subthemes
- Model and data integration (BIM + geoenv models)
- Big data mining, automated data technology
- Scenarios analysis (urban planning/forecasting)
- Digital urban planning workflows and systems

Stakeholders
- Data standards institutes
- Industry software developers
- Local authorities
- Urban innovation centres /data observatories
- National authorities (policy agenda)

Climate change and decarbonization (Energy)

Subthemes
- Renewables (shallow geothermal)
- CO2 reduction (urban adaptation)
- CO2 storage (urban soils)

Stakeholders
- National authorities (Nat. policy agenda)
- GSHP installers/technology providers
- Local authorities (urban planning)
- Policy advisors (end-users, influencing agenda)



Safety, Security and Well-being

Subthemes
- Urban geohazards (multi-hazard risk and impact)
- Geology Natural Capital and Ecosystem Service
- Nature-based solutions (e.g. sustainable drainage)
- Integrated urban resource management (links across themes)

Stakeholders
- DG-ENV (EC research agenda)
- Nat./Loc. Regulators (policy agenda)
- Advisors/regulators/boards (policy implementation)
- NGO's, citizens, etc. (influencing agenda)
- Local authorities

Resourcing Industry (Raw Materials)

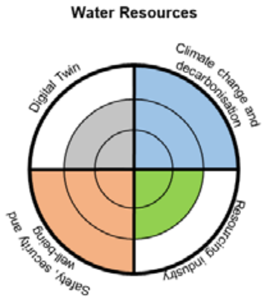
Subthemes
- Materials flows (construction - supply and demand)
- Re-use, circular economy of construction materials
- Engineered soils for construction

Stakeholders
- DG-GROW?
- Mine operators (planning)
- Infrastructure (planning and development)
- Local authorities (urban planning)

Example Mapping science topics to main themes: Water Resources

Subthemes
- Pan-EU harmonization > resource portfolio
- Integrating data across research disciplines
- Big data, Machine Learning, near real-time monitoring and modelling
- 3 and 4D visualization of monitoring and modelling results
- Safeguarding groundwater data for future generations

Stakeholders
- DG RTD, DG DIGIT?, DG-JRC (collaboration)
- Academia (collaboration)
- Research partners / Surveys / EPOS (collaboration)
- Consultants (defining specifications)
- Industry (data providers and users)



Subthemes
- Renewables (groundwater for heating and cooling)
- CO2 reduction (gw issues related to CCS)
- CC impact assessment, monitoring and modelling
- CC mitigation and adaptation

Stakeholders
- National authorities (Nat. policy agenda)
- EC Green Deal (EC policy agenda)
- DG CLIMA, DG RTD, DG-ENER, DG ENV, DG HOME (agenda, EC research agenda)
- Local authorities (planning distributed)
- JRC (end-user EC)
- Technology platforms, industry (agenda, tech. lobby)
- Policy advisors (end-users, influencing agenda)

Subthemes
- GW quantity and quality and legitimate uses
- GW quantity and quality, biodiversity and ecosystems
- induced hazards and impacts (overabstraction/ land subsidence / flooding)
- Nuclear waste storage

Stakeholders
- DG-ENV, DG RTD, DG HOME, DG ECHO, DG CLIMA, EU Civil Protection Mechanism (EC research agenda)
- Nat./Loc. Regulators (policy agenda)
- Advisors/regulators/boards (policy implementation)
- NGO's, citizens, etc. (influencing agenda)

Subthemes
- Groundwater issues related to mining
- Re-use of mines and related gw issues
- GW quantity and quality issues in industrial areas (incl. mining and agriculture)

Stakeholders
- DG-GROW / DG-ENER / DG ENV / DG AGRI (EC res.agenda)
- Mine operators (planning), agriculture
- ...

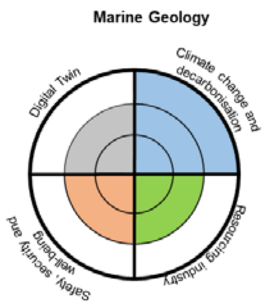
Example Mapping science topics to main themes: Marine Geology

Subthemes
- Modular modelling and intelligent decision making
- Standardization/harmonization of data (storage, management and distribution technology) and data products (scale and legend granularity)

Stakeholders
- DG MARE (European Atlas of the Seas)
- EASME
- Decision makers in government and industry
- Decision tool builders

Subthemes
- Seabed knowledge for offshore windfarms and other renewable energy
- Carbon capture, utilization and storage
- Subsurface energy storage

Stakeholders
- Energy companies
- Transmission network operators
- Windfarm and energy hub developers
- Licensing authorities



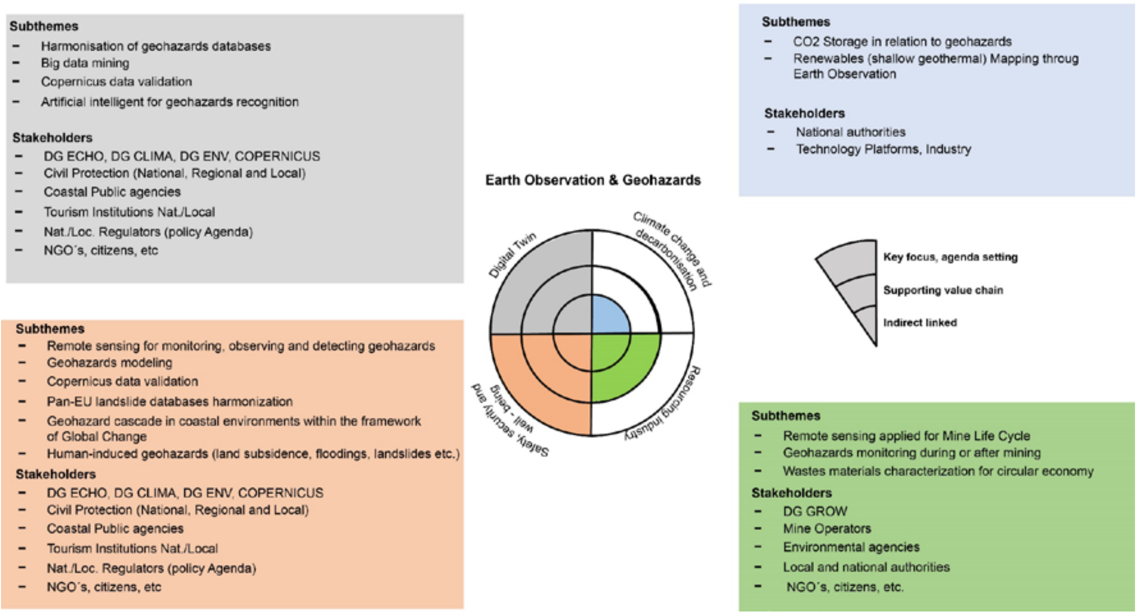
Subthemes
- Environmental baselines and monitoring
- Coastal and submarine geohazards
- Coastal and offshore environments

Stakeholders
- Infrastructure operators
- Coastal protection agencies
- General public (early warning, situational awareness)
- International Council for the Exploration of the Sea (Blue Economy)

Subthemes
- Seabed mining
- Aggregate inventory, assessment and classification (resources, flows and stocks)

Stakeholders
- International Seabed Authority
- United Nations Environmental Program
- Licensing authorities

Example Mapping science topics to main themes: Earth Observations & Geohazards



08 RETHINKING IMPACT – RESEARCH-POLICY-INDUSTRY RELATIONS

To strengthen relations between research, policy and industry and maximize their positive effect on our society, we first need to recognize that the impact can be applied on many levels.

This means that research outcomes, from specific data to generated knowledge, can only achieve the full extent of their significance if properly communicated. As such, we see the role of dissemination throughout the research process as a fundamental way to reach stakeholders, building trust and nourishing relations. However, this is not seen as a one-way interaction, but as a balancing act and exchange between these three sectors, since we know:

1/ knowledge shapes policy;

2/ politics shapes knowledge;

3/ co-production between industry and research lead to new knowledge;

4/ autonomous research spheres create different insights and views.

Attention will have to especially be given to new innovative and proven approaches to prepare and disclose geological information that are proven to be successful for policy support and subsurface management. However, impact works at many levels. Hence it will be a balancing act between research and other activities as providing a sound scientific basis for the progress of industrial activities and policy related to the subsurface is our way to contribute to sustainable societal prosperity and well-being.

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