Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe

Deliverable 4.5

REPORT ON FINAL IMPACT ASSESSMENT

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EXECUTIVE SUMMARY

GeoERA is a research programme establishing the European Geological Surveys Research Area that aims to deliver a Geological Service for Europe on subsurface resources. GeoERA is a network consisting of 47 national and regional **Geological Survey Organisations** (GSO) from 32 European countries. GeoERA aims to contribute to this goal **by integrating GSO information and knowledge** on subsurface energy, water and raw material resources to support stakeholders in addressing grand social challenges.

GeoERA is an **ERA-NET Cofund Action** of the European Union's **Horizon 2020** research and innovation programme. **European Research Area**, ERA, brings together predominantly European national funding agencies to provide a mechanism for the design and implementation of transnational activities. ERA-NET is a funding instrument designed to support public-public partnerships for mature networks with strong long-term financial commitment from participating states for preparation of joint activities, establishment of networking structures, programming, coordination, and implementation. The compulsory activity of the ERA-NET Cofund is the implementation of the cofunded joint call for proposals that lead to the funding of trans-national research and to synergy building.

GeoERA **co-funded 15 transnational research projects:** 14 projects in three vertical geoscientific **themes** (GeoEnergy, Groundwater, Raw Materials), and one horizontal Theme with one project (harmonised geo-information platform). Funding was partly covered by the GeoERA consortium members (67%) and partly by European Commission (33%). The co-funding has a total budget of 30.3 mio €. The GeoERA projects operated from July 2018 until oktober 2021. The GeoERA programme as a whole ran from 1 January 2017 until 28 February 2022.

Overall goal of GeoERA was to integrate the Geological Survey Organisations' (GSO's) information and knowledge on subsurface resources, to support their sustainable use in addressing Europe's grand challenges (GeoERA, 2016). Final Impact Assessment (FIA) obtained following insights about GeoERA's achievements:

1. About **integration**:

   – Cross-country networking is evaluated as Very Good, within initial expectation.

   – Cross-cutting integration (via Information Platform) was Extraordinary successful (beyond expectations).

   – Cross-thematic integration is Moderate and asymmetrical.

   Overall, achieved integration fulfils initial expectations (evaluated as Very Good).

2. About the **GSO's information and knowledge** (methods, procedures, metrics, recommendations, etc.) on subsurface resources: a score of 5 (out of 5) points for achievements beyond initial expectations. GeoERA contribution to knowledge and services aimed at European policy makers and stakeholders is also assessed with a score of 5 (Overachiever).

3. About **sustainability**: Ability to achieve self-sustained P2P networks that can operate without EU funding is assessed with a score of 3,5 (out of 5), which is at the lower range of being evaluated as Very Good.

4. About addressing **Europe's grand challenges**: GeoERA Projects assessed their contribution to EU Societal challenges as Very Good (a score of 3,6 on a scale of 1-5).

Final Impact Assessment of 15 cofounded Projects revealed several common features:

1. Several **changes in the deliverables and in partnership** were necessary in some Projects. Amendments were properly communicated with the Monitoring team and the GeoERA Secretariat. None of necessary minor changes negatively affected GeoERA aims.

2. The most important negative external factor was the **Covid** pandemic. It had an impact on the course of GeoERA and its projects. In December 2020, the GeoERA Programme was extended by two months, from 31.12.2021 until 28.2.2022, and the Projects by four months, from 30.6.2021 until 31.10.2021.

3. The **European Geological Data Infrastructure (EGDI)** has ensured that the results from all GeoERA projects are accessible on a single, user-friendly platform through the web-GIS interface and the associated search systems. It also gives access to the results in machine-readable forms using OGC services which also allows connection with other European e-infrastructure.

4. GeoERA delivered the **foundation for further work.** The case is, as one stakeholder reminded, that national geological surveys remain un-harmonised. So there is still much to be accomplished in this area.

5. **Capitalizing** on the achievements: several partners have already used their new collaboration experiences and research products in new Horizon Europe proposals.

6. GeoERA evaluators at different levels suggested the preparation of **specific guidelines**, e.g. policy briefs that can be used by policymakers at national and EU scale. Part of the information collected and presented by GeoERA is scientific and could be elaborated to reach a wider audience.

7. Some stakeholders reminded that to achieve the Geological Service for Europe, it will be necessary to work on extending efforts **from pilot projects to the GeoERA theme level, countries and beyond**.

8. Development of European Geological Services will also need **top down direction** from EU member states governments, and long term funding, to make further progress.

9. It is important to use the obtained results for promoting a shift of knowledge towards a **citizen/social science**, not forgetting young generations/scholars.

10. Enhance the **transnational character** of GeoERA Programme either by promoting the new standards and products to international bodies beyond Europe, by linking to other research infrastructures, associations, and by building capacity in countries and regions outside Europe, where needs are high and transboundary work is becoming more pressing.

Main GeoERA goal to deliver a Geological Service for Europe will continue to be supported in the next five years with the EU **Coordination and Support Action** 'Geological Service for Europe' (CSA GSE) if the submitted proposal is accepted. The expected outcomes and scope of the CSA GSE refer to further strengthening cross-cutting and cross-boundary integration, with cross-thematic dimension focused more on data and information (micro level) and less on Themes (meso level).

When also taking into account that cross-thematic integration is at present the weakest integration chain it becomes apparent that geological community may **need to secure additional efforts** for maintaining and further strengthening cross-thematic cooperation. One prerequisite is to take into account the difference between vertical and horizontal integration of knowledge or difference between **harmonisation** (cross-cutting) and **synergy** (cross-thematic) integration. Complex knowledge system requires balance between these issues.

The Final Impact Assessment (FIA) main motivations is to meet GeoERA demands for more integrated evidence that investments in research in geosciences are not only effectively spent in prescribed terms but also contribute with newly emerging synergies to broader scientific and social objectives. FIA applies a matrical approach to cross-thematic assessment of networked GeoERA Projects' impacts. FIA

accomplishes assessment of impacts with the evaluation of the implementation, application and effectiveness of GeoERA from the point of view of its goals and objectives. Assessment objects are in line with the Logical Framework Approach. FIA also provides cross-thematic analysis of impacts between GeoEnergy, Raw Materials, and Groundwater. Cross-thematic impacts determine how GeoERA performs as a whole. Impact assessment is accomplished with conventional assessment approaches as Desk study, Synthesis and analysis of findings obtained with monitoring, On-line questionnaires, Interviews with Stakeholders and triangulation of overall evaluation findings. Impact assessment methodology applied is conventional, while cross-thematic assessment is innovative.

List of abbreviations

CDA	Communication and Dissemination Activities
CRM	Critical Raw Materials
CSA	Coordination and Support Action
DOW	Description of Work
EGDI	European Geological Data Infrastructure
EGEC	European Geothermal Energy Council
EGS	EuroGeoSurveys
FIA	Final Impact Assessment
FPPR	Final Project Progress Report
GE	GeoEnergy
GSE	Geological Service for Europe
GSO	Geological Survey Organisation
GW	Groundwater
IAH	The International Association of Hydrogeologists
ICT	Information Communication Technology
IP	Information Platform
JP	Joint Programming Initiative
KPI	Key Performance Indicator
LFA	Logical Framework Approach
MPPR	Midterm Project Progress Report
MRO	Monitoring and Reporting officer
PRR	Project Progress Report
RHC	Renewable Heating and Cooling
RM	Raw Matherials
RMIS	Raw Materials Information System
SGE	Shallow Geothermal Energy
SME	Small and Medium Enterprice
SRA	Specific Research Area
TRR	Technical Review Report
UNFC	United Nations Framework Classification of Resources
WFD	Water Framework Directive
WP	Work Package

TABLE OF CONTENTS

LIST OF TABLES

LIST OF MATRICES

1   INTRODUCTION

GeoERA is not a single research project but rather a research programme. It is put forward by the national and regional **Geological Survey Organisations** (GSO) of Europe. GeoERA is organized as a network consisting of 47 national and regional GSOs from 32 European countries. The Programme aims at establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe (GeoERA, 2016) on subsurface resources.

Subsurface resources have a major influence on the way Europeans live today. Firstly, there is the large economic contribution to society's welfare and it sustains millions of jobs in Europe. Secondly, groundwater is vital to agricultural sector and the food industry in general and clean **groundwater** is a prerequisite for life itself not only supporting humankind but also ecosystems. Thirdly, much of our **energy** derives from fossil fuels, nuclear fuels and increasingly from geothermal sources and energy is at the heart of almost all of humankind's activities. Storage of CO_2 is essential for the realization of Europe's emission targets while storage of sustainable energy carriers will be needed to ensure a secure and affordable supply of energy in the future. Fourthly, **mineral raw materials** are key to almost every aspect of our daily life, whether as fertilizers, construction materials, or raw materials for a myriad of everyday implants, devices and goods. In short, society is strongly dependent on the availability of subsurface resources (GeoERA, 2016).

GeoERA aims to become **the starting point for a collaborative structure** supporting the implementation of a comprehensive and cohesive programme of scientific projects, aimed at developing optimized expertise and toolsets that can be employed both at regional/national and collaborative level. Every GSO has the national mandate to gather, store, maintain and disseminate subsurface data and information. However, each GSO has developed its own workflows, datasets and geological framework models. As regional geology, national interests and the basis for research funding also differ from country to country, these models and workflows are not always compatible, thereby hampering harmonised pan-European assessments of resources (SRA, 2018). Such assessments will improve the ability of GSOs to support stakeholders in addressing grand challenges.

GeoERA is an **EU Horizon 2020 ERA-NET Cofund Action**. GeoERA is supported under "Secure, Clean and Efficient Energy" topic LCE-26-2016 "Cross-thematic ERA-NET on Applied Geosciences" of the European Union's Horizon 2020 research and innovation programme. ERA, European Research Area, brings together predominantly European national funding agencies to provide a mechanism for the design and implementation of transnational activities. ERA-NET is a funding instrument designed to support public-public partnerships for mature networks with strong long-term financial commitment from participating states (Gøtke et al, 2016) for preparation of joint activities, establishment of networking structures, programming, coordination, and implementation. The compulsory activity of the **ERA-NET Cofund** is the implementation of the co-funded joint call for proposals that leads to the funding of trans-national research and to synergy building (Gøtke et al, 2016).

The overall goal of GeoERA is to integrate the GSO's information and knowledge on subsurface resources, to support their sustainable use in addressing **Europe's grand challenges** (GeoERA, 2016). Three main GeoERA **Specific Objectives:**

1. Address key challenges in geo-energy, groundwater, raw materials and data management by the majority of European GSOs on shared-funding basis.

2. Integrate available resources and national contributions to optimally support the goals on improving and optimizing harmonized pan-European coverage at a scale and resolution that is common to national and regional geological mapping programmes.

3. Develop a Geological Knowledge Base with the Geoscience Information Platform will provide European stakeholders with access to objective and seamless data, information, knowledge and expertise on subsurface resources and their sustainable management.

GeoERA co-funded **15 transnational research projects** (from now 'GeoERA Projects') and developed several deliverables directly contributing to implement the main GeoERA goal and specific objectives. 14 projects were thematic (vertical) and one horizontal (geo-information platform). Funding is partly covered by the GeoERA consortium members (67%) and partly by European Commission (33%). The co-funding has a total budget of 30.3 mio €. The projects ran from July 2018 to October 2021. Only members of the GeoERA consortium were beneficiaries of the GeoERA co-funding, other organisations had the opportunity to join the Projects as non-funded partners (non-beneficiaries).

GeoERA is designed to cover three geoscientific **Themes**: GeoEnergy, Groundwater, Raw Materials and an Information Platform matching Europe's need for pan-European geological knowledge and information. A GeoERA Theme is a **meso** (or middle) **level** concept situated between micro level of individual projects and macro level of GeoERA.

The **GeoEnergy** (GE) Theme considers hydrocarbons, energy derived from solid resources such as coal, geothermal energy from hydrothermal and petro-thermal resources, capacities for temporary storage of energy carriers and capacities for permanent storage of CO_2 and other energy effluents. It provides harmonized pan-European information. GeoEnergy delivers harmonized pan-European information. Expected Geo-Energy Impacts (GeoERA, 2016):

- Improved ability to predict potential subsurface contributions to **secure future energy supply** based on a transnational harmonized and unbiased inventory of hydrocarbon, solid fuel and geothermal resources and energy storage capacities.

- Improved evaluation of potential measures to limit further anthropogenically induced **climate change**, through improved and more comprehensive understanding of existing subsurface storage capacities for CO_2.

- Improved detection and anticipation of **potential bottlenecks** with respect to exploitation of geo-energy resources and storage capacities, based on an objective, science-based understanding of potential consequences from such exploitations (e.g. hazards, environmental impacts, conflicts and competitions).

- Improved basis for formulating and developing **future research and innovation** programmes through newly identified information and knowledge gaps and/or uncovered potential for technological developments.

- More comprehensive and scientifically supported basis for societal and economic **cost-benefit** analyses, subsurface **spatial planning** decisions and **strategic environmental assessments**.

- Increased opportunities for improving the **dialogue** with public and societal organizations, by providing transparent, unbiased, science- and evidence-based arguments for discussions on geo-energy uses.

The objective for **the Groundwater** (GW) Theme is to provide groundwater data, information and decision support tools for long-term protection, sustainable management and improvement in groundwater resources across Europe, taking into account societal challenges and EU policies, based on innovative methodologies to tackle diversity of hydrogeological settings and scales (regional to pan-European). Jointly developing harmonized and effective tools and methodologies for monitoring, modelling, data management and visualization. Expected Groundwater Impacts:

- Improved support for the implementation of **EU water policies** such as the Water Framework and Groundwater directives and the Blueprint to Safeguard Europe's Water Resources taking into account the exploitation of other subsurface resources (geo-energy and raw materials).

- Improved decision support for **climate change** adaptation by improved coupled climate and groundwater-surface water models.

- State-of-the-art **resource mapping and assessment** that will set the basis for an integrated Europe-wide monitoring system of groundwater in line with the Water Framework Directive.

- Improved insight in the **potential consequences**, hazards (e.g. land subsidence) and interactions of subsurface activities, climate change and groundwater abstraction and floods.

Raw Materials (RM) Theme Projects contribute to the security and sustainability of supply of primary and secondary mineral raw materials from EU domestic sources; and support in managing competing uses of the European surface and subsurface, both on-shore and offshore (GeoERA, 2016). Expected Raw Materials Impacts:

- Continuously reinforced **synergy at international level** and reduced fragmentation of raw materials research and associated innovation efforts across Europe facilitating a more efficient use of natural resources, minimizing waste and improving recycling.

- **Technical solutions** helping the market to enhance the exploration phase, making it more efficient and less invasive, and optimizing the performance and cost of deposit exploration (e.g., re-evaluating old mines).

- **Innovative** solutions for mineral exploration and development (e.g. Knowledge discovery in databases techniques, including Data Mining, of newly created Knowledge Bases), helping business and other stakeholders to optimizing their investment.

- **Data and tools** to facilitate the re-use and recycling of mineral based waste.

- Reduction of the **import dependency** of Europe's industries for critical raw materials.

GeoERA's different challenges share the objective to provide and disseminate spatial information on their respective resources and underpinning geological data. As the cross-cutting integration of information is an important aspect, GeoERA introduced a specific **Theme on Information Platform** to integrate all ICT-related and technical issues (database and

dissemination) from the other three Themes. The Information Platform addresses the development of a common geoscience information platform capable of integrating up-to-date data, interpretations and models from different and distributed sources. The Information platform's expected Impacts are:

- **Better access** to integrated information and knowledge on subsurface resources and potentials, including functionalities to investigate such data (e.g. maps, cross-sections, etc.), contributing to improving and structuring the dialogue between various policy domains and subsurface stakeholders in support of subsurface spatial planning and decision making;

- Improved ability of GSOs to effectively **define future actions** with regards to improving key knowledge on geo-energy, groundwater and mineral resources, through provision of a sustainable and expandable spatial information framework;

- Improved ability for end-users **to combine geospatial databases**, developed in GeoERA or at national/regional level, **with other environmental data** and information sources, to support e.g. environmental assessment, management of spatial planning, or evaluation and resolution of conflict of usage through implementation of standardized access (including INSPIRE compliant web services).

Cross-thematic integration between GeoEnergy, Raw Materials and Groundwater is a main objective for GeoERA. It takes place in developing common models and assessment frameworks that allow simultaneous appraisal of the interactions between projects that impact different subsurface resources. Cross-thematic integration is a prerequisite for adequately addressing cross-thematic social challenges like climate change mitigation, surface and subsurface spatial planning, or dealing with regional geo-hazards and geological impacts (floods, land subsidence, landslides, earthquakes etc.) related to deployment of geo-energy, groundwater and mineral resources. EuroGeoSurveys (EGS, 2021) makes it clear that 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. The increasing reliance on subsurface resources and uses to achieve a climate-neutral economy highlights that we need to embrace a coherent cross-thematic integrated perspective where different factors can be assessed as complementary to each other. In this way GeoERA contributes to the optimal use and management of the subsurface, maximizing its added value, while minimizing environmental impacts and footprint.

GeoERA dedicates information and knowledge to support **stakeholders** such as the European Commission, academia, industry, regulators and legislation authorities in answering key resource-related questions and needs. The exploitation of this valuable and currently underused knowledge to its fullest potential is a key aspiration of GeoERA. To fulfil it, GeoERA invited active interaction with and engagement of stakeholders during the preparation, implementation and evaluation phases.

Key to the success of GeoERA is **dissemination and exploitation** of obtained results, facilitated by the efficient and easy-to-use information platform. The Information platform acts as the main instrument for dissemination and exploitation of results beyond the end of the Programme. The principal **aim of the dissemination and exploitation** is to inform and engage the wider stakeholder community, allowing their needs to direct GeoERA projects and to maximise their impact. Activities include:

- Communication and promotion through the GeoERA website, newsletters, press releases, interviews and presentations.

- Dissemination of data and information services through the Information Platform developed in the project (and building on existing initiatives).

- Dissemination to academic researchers and networks through scientific publications, presentations at meetings and conferences, and the organization of dedicated workshops and seminars.

- Direct and indirect collaboration with stakeholder organisations and networks.

- Dissemination to National and regional stakeholders through dissemination channels of the GeoERA participants themselves.

Final Impact Assessment is one of specific objectives of GeoERA Programme's **Work Package 4** ('Follow-up and monitoring of projects resulting from co-funded call'). WP4 ensures timeliness and quality of implemented project activities. Specific objectives of WP4 are to:

- Develop a common set of monitoring indicators, reporting procedures and mitigation measures.

- Prepare of reporting templates.

- Ensure timely reporting.

- Analyse progress and initiate necessary corrective action

- Conduct an Final Impact Assessment.

The main motivations of this Final Impact Assessment (FIA) is to meet GeoERA demands for more integrated evidence that investments in research in geosciences are not only effectively spent in prescribed terms but also contribute with newly emerging synergies to broader scientific and social objectives (ERA-NET, Horizon 2020). GeoERA asks the Assessment to go beyond conventional monitoring of projects' outputs and assessment of its outcomes' efficiency and effectiveness. For this reason FIA **applies a matrical approach to cross-thematic assessment of networked GeoERA Projects' impacts** (Section 2.3, below).

1.1 Integrative assessment approach

The GeoERA evaluation system is designed at four distinctive but connected levels, presented in Table 1:

1. **Monitoring** (continuous) collects, observes and analyses project performance concerning finance, time and administration according to indicators set in the work of Projects Description of Work (DOW). The Geological Survey of Slovenia established the Monitoring team, which is in constant communication with the projects, provides support to Projects Leads and checks the submission of deliverables, consumption of finance and overall project management procedure.

2. **Scientific review** (midterm, end of project) evaluates the quality of submitted deliverables and achieved scientific and professional goals based on expected and reported impact. Every project deliverable is evaluated by one or two scientific reviewers and two Data management reviewers.

3. **Review of the theme progress** (midterm, end of project) evaluates the Projects contribution to the theme objectives. All GeoERA Projects were reviewed by the respective Theme coordinator, two projects, HIKE and GIP-P, were evaluated by additional Theme coordinators. The HIKE project was evaluated by two Theme coordinators, the GeoEnergy Coordinator and the Information Platform Coordinator, because the GeoEnergy Coordinator is also the project manager of HIKE. The GIP-P project was evaluated by all Theme coordinators, because the project is overarching, linked to all 14 projects, most complex, and combines data from all projects into one comprehensive system. As with project HIKE, the Information Platform Theme Coordinator is also the project manager of GIP-P.

4. **Final impact assessment's** (midterm, end of project) evaluates overall progress and the impacts, including external stakeholders and external evaluator. Final Impact Assessment integrates GeoERA's main findings, obtained at preceding levels of it's evaluation system.

Table 1: GeoERA Monitoring and evaluation framework

Evaluation Levels	Aim	Evaluator	Method	Flow of information (Input→Output)
1 – Monitoring of progress indicators	Monitoring of perfor-mance indicators (finance, time, administration)	Monitoring and reporting officer	Desk-based	MPPR → TRR1
2 – Scientific review	Quality review of deliverables, review of achieved scientific and professional goals	Scientific reviewer	Desk-based	Deliverables; project impact → TRR2
3 – Review of the Theme progress	Review of achieved theme Specific Research Topics	Theme coordinator	Desk-based	MPPR → TRR3
4 – GeoERA level Evaluation	Final Impact Evaluation and general recommendations	Stakeholders, External evaluator	Discussion with Stakeholders Desk-based: Questionnaires Interviews	TRR (1 to 3) → TRR4

Source: Adapted from PPR, 2020.

FIA accomplishes assessment of **impacts** with the evaluation of the **implementation**, **application** and **effectiveness** of GeoERA from the point of view of its goals and objectives. Assessment objects are in line with the Logical Framework Approach consisting of:

- **Outputs** of implemented Programme or Project activities,

- **Outcomes** or achieved results for targeted beneficiaries and

- **Impacts** of GeoERA Programme and its Projects. According to OECD (2010; UNIMAN, 2016) impacts are defined as positive and negative, primary and secondary long-term broader effects produced by an intervention.

The GeoERA Programme specifies a set of GeoERA Projects' **wider social impacts**: Scientific and Societal Impact, contribution to Theme, European Impact, and Communication. The latter consists of exploitation and dissemination of the project results, management of research data,

knowledge management and protection, and communicating of the project activities to different target audiences.

FIA also provides **cross-thematic** analysis of impacts between GeoEnergy, Raw Materials, and Groundwater. Cross-thematic impacts determine how GeoERA performs as a whole. The Information platform is not included in the cross-thematic analysis since it (IP) is a cross-cutting or **overarching** theme, not a cross-thematic or **overlapping** issue.

Impact assessment is accomplished with conventional assessment approaches (in consultation with MRO, WP partners, and others):

1. **Desk study** of GeoERA programme and project documents, deliverables; review of related documents: Horizon 2020, ERA-NET, assessment documents and studies on ERA-LEARN 2020, the ERA-NET scheme, ERA-NET Cofund, M-ERA.NET, FACCE-JPI, ICT-AGRI, JRC-IPTS, BiodivERsA, and JPND.

2. **Synthesis** and analysis of findings obtained with monitoring.

3. On-line **questionnaires**[1] for assessment of impacts by partners in GeoERA Projects. Questionnaires were answered by Project leads in December 2021.

4. **Interviews** with Stakeholders about preliminary impact assessment results. Stakeholders are a core GeoERA target group. They:

   - discussed the GeoERA impact evaluation plan and its instruments (Kick-off meeting),

   - were invited to fill out short questionnaire for assessment of additionality of GeoERA impacts and about broader contribution to ERA NET and to H2020.

5. **Overall evaluative findings are triangulated** from different assessment sources in order to frame recommendations for GeoERA.

Impact assessment methodology applied is conventional, while **cross-thematic assessment is innovative**. Cross-thematic assessment methodology is based on an approach developed by American **geologists from the US Geological Survey, Luna Leopold** et al. (1971). For cross-sectional assessments they applied special impact assessment matrix, we call it the Leopold matrix, which intersects industrial policy measures with environmental criteria of evaluation. In this GeoERA impact assessment, the Leopold matrix is used for assessing impact (direct and side-effects) of each GeoERA Project on other GeoERA Project's main impact assessment criteria.

The Leopold matrix of GeoERA (Table 10 in Appendix) is divided into three GeoERA themes horizontally (GeoERA Projects' results) and vertically (assessment criteria for three Themes). This operation translates the detailed Leopold matrix into a partly aggregated (meso) **matrix** (Radej, Golobič, 2021), with only three rows and three columns. Meso level is higher than micro level of the Leopold matrix but lower level than macro when all assessed impacts are expressed as one impact (such as from poor to exceeding). Texas State Geologist, professor Scott Tinker (2013) similarly developed a concept of **radical middle** in geosciences that relies on possibility to allocate peripheral or cross-thematic overlap between otherwise independent ways of seeing things.

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[1] via freely accessible web program www.1ka.si, established and maintained by University of Ljubljana

2   IMPLEMENTATION OF GEOERA PROGRAMME

GeoERA is an umbrella programme for cooperation between 15 Projects. It is a cooperation of 47 organisations from 32 countries (the situation in December 2021): 27 member states of EU, other European countries (including Russia) and the USA. The number of participating organisations / countries was different in earlier Programme phases, but some participants terminated participation while some new moved in.

According to GeoERA monitoring, some potential participants (all from non-EU countries) have not made the deadline for delivering the required Grant Agreement documentation. Some participants have decided to withdraw after submission and review of the GeoERA proposal, both because of reorganisations, having impact on their financial resources available for the cooperation, and because of concerns on the administrative requirements of EU projects. The withdrawal had an impact on the GeoERA, in particular on the coverage of data and information products but also from financial reasons (3,1% reduction of the original total maximum co-funding commitment). However, impact on the functioning of the Programme as a whole was limited, because none of the withdrawing surveys had a major role in activities of GeoERA.

The most cross-border operating Projects are Resource (35 organisations, 30 states), Hover (34 / 29), MINTELL4EU (27 / 25), and GIP-P (24 / 22). Even Projects with the smallest number of cross-border partners brought together 7 organisations from 6 countries (VoGERA; Table 14 in Appendix).

GeoEnergy (GE), Groudwater (GW) and Raw Materials (RM) achieved cross-border cooperation in broadly comparable extent.

Table 2: Cross-border cooperation and number of participating organisations, by Themes

	No. of organisations	No. of countries
GE	41	28
GW	42	31
RM	35	30
GIP-P	24	22
GeoERA	**47**	**32**

Source: Monitoring team's internal tables

Is the achieved cross-border cooperation in GeoERA Moderate, Very good or Exceptional? The answer partly depends on defining a benchmark. GeoERA is financed by the EU with 27 member countries. GeoERA also wants to build pan-European results and the European Geological Survey that represents 38 National Geological Surveys. However, the Council of Europe as the most representative EU organization, hosts 48 member states in their definition of Europe.

As this evaluation is accomplished from the perspective of GeoERA (and ERA-NET), the achieved cooperation (32 countries) should be compared either to the number of EU member states, or to the number of EGS members. With this, achieved **cross-country cooperation of GeoERA would be assessed as Very good** (from Poor, Moderate to Exceptional).

2.1   GeoERA outputs and outcomes

GeoERA outputs (accomplished project activities) and outcomes (obtained project results for beneficiaries) are identified with the Programme and Project monitoring. Detailed results are presented in the monitoring system. This section focuses on aggregated outputs on GeoERA and Tematic level. Specific outcomes from the Project perspective are addressed in Chapter 3.

This section presents only selected aggregated main monitoring indicators (evaluation level 1, see Table 2, above). Detailed content and structure of presentations are given in D4.1-3, and especially D4.7, and in excel file 'GeoERA_master table'.

GeoERA results are represented at EGDI: https://data.geus.dk/egdi/?mapname=geoera.

Only three monitoring indicators are selected for final assessment: Person Months, Budget, and Number of submitted deliverables. Table 3 (below) shows that GeoERA spent all allocated funds and produced 99,4% of the planned number of deliverables with on average investing 7,5% more person months input than initially expected. The Person Months and Budget indicators are covering the period 1. 7. 2018 – 31. 10. 2021, without the Person Months and budget incurred after the end of the Projects. The costs for participation at the final on-line review meeting and at the GeoERA Concluding conference are eligible, as well as costs for peer review publications incurred until 28. 2. 2022. For these reasons the final Person Months and budget, reported by the beneficiaries to the European Commission, might be slightly higher than shown in this document.

The number of deliverables remains below 100% since three deliverables were not submitted. Two deliverables were officially not submitted in the Groudwater Theme. The Project delivered data for upload and testing of GIP-P twice, in month 18 and later updated the date in month 30. The data were delivered to GIP-P, but only in the form of raw data rather than a written deliverable. Scientific and thematic reviewers believe that the Project nevertheless fully met all of its objectives. The data and the results were presented at the review meeting.

One Project (RawMaterials) failed to submit the deliverable about evaluation of IP prototypes. The project assessment at Level 1 was lowered as a result (see section 3.2, below for explanation). Not submitting the deliverable did not derail realisation of the overall GeoERA objectives.

Differences in the assessment score between Themes are addressed in Chapter 3 where divergence from plans is assessed (except financial aspect).

Table 3: Selected main monitoring indicators, % difference from modified plans, per Theme (above +, or below -), per 24. Jan. 2022

Theme	Person Months	Budget (in EUR)	No of submitted deliverables
Geothermal Energy	+13,7	+7,8	0,0
Groundwater	-1,9	-3.3	-1,6
Raw Materials	+10,6	-4,9	-0,7
Information Platform	-4,5	-4,9	0,0
GeoERA	**7,5**	**+0,1**	**-0,6**

Source: Monitoring team's internal tables

GeoERA Projects were subject to four levels of evaluation, the fourth level covering also evaluation of the GeoERA programme. The average assessment scores by four evaluation levels and Communication and Dissemination Activities (CDA), by Themes are presented in Table 4. One thing is immediately obvious: All four evaluation levels agree that achievements surpassed initial expectations, and as a result the **GeoERA Programme as a whole is overachieved**.

Table 4: Average assessment scores, by four evaluation levels and CDA, by Themes, 1 to 5

	Monito-ring	Scientific review	Theme Review	GeoERA Review	**Average evaluation**	Communication & Dissemination
GeoEnergy	4,3	4,2	4,2	4,3	**4,3**	3,8
Groundwater	4,0	4,0	5,0	4,3	**4,3**	3,8
Raw Materials	3,8	4,3	4,0	3,8	**3,9**	5,0
Information Platform	5,0	5,0	5,0	5,0	**5,0**	5,0
Average by level of evaluation	**4,3**	**4,3**	**4,5**	**4,4**	**4,4**	**4,4**

Source: GeoERA Deliverable D4.7.
*Legend: *Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.*

In conclusion: GeoERA as a whole is recognized as a highly effective action in terms of achieving its main Programme goals and accomplishing its primary mission. Participation in GeoERA led to **results that would not have been possible** without the scheme – the highest scores were reached for Creating new opportunities for enabling transnational R&D activities; Overcoming fragmentation of research in Europe; Removing obstacles for undertaking transnational coordination of, and cooperation between, R&D programmes (Table 13, Appendix).

For a Programme dealing with subsurface resources as a foundation for prosperous societies, their excellent effectiveness in achieving primary goals is not the only important thing. Another important issue is GeoERA Projects' indirect impacts, that is how GeoERA impacts grand social challenges at EU, national, and regional level.

2.2   GeoERA's wider social impacts

Monitoring of outputs and outcomes in the previous section focused on findings obtained with direct measurement of the evaluated project's accomplishments (outputs) and achievements (results). Yet, projects with strategic aims and macro level performance also produce wider impacts. These emerge on a longer term and impact broader environments, prevailing patterns, typical behaviours. Wider social impacts may not be directly measurable and cannot be unanimously attributed to specific projects or programmes.

Wider impacts can be assessed qualitatively. Evaluators developed a questionnaire for GeoERA Projects containing questions recommended by ERA-NET and already applied in other ERA-NET project impact evaluations. These questions are not designed specifically for GeoERA participants so they may sometimes appear artificial from a narrower GeoERA Project perspective. The questionnaire was answered by project leads and stakeholders and evaluated by theme coordinators.

Project Impacts are assessed on **a scale** from Absent or Not relevant (0 or n.r.), Negative impact (1), Weak positive (2), Moderate positive (3), Excellent Impact within expectations (4) or Outstanding impact, beyond expectations (5). Cumulative impact assessment results by Themes and GeoERA as a whole are interpreted as Poor (from score 2,0 to 2,5), Moderate (satisfactory; from score 2,6 to 3,4); Very Good (3,5-4,0); Exceptional (score higher than 4,0).

Collected results were analysed for their quality. Initially achieved scores were reassessed for assuring their quality. Nonetheless, certain extent of heterogeneity in assessment scores still remains in collected data.

GeoERA impacts are presented below with average scores by main groups of questions. Detailed results to the questionnaire by projects, themes and GeoERA as a whole are available in Appendix, Tables 1-9.

Contribution of GeoERA **to European Impact** (Table 1 in Appendix) is assessed in accordance with deliverable GeoERA D2.2 and available evaluation literature in ERA-NET. It identifies a series of questions, specific and general. Specific assessment questions are about establishing interoperable, pan-European data and information services, about Developing European common assessment frameworks with methodologies as well as about Knowledge and services aimed at European policy makers and stakeholders. General questions ask how GeoERA Projects contribute to removing obstacles regarding European cooperation and about achieving H2020 and ERA NET goals.

GeoERA Projects overall contribution to European impact in **specific criteria**, is Exceptional, beyond initial positive expectations. The most profound European contribution relates to producing Knowledge and services aimed at European policy makers and stakeholders and Establishing interoperable, pan-European data and information services. Little variation is observed in this regard pointing to undifferentiated European contribution across all four GeoERA themes. GIP-P contributed with the most outstanding European impacts.

Assessment of effectiveness of **GeoERA to removing obstacles** for undertaking transnational coordination in Europe (Table 1 in Appendix) shed light on the misalignment of national thematic programme priorities, national administrative procedures and legal conditions as well as European (EU Commission's) administrative procedures or legal requirements. Overall impression is that GeoERA Projects on average contributed Very Good to all three types of obstacle removal. GW, RM and GIP-P report about Very Good overcoming obstacles, while GE reports Moderate achievements which is explained with contextual reasons.

Overall contribution of GeoERA Project **to H2020** is assessed with three sub-criteria (Table 1 in Appendix): Industrial leadership, Societal challenges, Digitising European industry and services. The GeoERA Projects reported from Moderate to Very good contribution to H2020. Result is somewhat lower since establishing industrial leadership and industrial digitalisation are not within the scope of the GeoERA project. Stakeholders assessed GeoERA contribution to H2020 with the same score from Moderate to Excellent (Table 15, Appendix).

Overall contribution of **GeoERA Projects to ERA-NET** was assessed relative to their success in achieving Critical mass and provide Common answers to common problems by Developing common approaches, Speaking with 'one voice', Avoiding overlap and Build up expertise, Exchanging good practice, as well as Aligning the national focus with GeoERA funding. The achieved contribution is assessed as Very Good to Exceptional (beyond initial expectations, in particular for GIP-P) except for one criterion: Aligning the national focus with GeoERA funding, indiscriminately for all themes. Only GIP-P reports Exceptional contribution to ERA-NET except in addressing specific geographical issues internationally (Moderate contribution).

Stakeholders also assessed GeoERA contribution to ERA-NET. They **compared the present situation with the situation at the beginning of the project** five years ago in Coordination, harmonisation; Enhancing research capacities; and Facilitating practical initiatives. Summary of their scores shows that present situation received from one half to two thirds higher scores than at the beginning (Table 11, Appendix).

Overall, indirect contribution of GeoERA Projects to **other important European goals** is assessed in areas such as Employment, Creating new market opportunities, Strengthening competitiveness and growth of companies, Enhancing innovation capacity, Synergies with science education, Improving potentials for climate and environmental policy, Engaging researchers with civil society. The overall impact is Moderate (except for GIP-P, Very Good impact), especially in the intersection between GeoERA and business sector – which have not been among GeoERA main goals (neither of ERA-NET, but nonetheless involved as specific goal of some GeoERA Projects and Themes (Table 3, Appendix)).

GeoERA is macro level Programme so it is important to asses it not only against its own primary goals but also against all other main social concerns (as outlined in GeoERA's D2.2, D3.1, PID2). GeoERA Projects especially outline contribution to climate and environmental policy and to enhancing innovation capacity.

In conclusion, the overall extent to which all **GeoERA Projects contributed to European Impact** is Very Good, while contribution to ERA-NET is exceeding high expectation (Table 5).
European impact is Very good for all Themes except for GIP-P surpassing expectations.

Table 5: European Impact of GeoERA Projects, scores 1-5

	GE*	GW*	RM*	GIP-P*	GeoERA	
Specific questions, total	4,1	4,2	4,1	4,3	4,2	**Exceptional ****
General questions – GeoERA contribution to:						
- **H2020**	3,4	3,1	3,6	4,0	3,5	**Very Good****
- **ERA-NET**	4,1	3,9	4,2	4,4	4,1	**Exceptional ****
- **Removing obstacles to international cooperation**	3,1	3,8	3,8	3,7	3,6	**Very Good****
- **Contribution to other European Impacts**	2,9	3,0	3,2	4,0	3,3	**Moderate****
GeoERA European Impact	**3,8**	**3,8**	**3,9**	**4,1**	**3,9**	**Very Good ****
	Very Good **	**Very Good ****	**Very Good ****	**Exceptional ****	-	

Source: Table 2, Appendix. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

**Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

The ERA-LEARN 2020 project developed a framework for monitoring and assessing **the impact of public-to-public (P2P) networks** and associated GeoERA Projects. The University of Manchester, an ERA-LEARN project partner, developed Background Document for the Guide for P2P impact assessment (UNIMAN, 2016b). It proposes, among other things, to take into account different areas of possible impact in the assessment from cultural, scientific, symbolic, economic, societal, organisational, health impacts. GeoERA Projects contributed the most importantly with their Policy impacts, Innovation, Scientific and Environmental impacts (Table 2 in Appendix).

GeoERA Projects further assessed **the most important longer-term impacts** of their involvement in GeoERA. Following Mostert (2012) the most important longer-term impacts consist of: An increase of knowledge exchange, the amount of research funding, new methodologies, tools, knowledge, A better integration of basic and applicative research, Transdisciplinary approach, and Strategic cooperation. GeoERA Projects assessed all impacts as relevant. Nonetheless, they outline special importance of Adopting new methodologies and Increase in knowledge exchange. These impacts even surpassed ambitious initial expectations (Table 6 in Appendix).

ERA-NET Project ICT-AGRI (2015) suggested assessing the following main factors of **the success factors** for the project outcomes: Networking activities, Consortium of partners with different expertise and skills, Research strategy and aims of the project, Internal and External communication, Education and Quality of results. GeoERA Projects assessed all factors as important. Nevertheless, they outlined the highest importance of established Consortium, Internal communications, Application of the innovative methods/tools/techniques, Quality of project results and Strategy. These success factors decisively surpassed initial expectations. In

GeoERA, external communication, on average contributed less than other factors (Table 7 in Appendix).

The GeoERA Projects also considered the extent to which their Projects directly contributed with their results to **benefits of different groups of users/beneficiaries**. Overall contribution of Projects to beneficiaries at GeoERA level is Very Good. The lowest contribution at GeoERA level is to the business sector (this is not its main goal), except for RM, where contribution is Very Good. The strongest contribution to beneficiaries, beyond expectations is in Research sector, and in Geosciences (Table 8 in Appendix).

NETWATCH Project (in JRC-IPTS, 2012) proposed a special measure '**Maturity Score**' (Table 9 in Appendix). Its aim is to measure maturity of ERA-NET projects or how sustainable they are for their continued operation. According to ERA-NET (2013): "actions should be ambitious and result in concrete progress towards the opening up of, or cooperation between, the participating research programmes. The cooperation should be sustainable beyond the duration of the ERA-NET action itself." ERA-NET Cofund Projects need to mobilize national resources to tackle shared EU challenges (Gøtke, Amanatidou, 2016) but also by achieving critical mass and by developing synergies).

Measuring maturity is relevant for GeoERA as relatively young but quickly developing structure. Maturity score consists of the following factors, listed in hierarchical order: Systematic exchange between partners; Identification of common strategic issues; Development of joint activities. Achieving self-sustained network and finally, as the indication of highest maturity, Implementation of joint transnational research activities (consisting of sub-factors: Identifying and Implementing joint research agendas, Jointly implementing and financing calls and projects; Engaging in transnational R&D cooperation beyond the GeoERA; and Mutual learning).

Assessment of maturity of GeoERA Projects confirms that considerable progress toward maturity is achieved, especially their Very Good to Exceptional ability to implement joint transnational research activities (including defining and implementing common priorities and agendas, mutual learning). The weakest factor of their maturity is only moderate ability of Projects to operate without EU funding. The most in need for EU funding appears GW, the lowest **GIP-P, which arises as the most mature GeoERA Theme**.

2.3 Cross-Thematic Impacts

Cross-thematic impacts are a main objective for any ERA-NET project. However ERA-NET gives no specific guidance on how to accomplish cross-thematic assessment of networked projects. There are no common models and assessment frameworks that allow simultaneous appraisal of the interactions **between GeoEnergy (GE), Raw Raterials (RM) and Groundwater (GE)**.

The Final Impact Assessment then needs first to find an appropriate model for cross-thematic assessment. The evaluator proposes to apply matrical approach. It was first employed by **Luna Leopold** (1971), a geologist from US Geological Survey. He developed a matrical approach to assessing cross-sectoral impacts of industrial projects to natural environment.

In this case, **Leopold's type of impact matrix** consists of 14 rows (as there are 14 GeoERA Projects, GIP-P excepted) and 19 columns (because of 19 assessment criteria; see Table 10 in Appendix). Projects' impacts were assessed with the Questionnaire for the 14 GeoERA Projects. Their results were grouped vertically and horizontally in three GeoERA Themes (Matrix 1) from Leopold matrix so as to aggregate detailed assessments by source (rows) and area of impact (columns).

Thematic synthesis of the Leopold matrix enables constructing one with square input-output matrix with three rows and three columns (GE, GW, RM). In the final step of the cross-thematic assessment, non-diagonal contents of matrix are **correlated,** indicating how strong GE, GW, RM are connected and how mutual their connectedness are. Venn diagram of three partly intersecting circles graphically illustrates the concept and obtained results (see Matrix 1, below).

Cross-thematic impacts were assessed on a scale from Absent or Not relevant (0), to Negative (1), Weak positive (2), Moderate positive (3), Excellent Impact (4) or Outstanding, beyond expectations (5).

If scores from 2 to 5 in the assessment scale are beyond immediate dispute, then scores 1 and n.r. require some additional justification. **Negative scores** are always possible in comparative assessments due to complex nature of their relatedness. It is clear that conflicts arising from the use of geological resources, the non-optimal use of geological resources, or overlooked synergies are issues that need to be avoided or at least clearly acknowledged (as claimed in GeoConnect3D, Midterm Report). Cross-thematic perspective aims to understand the potential **effects or interactions** associated with exploitation of different sorts of geological resources. As HotLime project comments in the Questionnaire, achieved Project results are sometimes fairly double-edged. They may produce excellent results in one respect but several negative effects in some other respects that are usually not in the immediate focus of the concrete Project. For instance: areas with good results (high Heat-in-Place) might trigger / attract more private investment, areas with poor results (low Heat-in-Place) probably will deter investors. It is actually quite surprising that so small number of GeoERA Projects report negative side effects on other GeoERA Projects aspirations or on wider social goals (previous Section).

Secondly, what justifies application of **score 0** or not relevant (**n.r.**) in evaluation? Score 0 means that there is no impact of a Project X on assessment criterion of Project Y (or on society, science, climate change…). Cross-thematic assessment does not assume that every detail must be related (positively, negatively) to every other detail (at micro level). Even in strongly connected networks, many specific things may remain unrelated. In turn, n.r answers to the Questionnaire

is not only needed as a separate score but pattern of n.r. scores itself becomes an object of analysis that contributes to forming evaluative findings. It is not sufficient only to indicate n.r. where needed but also to study a specific pattern of n.r. (mostly on non-diagonal fields).

Furthermore, cross-thematic assessment consist of comparisons between small number of main Project Themes, not of detailed Project activities or detailed impact assessment criteria. Cross-thematic assessment operates **at meso level not from micro to macro** level like in ordinary networks. For cross-thematic assessment ERA-NET projects evaluations need to go beyond network analysis and replace them with matrix analysis. Matrix as a concept is special type of organised network. GeoERA and ERA-NET projects in general are **highly organised networks**.

(Meso)Matrix 1 presents summary results of cross-thematic assessment of impacts for GeoERA as seen by Projects.

One thing is immediately obvious: achieved impact scores tend to be considerably **higher for the diagonal cells** of the matrix. Diagonal cells describe Theme's effectiveness in pursuing their own primary concerns. GE achieves best scores when its activities impact its own primary goals (4,2) than it contributes to achieving goals of other Themes (2,9; 2,1). Analogously for GW (4,1 vs 3.2 and 4,0) and RM (3,9 vs 0,0).

The non-diagonal cells describe size of the cross-thematic impacts between three Themes. Matrix 1 reveals that **GW is the most cross-thematic**; it impacts GE Moderately (score 3,2); it impacts own goals (GW) with score 4,1 and RM with score 4,0. Quite the opposite are cross-thematic impacts of RM to GE and to GW, both n.r., even though there is positive impact from GE to RM (score 2,1) and from GW to RM (score 4,0).

Matrix 1: (Meso)Matrix of cross-thematic impacts

	GE	GW	RM
GE	4,2* (Exceptional)**	2,9 (Moderate)	2,1 (Poor)
GW	3,2 (Moderate)	4,1 (Exceptional)	4,0 (Very Good)
RM	0,0 (n.r.)	0,0 (n.r.)	3,9 (Very Good)

Source of data: Appendix, Table 10 (Leopold matrix), summarised by source (GE, GW, RM in rows) and area of impact (GE, GW, RM in columns). Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact, within expectations. 5—Outstanding Impact, beyond expectations.

**Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

To assess cross-thematic impacts, evaluators correlated score of GW impact on GE with opposite impacts of GE on GW – in this way obtaining information about **strength and mutuality or symmetry of cross-thematic impact** between GW and GE. The same was done for the relationship between GE and RM and for the relationship between GW and RM, as presented in (meso)Matrix 2.

Matrix 2 presents a GeoERA specific pattern of connectedness between GeoERA Projects. It is evident that some cross-thematic impacts are balanced between themes (GE and GW) while others are not. Obtained correlated results are visualized with a Venn diagram (see bellow, Matrix 2). **Overlap of overlaps** (obtained as an average value from values of three dual overlaps) identifies that **GeoERA Themes are moderately strong connected with their positive impacts that are prevailingly asymmetrical**.

Matrix 2: Correlated cross-thematic impacts between GE, GW, RM

	GE	GW	RM	Venn diagram of cross-thematic overlaps
GE	Exceptional	Moderate / Moderate	N.r. / Poor	
GW	-	Exceptional	N.r. / Very Good	
RM	-	-	Very Good	

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations. See also Radej, Golobič, 2021, for complete presentation of the methodology (Ch. 2 and 3).

Legend. Scale: see Matrix 1.

GeoERA achieved **moderately strong and asymmetric connectedness between Themes**. This result at least matches results obtained in reference studies. Matrix-Rambøll (2009b) found that the ERA-NET scheme **did not have a major structuring effect** between research areas. ERA-NET networks in the Health research field in the FP6 and FP7 also presented itself as **network of loosely to moderately connected networks**, not as **one large strongly connected network** (JRC-IPTS. 2012). Gøtke and Amanatidou (2016) also report that coherence and complementarity between ERA-NETs within the same sector/area only reached 25% (evaluated as 'Poor' on the assessment scale of this study). It has also been outlined by stakeholder that one of the main problem in the H2020 projects is the lack of communication and follow up between projects with similar objectives (GeoERA D5.3).

Asymmetrical instead of balanced impacts of a project at meso level may be acceptable such as if GeoERA or Themes respond to asymmetrical challenges. When asymmetry in impacts is intentional, this needs to be clearly justified already in programming phase. This is obviously not possible when cross-thematic black spots become visible only after launching of a Programme.

'N.r.' score indeed appears as the best explanation of cross-thematic impacts for RM. These characteristics of projects in RM Theme were observed **already in project evaluation of submitted proposals** (GeoERA Consensus Report). Evaluators noticed that some projects exhibit narrow project scope already within the Theme, or that they do not adopt a true interdisciplinary approach between GeoERA Themes.

The assessment claims that RM is the least cross-thematic. This claim is cross-checked with other available evidence. Thematic coordinators identified cooperation between the 14 GeoERA Projects (GIP-P excepted). They have distinguished three possibilities: Active cross-thematic cooperation (Matrix 3, below), Planned cooperation (Matrix 4) or Potential cooperation (Matrix 5). In this way they identified what is relevant in cross-thematic assessment of GeoERA Themes and what is not.

Thematic cooperation between projects in the same Theme (diagonal values in Matrix 3) is the strongest in RM (100% of total – active, planned, possible). Achieved corresponding rates are lower for GE 62% and GW 33% (where all remaining cooperation is potential, still lacking concrete plans).

Matrix 3: Rate of active cooperation between GeoERA Projects, % of total, at Theme level

	GE	GW	RM
GE	62	50	50
GW	25	33	0
RM	50	0	100

Source of data: GeoERA Monitoring Excel file. Own calculation.

When assessing cross-thematic as indirect impacts it is not inconsistent to have high effects in intersections between two Themes without an active Project (second row, third column in Matrix 3). Such as due to knowledge sharing between two Themes.

Matrix 4: Rate of planned cooperation between GeoERA Projects, % of total, at Theme level

	GE	GW	RM
GE	38	50	0
GW	25	0	0
RM	0	0	0

Source of data: See Matrix 3. Own calculation.

Matrix 5: Rate of possible cooperation between GeoERA Projects, % of total, at Theme level

	GE	GW	RM
GE	0	0	50
GW	50	67	100
RM	50	0	0

Source of data: See Matrix 3. Own calculation.

Thematic reviewers' assessment of **cross-thematic cooperation between Projects** helps to understand why certain Themes are not linked through side effects (Matrix 2, nondiagonal fields). Comparison between Matrix 1 (of cross-thematic impacts) and Matrix 3 identifies that cooperation between RM and GE is considerable (50% of total possibilities are actualised), but produces other effects that are not specified among main GeoERA impacts. Furthermore, n.r.

score of cross-thematic impact from RM to GW is necessary because their cooperation is not foreseeable neither in future plans nor potentials (Matrix 4 and 5).

The case is, that GeoERA actually published a very interdisciplinary call in RM Theme for projects covering 'Raw Materials Modelling and interactions with energy and groundwater' but received no submissions (IEPM, 2018).

Cross-thematic cooperation is of course an important indicator of integrative operation of a network-based project like GeoERA. Yet, it is not the only one, since there exist three paths to integrate: **cross-thematic**, **cross-border**, and **cross-cutting** paths. It is not hard to imagine a project applying only one path to integration. However, in GeoERA all three are operating simultaneously. To interpret above findings about cross-thematic cooperation, one needs to take into account the distinctions between the three paths.

The first, **cross-border** (or cross-country) cooperation is the most regularly addressed in the assessment of ERA-NET projects such as when emphasizing contribution to strengthening transnational networking. Thematic scope of cross-border cooperation is sometimes narrow (such as Project EuroLithos in GeoERA) but it nevertheless establishes cohesive international cooperation.

Cross-border impacts are valuable as such and integrative even when not pursuing cross-thematic or cross-cutting imperatives. In turn, it seems sufficient to assess cross-border (-country) cooperation with **evidence of its existence**, accomplished outputs (not of results or impacts).

Another sort of cooperation is linked to pursuing **cross-cutting**, overarching issues, such as integrated knowledge base, or gender equality. Cross-cutting issues materialize through harmonisation or standardisation such as for digitalisation, for building data bases, information systems. But also with adoption of common guidelines, frameworks, modelling, introduction of novel semantics concepts, assessment methodologies. Due to their general justification and clear purpose, cross-cutting issues are typically well defined and can be expressed with **result indicators** (not outputs or impacts!). Cross-cutting issues are horizontal, but nevertheless implemented with predominantly vertical and direct means (from problem to solution in standardized way).

The third path toward integration is with **cross-thematic** achievements, such as synergies and cohesion between Themes, from meso (or matrical) perspective. GeoERA explicitly calls for cross-thematic integration beyond merely the cross-cutting integration (GeoERA, Joint Call Document No.3, Admissibility and Eligibility, 31 March 2017). Cross-thematic impacts are usually not anybody's primary aim (Eurolithos, comment to the Questionnaire).

What is important to note is that a project's **cross-border or cross-cutting achievements cannot replace cross-thematic impacts because** it is necessary **to take all three into account as equally important**.

2.4 Communication and Dissemination of results

The overarching goal of **communication** activities was to actively engage with specific stakeholder groups: policy makers, geoscientific communities, industry, and other interested parties or the general public in order to integrate different views and assess the different needs. Each project funded under GeoERA needed to engage with specific targeted stakeholder groups, in order to ensure appropriate scope and uptake of the project results. Communication actions consisted of preparation of a visual identity, website, newsletter, info-materials and engaging in social media.

GeoERA Projects' Communication and dissemination activities (CDA) covered by monitoring are:

- Publications: Abstracts, scientific publication, non-scientific publication, thesis, technical report, leaflet, poster, newsletter, oral presentation, white paper, other.

- Events: Workshop, webinar, seminar, training, exhibition, pitch event, congress, other.

- Meetings: Internal project meeting, meeting with other geoera projects meeting with other projects, meeting, other.

- Media: Radio / tv, newspaper, magazine, other.

- Online media:

  o Website (https://geoera.eu/.
  o Facebook, Twiter, Youtube, Linkedin, Researchgate, blog, newspaper, Pinterest, other.

Table 6: Key output and outcome indicators for CDA (Key Performance Indicators)

Tools	CDE Key Performance indicators	Expected Results		Achievements
		per year	**5 years**	
Website	No of unique visitors	300	1500	**73.904** visitors, 253 blog published
Social Media (LinkedIn, Fb & Twitter)	Number of Followers, Number of Tweets	250 50	1250 250	Twitter: **5.140** tweets, **2.157** follower LinkedIn: **984** posts, **1.550** followers Facebook: **1.170** posts, **1.220** followers
Brochures	Number of copies distributed	1000	5000	GeoERA 1 leaflet / **1050** distributed MUSE 2 leaflets / **100** distributed MINTELL4EU 1 leaflet / **100** distributed GIP-P 2 leaflet / **100** distributed FRAME 1 leaflet / **2000** distributed
Video	Number of views	100	500	**25** videos / **12.429** views
Conferences / events	Number of Conferences/events attended	4	20	**43** congresses & **109** activities (oral presentations, posters, abstract, article); Webinar **47**; Workshop **46**; Seminar **10**
E-Newsletters	Number of online readers, subscribers	300	1500	**16** GeoERA Newsletters with **616** subscribers **9** FRAME Newsletters with **100** subscribers **7** HOVER Newsletters with **98** subscribers **5** EuroLithos Newsletters with **100** subscribers **4** MINDESEA Newsletters with **150** subscribers
Articles	No of articles published	10	50	Scientific Publications **100 (>50 Peer reviewed)** Non-Scientific Publications **16**; Abstracts **83** Posters **33**
Stakeholder workshops/ info days	No of participants	100	500	**2530**

Source of data: GeoERA D4.7.

All Projects accomplished 4248 communication and dissemination activities. 75% were, due to COVID 19, online media (Website, Facebook, Twitter, YouTube, LinkedIn, Blog), 17% were meetings and events and 8% publications and media.

Key output and outcome indicators (KPI) for CDA are specified in D5.1 (GeoERA Dissemination and Exploitation Plan). They measure outputs and outcomes of the dissemination and communication activities (Table 6).

The majority of CDA surpassed expectations in absolute terms, some of them impressively thus they are evaluated as **Exceptional** according to the terminology of the applied evaluation scale in this report. Only the Number of leaflet distributed stayed behind plans, which is because of the Covid-19 situation and lack of face to face events. This alone does not overshadow overall achievements in communication and dissemination activities.

Table 7 (below) presents average scores for CDA for each Theme and globally, obtained with monitoring of progress indicators. GeoERA Programme **overall** achieved **exceptional** results in CDA. Seven Projects scored 5, four Project scored 4 and four Projects scored 3. All project from Raw Materials and Information Platform Theme achieved score 5. Table 16 in Appendix reports CDA assessment scores for GeoERA Projects.

Table 7: Assessment scores for CDA, by Themes, 1-5

GeoEnergy	3,8	Very Good
Groundwater	3,8	Very Good
Raw Materials	5,0	Exceptional
Information Platform	5,0	Exceptional
GeoERA Programme	**4,4**	**Exceptional**

Source of data: FPPR (Final Project Progress Reports, Communication and Dissemination Activities).
Legend: See Table 4.

GeoERA implemented additional measures aimed at maximizing Programme and Project results with **Dissemination and Exploitation Plan** (GeoERA D5.1, 2017). The main purpose was to raise awareness of GeoERA objectives and foster stakeholder engagement; to promote the GeoERA cofounded call for both call Stages; and to ensure regular information flow of GeoERA progress and results to the relevant stakeholders. Furthermore, GeoERA Projects **promoted** the Programme by disseminating data and information services through the European Geological Data Infrastructure (EGDI). GIP-P supported the Projects in structuring and disseminating their results in an up-to-date, user-friendly and harmonized form on EGDI thereby strengthening their scientific and societal impact. The GeoERA participants disseminated results also to national and regional stakeholders through their standard dissemination channels. Dissemination activities also involved collaboration with stakeholder organisations and networks.

GeoERA Partners also adopted Strategy for knowledge management (and protection) The Consortium Agreement on protection of GeoERA results. They agreed to an Open access to its published results in scientific publications.

Implementation of the GeoERA Exploitation Plan has been taking place during the project lifespan but will also facilitate the benefits of the projects being applied **beyond the end date of the GeoERA Projects**.

Projects' assessment (in line with D2.2) suggest that GeoERA accomplished knowledge management and protection activities from **Very Good to Exceptional** degree and indiscriminately for all four Themes. GeoERA as a whole accomplished majority of suggested activities for knowledge transfer with a Very Good degree, with certain asymmetry between Themes (Tables 4 and 5, Appendix).

3   ASSESSMENT OF GEOERA PROJECTS

This chapter **summarises findings from previous four levels** of GeoERA Project evaluation system: monitoring of Project outputs and outcomes, scientific review, thematic review, and GeoERA overall assessment of Projects, including stakeholders' views. Detailed assessment information on Projects' performance is available in Final Project Progress Reports and in Technical review reports.

Projects that were assessed as effective and had achieved all initial expectations were evaluated routinely. More focus is directed toward Projects that **surpassed** initially programmed achievements or for some reason **struggled to reach** them.

To avoid repetition, some evaluation findings similar for several GeoERA Projects are summarized below:

1. Several **changes in the deliverables and in partnership** were necessary in various Projects. Amendments to the project plans were properly communicated with the Monitoring team and the GeoERA Secretariat. None of these necessary changes negatively affected GeoERA main goals.

2. The most important negative external factor was the **Covid** pandemic (since March 2020). In December 2020, the GeoERA programme was extended by 2 months (from 31 December 2021 to 28 February 2022) and the Projects by 4 months, from 30. June 2021 until 31. October 2021, with the exception of the HotLime project. The pandemic limited fieldwork or excursions to sites, fewer meetings and unspent budgets in the travel category. Closed laboratories prevented generation of analytical data. To overcome pandemic related challenges and achieve planned objectives, the Projects needed to display a high degree of flexibility of partnership and adaptability of their activities and management. The full achievement of initially programmed goals is actually better than expected.

    Before the pandemic, the ambitions of some Projects were even higher.

3. **Technical improvements** after the completion are invited for certain Projects with the aim to further improve presentation, access, security or external comparability of achieved results.

4. **EGDI** has ensured that the results from all GeoERA projects are accessible on one single, user-friendly platform through the web-GIS interface and the search systems. It also gives access to the results in machine-readable forms using OGC services which also allows connection with other European e-infrastructure. With this, the GIP-P has contributed to the ambition of the Geo-ERA Projects to reach their target groups.

5. Several projects combined pan-European and national databases for the first time. These results represent a significant improvement of the knowledge and of the research beyond state of the art. However, the projects also deliver the **foundation for much further work** as bottlenecks and challenges have been identified. These achievements should be used as a starting point for further undertakings supporting the implementation of a comprehensive and cohesive programme of scientific projects. The case is, as one stakeholder reminded,

that national geological surveys remain 'hopelessly un-harmonised' despite some decades of effort. So there is still much to be accomplished in this area, starting with trainings.

6. **Capitalizing** on the achievements and investments reaches beyond GeoERA, but are decisive for its long-term impact. Several partners have already been using their new collaboration experiences and research products in Horizon Europe proposals.

7. The GeoERA Programme achievements are in several Projects assessed as stepping stones for future programmes for GeoERA partners in the **Coordination and Support Actions** for establishing Geological Services for Europe.

8. Evaluators sometimes suggested the preparation of **specific guidelines**, policy briefs that can be used by policymakers at national and EU scale. Part of the information collected and presented by GeoERa is scientific and could be elaborated further to reach a wider audience.

9. Stakeholders may be concerned if GeoERA is ensuring at sufficient extent the **development of new services** for scientists and other stakeholders? The answer to this question is a decisive factor for the sustainability of GeoERA results.

10. Several stakeholders reminded that to achieve the Geological Service for Europe, it will be necessary to work on extending efforts **from pilot projects to the GeoERA theme level, countries and the whole continent** to demonstrate its utility at the comprehensive scale. Several projects focused on methodology to harmonize data and collaboration but they still need to upgrade in terms of integration between GeoERA themes and so on the GeoERA level.

11. The development of a European Geological Services will also need **top down direction** from EU member states governments, and long term funding, to make further real progress.

12. A recurring recommendation is to use the obtained results for promoting a shift of knowledge towards **citizen/social science**, not forgetting young generations/scholars. In particular, GeoERA concerns usually involve local dimension (public acceptance of mining activities, local tourism related to historical mine sites, local knowledge and education, such as 'geological paths') that could be sometimes more emphasized in GeoERA Projects.

13. Further enhancing the **transnational character** of the GeoERA Programme either by promoting the new standards and products beyond Europe, by linking to other research infrastructures or associations or by building capacity in countries and regions outside Europe, where needs are high and transboundary work is becoming more pressing.

3.1   3DGEO-EU: 3D geomodelling for Europe. GeoEnergy

Project dealt with methods for harmonization of geological data and 3D geomodels across international borders. It aimed to:
- Establish consistent data and model base in cross-border regions.
- Establish a set of cross-border consistent geomodels in the pilot areas.
- Harmonize stratigraphic as well as structural modelling workflows in border areas.
- Develop methodologies for semantic and geometric harmonization of data and geomodels across borders.

- Improve visualization methods for uncertainties and optimized reconstruction and restoration workflows.
- Advance mapping and 3D geomodelling strategies that allow for regional to pan-European cross-border consistency and integration.
- Develop common standards and disseminate best practices for cross-border harmonization between European countries.

As an example, Project has created a generalized cross-border 3D depth model of the 'Entenschnabel' region in the North Sea. That geomodel is used by the GeoEnergy project GARAH for Petroleum System modelling.

Summary assessment scores for all four evaluation levels are presented in Table 8.

Table 8: 3DGEO-EU overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	3	4
Scientific review	4	4
Theme level review	3	4
GeoERA level review	4	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 4 (Objectives and targets fully achieved; some planned deliverables were abandoned – technical justification in Final Project Report). The project has contributed to the overall objectives of GeoERA by increasing the knowledge concerning ways and means to harmonize underlying geological base data. Stakeholder also observed that the Project made excellent progress on their objectives.

3.2 GARAH: Geological Analysis and Resource Assessment of selected Hydrocarbon systems. GeoEnergy

The Project dealt with the identification of new potential areas for hydrocarbon exploration with the aim to give further information regarding basin development and evolution, and the HC resources assessment. Results will be used by planning and policy makers (licensing of areas for exploration), commercial exploration strategies and to highlight remaining knowledge gaps.
The Project identified new potential areas for hydrocarbon exploration, directly addressing the requirement for identifying secure energy HC sources. This will give further information regarding basin development and evolution.

The generated catalogue of the multiple-use (or sequential-use) potential and impacts of hydrocarbon reservoirs enable the European community to improve efficient, sustainable, and climate friendly use of the subsurface. A consistent estimation of hydrocarbon resource is a first step in assessing and quantifying the hydrocarbon reserves in the main hydrocarbon basin in Europe.

Project aimed to identify potential zones to store CO_2 as a hydrate within the European offshore and onshore areas. The results foster the development of new HC technologies in areas previously considered uneconomic. The outcomes of this project improves understanding of offshore methane hydrate and shale gas/oil resource and help developing legislation and regulation.

GARAH is compliant to the GeoERA scope. However, since the preparations of GeoERA, the position of hydrocarbons (and fossil fuels in general) is rapidly changing with regards to the European and national energy research agendas. Although fossil fuel is not in the scope of the EU Green Deal, the project results may still contribute to important energy security climate goals.

Summary assessment scores for all four evaluation levels are presented in Table 9.

Table 9: GARAH overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	4	4
Theme level review	3	4
GeoERA level review	4	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 4 (Objectives and targets fully achieved). Stakeholder observed that the very topical and comprehensive Project has achieved impressive results, it performs beyond the project scope and raises the overall profile of the Energy Theme and GeoERA as a whole.

3.3 GeoConnect³D: Cross-border, cross-thematic multiscale framework for combining geological models and data for resource appraisal and policy support. GeoEnergy

Project aimed to develop and test a new methodological approach to prepare and disclose geological information for policy support and subsurface management based on two regional case studies. The project envisaged methodology that bring together different types of geological information in a harmonized and self-explanatory manner, while making full use of modern visualization technology.

This Project highlighted the structural framework model for connecting data that is cross-border, cross-thematic and multiscale.

The central methodology developed in GeoConnect³d is fundamentally different from state-of-the-art approaches in bringing together different types of geological information in a way that is transparent for a general public, policy makers and experts. The methodology entails a redefinition of the structural framework and the introduction of a concept of geomanifestations. An alternative approach to harmonization identifies shared limits and units and introducing

zoom to allow for different levels of detail, rather than attempting to reach one agreed geological model at one specific scale.

Summary assessment scores for all four evaluation levels are presented in Table 10.

Table 10: GeoConnect[3]D overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	4	5
Theme level review	5	5
GeoERA level review	5	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 4 as the project fully achieved all its objectives and even more (Overachiever) in scientific area and due to contribution to the Theme. Scientific reviewers emphasizes that the Project develops 'brilliant' fundamental concepts which are broadly applicable to different themes and types of geoinformation – the concept of structural frameworks annotated as geomanifestations which helps to better understand the high complexity of 3D geological structure and its role in natural processes.

In the Thematic reviewer's opinion, the idea has been excellently implemented through the case studies. Novel concepts are broadly applicable to different themes and types of geoinformation. This can be a good basis for sharing and communicating geoscience information for stakeholders and policy support.

Stakeholder also remarked that this project may be considered an overachiever for demonstrating the power of geomanifestations as a perfect communication tool. Other exemplary achievements include the structural model, the benchmarking tool, traffic light system, communications products such as photo databases, fact sheets, social media.

3.4 HIKE: Hazard and Impact Knowledge for Europe. GeoEnergy

Project HIKE aims to support the state of the the art in hazard and risk management through development, demonstration and implementation of essential subsurface data sets, assessment methodologies across Europe and setting up a knowledge share point where research institutes and stakeholders are guided towards the information they need.

The project supports the integration of the Fault Database and Knowledge Share Point in the larger European Geological Data Infrastructure (EGDI). The Fault Database and Knowledge Share Point produces novel pan-European data and information services inside EGDI that helps to better manage and reduce anthropogenic risks related to exploration and exploitation of subsurface capacities and resources (e.g. by developing and disseminating public data and knowledge needed for identifying and analysing geological features that pose a hazard during subsurface exploitation).

The successful implementation of a Project provides the foundation and platform for the (future) alignment of national research on geo-energy related (induced) impact and hazard assessments. The gathering, harmonization and central dissemination of geosciences data sources, methodologies and case study results deliver the means and support to develop and improve methods to predict, prevent and mitigate hazardous and polluting effects induced by subsurface exploitation. The project indirectly contributes to the reduction of economic and societal costs resulting from such effects by minimizing the risks. Through the implementation and demonstration of real and actual use cases, the project is better able to translate the achievements and results to the policy and societal domains. The collaboration between project partners as well as between the project and other national/transnational studies is vital to establishing common agreed and broadly applicable standards and functionalities in alignment with end-user needs as well as to increasing the effective deployment of innovation capacity in the entire research area. This helps countries to improve their own assessment and determination of induced hazards and impacts. The open-access and dissemination of information via the GIP-P will allow stakeholders and end-users to benefit from the established results and thereby avoid unnecessary data acquisition and research costs.

The project established a clear transnational focus. Through the development of generic information sources and methodologies as well as national oriented sources and use cases, the project reaches out to both national and European stakeholders and end-users. The public availability of information regarding hazards and impacts may be subject to confidentiality and other access restrictions that are imposed by national and local regulations. These restrictions could not be resolved within the project yet attempts were made to include references where possible. Furthermore, it can be expected that certain use cases cannot be promoted by the project due to their politically and societally sensitive nature.

Summary assessment scores for all four evaluation levels are presented in Table 11.

Table 11: HIKE overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	5
Scientific review	4	4
Theme level review	3	4
GeoERA level review	4	4/5

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 4/5 (Partly overachiever). In addition to the collection and publication of fault data and information, HIKE has also led to a new incentives and approaches to produce and improve fault information at national and transnational levels according to common pan-European workflows and standards. The results obtained and the discussions with the project team have clearly shown that the consortia have achieved all the objectives set and even exceeded some of them. Stakeholder also opined that in overall, the project achievements were outstanding.

3.5 HotLime: Mapping and Assessment of Geothermal Plays in Deep Carbonate Rocks – Cross-domain Implications and Impacts. GeoEnergy

The Project aimed to improve the understanding of geological conditions that determine the distribution and technical recoverability of their potential resources.

It pursued joint development of a common procedure for assessing the viability of geothermal reservoirs and its application to different pilot areas. It aimed at developing generic information and methodologies based on and validated by trans-regional and cross border use cases to serve national and European stakeholders and end-users.

The project tested HotLime's approach in deep carbonate rock suites of contrasting geological settings and providing reliable data and additional mapping products pertinent to the development of deep geothermal installations which increases the confidence in the prospectivity and potential contribution of those geothermal resources across Europe. In addition, as deep carbonate rocks are widespread in many parts of Europe, the outputs of HotLime are applicable to promoting geothermal exploitation in many regions of the EU. This will further stimulate green thermal energy uptake especially in urban regions and populous areas with a high density of potential customers for direct heat use.

HotLime increases awareness of the economic viability of deep geothermal installations in carbonate environments. Increased understanding and knowledge transfer and the provision of a consistent and data-driven knowledge base aids the formulation of policy tools and strategies aiming for large-scale geothermal energy developments across Europe.
Implementing scientific intelligence and information into the policy domain considering relevant cross-thematic links to groundwater and mineral resources helps to evaluate competition, interference and synergies between different uses of subsurface space.

The Project delivers a sound basis for further site specific, in depth research and development. Sharing the improved understanding of potential benefits and impacts will raise public awareness and support the social licence to operate. In some countries, demonstration of geothermal potential, including in deep carbonate basins, will facilitate and accelerate development of licencing regulations for commercial exploitation of geothermal energy.

Summary assessment scores for all four evaluation levels are presented in Table 12.

Table 12: HotLime overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	5
Scientific review	4	4
Theme level review	3	4
GeoERA level review	4	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 4, it is in full accordance with aims, objectives, and ambitions. Monitoring and Reporting Officer outlines that the project concluded without an extension of the deadline and so four months earlier than other GeoERA projects. Some deliverables were dependent on the collaboration and work of other Projects. Nevertheless, the Project has managed to stay on track thanks to good preparation and sound project management. For this reason, the project is rated as Overachieving at the first level of evaluation.

3.6   MUSE: Managing Urban Shallow geothermal energy. GeoEnergy

MUSE addresses measures to enhance and manage sustainable and efficient use of shallow geothermal energy in European urban areas for promoting green energy uptakes.

The European Union already faces a rather high degree of urbanisation. Therefore, strategies and actions on the uptake of green energy supplies in Europe need to focus on urban areas. Here, shallow geothermal energy (SGE) used for heating, cooling and seasonal storage has the potential to become a key instrument for reducing the dependency on energy imports and lowering emissions by enhancing the decarbonization of the heating and cooling market. Although around two thirds of the total installed capacities and more than 85% of all investments in the European geothermal sector is related to SGE use, these simple and very adaptable heating and cooling techniques still suffer from a lack of visibility and awareness by the general public.

Taking the above-mentioned aspects into account, MUSE addresses measures to enhance and manage sustainable and efficient use of SGE methods for fostering green energy uptakes in Europe.

The project contributes to:

- Delivery of a well-documented knowledge base (catalogue of joint methods and workflows) for local-scale assessment of resources and possible conflicts related to shallow geothermal energy in cities.

- Developing interoperable quality standards and criteria for supervising the whole management circle including exploration and assessment, planning & licensing as well as monitoring of use and related impact on the subsurface, especially on shallow groundwater bodies. In this context, the project especially addresses the problems of mutually interfering SGE installations.

- Developing strategies and related actions (roadmaps), as well as policy tools, for managing and supporting SGE use in cities. This also includes the evaluation of the current legal framework on regulating and support for shallow geothermal energy.

- Identifying and describing proven and promising technical concepts of SGE use for heating, cooling and seasonal heat storage.

- Describing technical and environmental risks related to inappropriate SGE use and providing risk intervention and mitigation measures.

- Demonstrating the developed methods, workflows and concepts in 14 urban pilot areas across Europe.

- Developing modern web-based information-and decision-support systems for investors and regulators.

- Involving local stakeholders in the pilot areas by targeted communication and transfer of knowledge activities to ensure a long-term impact of MUSE with regard to enhancing the use of SGE to reduce greenhouse gas emissions and improve air quality and urban well-being.

All results can be transferred to other Geological Survey Organisations or similar entities to be used in other European urban areas. The comprehensive toolboxes provided by the Project aim to cover all relevant aspects dealing with possible future SGE use in European urban areas.

Summary assessment scores for all four evaluation levels are presented in Table 13.

Table 13: MUSE overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	4	4
Theme level review	4	4
GeoERA level review	4	5

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 5 (Overachiever). The Project surpassed initial expectations:

- Several national spin-off projects were started, linked to the activities performed in the Project.

- The produced resource and limitation of use maps were adopted by local stakeholders in several Project's pilot areas.

- Strategic cooperation was initialized with other European networks like JPI, EGEC, RHC and IAH.

3.7 HOVER: Hydrogeological processes and Geological settings over Europe controlling dissolved geogenic and anthropogenic elements in groundwater of relevance to human health and the status of dependent ecosystems. Groundwater

Project HOVER addresses groundwater management issues related to drinking water, human and ecosystem health across Europe in relation to both geogenic elements and anthropogenic pollutants. The technical and scientific fundamentals of the Project are the geological knowledge and comprehensive understanding of the hydrogeological processes involved in the transfer of

organic and inorganic elements of natural and anthropogenic origin to the groundwater resources.

The Project is of importance – first of all – for water management. It invokes an international exchange about different approaches concerning special groundwater, which is not only interesting for the water management of bottled mineral water, but also for the beverage industry. Furthermore, an overview on medical springs and spas could be of interest for tourism industry and health service.

The Project also increases political and public awareness of health issues related to groundwater quality permitting, by developing and mapping indicators, a quick overview on a homogeneous way of the sectors with high concentration of toxic or adverse effect dissolved elements.

Delineating the range of concentration of elements of natural origin over European aquifers supports the implementation of the water framework and groundwater directive in giving a homogeneous basis for deriving at national level the threshold values to be used in the evaluation of the chemical status and the risk evaluation. Based on indicators and maps best practices in GW management recommendation are proposed on: i) data quality monitoring, ii) data treatment, iii) delineation of indicators in relation to geological families and case studies of specific GW exploitation in areas of high natural background level would be compiled.

The development of a framework for groundwater ecosystem assessment provide information on presence of degraded bacteria and potential degradation activity and reduce costly monitoring of contaminants at the GW-SW interface in future. Evaluating the potential degradation of the surface water (rivers, humid zones...) due to groundwater, requested by the WFD and helping management of drinking water wells are quite complex and need a great amount of data. Looking for indicators such as bacteria is one of the tools with good application perspectives at basin scale. The Project should lead to the development of better groundwater protection strategies through establishing travel times for nitrate and pesticides from infiltration to recharge and discharge zones, and thus the time lag between measures and trend reversal and the recovery of water quality. This will assist stakeholders in the evaluation of measures including nitrate vulnerable zone designations.

This data is also needed at the time of making the evaluation of the efficiency of programme of measures to reduce impact of pollution pressure associated to diffuse agriculture. Indeed, delay between the application of corrective actions and the decreasing trend of contaminant concentrations in groundwater makes difficult not only the confirmation of the efficiency of measures but also the awareness of stakeholders.

Geological and hydrogeological settings are the entry point to classify the samples in age intervals as an indicator of the susceptibility/vulnerability of the aquifers to contamination from human activities on the surface, elevated toxic geogenic elements in deeper aquifers and over abstraction. This information, combined with other indicators, is of great importance for better groundwater protection strategies. The project demonstrates the use of groundwater age distributions for design and assessment of monitoring programmes, pollution trends and history and the evolution of ground water quality (chemical status).

The main outcome of the project is harmonized assessment for groundwater vulnerability to pollution. The main deliverables are maps that can be used in ground water management, subsurface spatial planning and environmental decision-making processes both at least the national and regional scales, and at a cross-border scale. The project results in methodological harmonization and the establishment of data interoperability at Cross Border, Pan European optionally national scales.

The Project helps countries to identify Emerging Contaminants of high concern regarding global pan-European settings and adapted to local specific contexts and knowledge and:

- Allow wide access to reliable data to support decision making such as groundwater protection.
- New challenges in sampling and analytical methodologies developments regarding the increase of the number of substances of interest and the need for streamlining the Emerging Contaminants monitoring across Europe.
- A key outcome is an overview of GW monitoring status of Emerging Contaminants across Europe. Collected Emerging Contaminants occurrence data were supplied to the European Commission Data Base IPCHEM.
- The development of novel methods to link EC presence with anthropogenic activities, environmental conditions and co-occurring tracers help to identify hot spots regarding GW contamination by Emerging Contaminants.
- Identify what are the chemical properties that can be used to estimate the leaching potential of Emerging Contaminants to GW and to evaluate how to take into account usage data in risk assessment procedure.
- Supporting the implementation of the GW "watch list", definition of pollutants of concern.

Overall impact of this GeoERA initiative is the compilation and delivery of harmonized, interoperable and comparable geoscientific information, contributing to national and EU general activities in fulfilling the objectives of the Water Framework Directive. The degree of harmonization depends on data availability, scale of investigation and applied methodology. The improved databases and visualization tools proposed related to thermal and mineral water distribution, natural background levels and related indicators, vulnerability assessment, on groundwater age tracers and indicators currently existing in EU member states are some of the products that will be produce at pan-European scale for supporting health and environmental issues related to the quality of groundwater.

Also, best practice guidance from demonstration projects are proposed in different hydrogeological settings to support harmonized management strategies and most widely:

- To apply statistical data treatment related to the development and mapping of indicators.
- To define the best methodology to organize and visualize data collected-to test and develop new techniques for estimating age distributions of groundwater bodies.
- To monitor key parameters with reference to environmental context, geological setting and risk assessment.

Summary assessment scores for all four evaluation levels are presented in Table 14.

Table 14: HOVER overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	3	4
Scientific review	4	4
Theme level review	3	5
GeoERA level review	3	5

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 5 (Overachiever). Team review explains the reason for the highest rating with the publishment of more than 10 scientific papers, as no research papers were anticipated as deliverables from the Project. This is a significant additional achievement, which increases the impact of the project and improve the chances for the partners in the consortium to get involved in other Horizon Europe proposals. Several HOVER partners have already been using their new collaboration experiences and research products in new Horizon Europe proposals.

Stakeholder also opines that the project, given its initial goals and available budget, has exceeded the expectations in terms of what it delivered.

3.8 RESOURCE: Resources of groundwater, harmonized at Cross-Border and Pan-European Scale. Groundwater

The Project aims at demonstrating the potentials of the harmonization of information about Europe's groundwater resources through cross-border demonstrations projects, through harmonized characterization approaches for Karst and Chalk aquifers and through a first information product at Pan-European scale, where available data is compiled and integrated to produce a map of fresh groundwater resources of Europe.

Although EU member states deliver information about their "groundwater bodies" to the EU for the Water Framework Directive (WFD), this does not yet lead to a harmonized pan-European assessment of the 3D structure of aquifers, the volumes of water involved and its quality.

Harmonisation of geological and hydrogeological information and harmonized 3D characterization of groundwater bodies (aquitards and aquifers) is a prerequisite for any transboundary groundwater management. To date there has been no attempt to make pan-European harmonized compilations of available groundwater and hydrogeological data.

The Project yields information and methods for water managers to balance the pressure of the many activities demanded and the ecosystem services that the groundwater/subsurface can provide, both at cross-border scale and EU scale. The EU scale maps will help member states and the commission to obtain an up to date overview of groundwater resources and special groundwater at an appropriate scale for policy development and evaluation.

The project yields considerable progress beyond the current state-of-the-art in demonstrating the merits of 3D cross-border geologic and hydraulic and chemical characterization, as such enabling groundwater managers of cross-border regions to manage their resources with a good understanding of geological structure, groundwater flow and age patterns in order to prioritize competing uses of the subsurface and effectively protect their resources.

The Project provides a strong impulse to consolidate the cooperation and communication between national/regional subsurface surveys and national and EU stakeholders that deal with groundwater management and protection.

The Project provides improved access to downloadable hydraulic and (hydro)chemical parameters of main European groundwater bodies that can be implemented in groundwater models and coupled surface water – groundwater models at regional and EU scale. The parameters can also be applied to the assessment of trends in groundwater quantitative and chemical status based on both human health and well-being and good status objectives for groundwater dependent or associated ecosystems.

At EU scale, the Pan-EU mapping effort yields an information product that visualizes the extent and importance of Europe's main aquifer systems including important characteristics such as volumes, depths of confining and permeable layers and the depth of the salt-fresh water interface. Often depths and volumes are not registered for the WFD. By providing a harmonized map of depth and volumes of European groundwater, together with first estimates of abstracted volumes, groundwater recharge and surface water discharge, the Project makes a major step forward. The maps do not intend to break up groundwater systems into administrative groundwater bodies, but rather emphasize the connectivity across borders and thus gives insight in transnational important systems. A map of the depth and volume of fresh groundwater as a principal resource of water for the EU can be considered as a basic information layer, needed for almost all attempts to manage groundwater at a scale larger than member states and to formulate policy goals for groundwater within the EU. Indirectly, the map gives information about residence times of groundwater in the subsurface, which yields information about the long-term susceptibility of groundwater systems. The maps and water balance estimates also form the basis for more thorough analysis of the development of groundwater systems in time.

Summary assessment scores for all four evaluation levels are presented in Table 15.

Table 15: RESOURCE overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	4	4
Theme level review	3	5
GeoERA level review	4	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The project fully achieved all objectives and goals. Its overall score at GeoERA level of assessment is 4. Theme review justifies the highest rating of the Project as overachiever because of WP3 and WP5 that delivered considerably more deliverables with useful information products

than were planned in the original proposal. Stakeholder also outlined significant and positive outcomes of the Project. In general, capitalizing on the achievements and investments made in the Project will be a major measure of success of GeoERA Project going forward.

3.9 TACTIC: Tools for climate change impact assessment and adaptation. Groundwater

The project aims to improve the support to EU decision and policy making by contributing to the development of coherent and transparent assessments of climate change impacts on groundwater and surface water using common and integrated approaches, methodologies and tools.

The Project compiles and harmonises European subsurface databases on the common GeoERA Information Platform providing findable, accessible, interoperable and reusable data according to the 'FAIR' principles e.g. in the form of tables of hydraulic parameters, maps, cross sections and model results in collaboration with the GeoERA Information Platform and the other GeoERA themes.

These data are required for scientifically sound climate change impact assessments, decision and policy making, and the developed databases and maps demonstrate where e.g. data for sound assessments are missing in order to be able to make projections with an acceptable uncertainty. The improved decision support data and tools are easily accessible via the GeoERA information Platform primarily for stakeholders involved in the development of sustainable management of Europe's water resources and climate change adaptation.

The Project provides data for the development of on-top services by e.g. private consulting companies contracted by authorities to develop services at local to Pan-European scale, and it promotes the development of new monitoring instruments and networks required for cost-efficient monitoring and assessment of the chemical and quantitative status of the water resources according to the Water Framework and Groundwater directives and the Blueprint to Safeguard Europe's Water Resources.

Summary assessment scores for all four evaluation levels are presented in Table 16.

Table 16: TACTIC overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	5	4
Theme level review	4	5
GeoERA level review	3 / 4	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The project is expected to ultimately publish more than 15 scientific papers within the next half a year (12 is already published). This increases the impact of the Project and improves the chances for the partners in the consortium to get involved in other Horizon Europe proposals

related to the TACTIC topics e.g. in the anticipated new European Partnership – "Water4All – water security for the planet". Scientific reviewers recommend the project partners to summarize their findings in a scientific paper and as a report available to the stakeholders.

3.10 VoGERA: Vulnerability of Shallow Groundwater Resources to Deep Sub-surface Energy Related Activities. Groundwater

In recent years there has been increasing interest in the use of the deep sub-surface for energy related activities in Europe, due to concerns for energy security and a demand to meet international targets to cut greenhouse gas emissions and increase the supply of energy from renewables (as defined in the European Commission's '2020 climate and energy package'). Sub-surface energy-related industries include conventional and unconventional oil and gas exploitation, geothermal energy and sub-surface storage. These industries may impact the sub-surface by introducing new chemicals (potential pollutants), disturbing/mobilizing existing natural contaminants within rocks, or by changing the permeability structure of the rock (introducing new pathways). These represent additional hazards which may impact groundwater and subsequently ecosystems and human health. However, the vulnerability of groundwater to these hazards is not uniform and varies depending on the geological and hydrogeological setting in addition to the industrial processes and risk management measures being applied.

VoGERA aims to improve the scientific understanding of the processes occurring from subsurface energy activities which are potentially harmful for shallow groundwater resources and to identify the potential pathways between deep energy activities, and shallow groundwater to develop conceptual models of shallow groundwater vulnerability due to deep subsurface energy activities. The conceptual models are developed for different sub-surface energy activities, and for a range of geological and hydrogeological settings across Europe.

The scientific outputs are designed to support evidence-based decision making and an integrated approach to management of groundwater vulnerability and associated hazards across Europe in relation to deep sub-surface activities.

The project expects to reach multiple beneficiaries. For improved sub-surface spatial planning by groundwater managers and decision-makers it will be vital to understand various stakeholders' needs. Theoretically, a greater understanding of the issues at hand should provide decision-makers with the confidence to allow development of these industries under the right circumstances, however, there is a large amount of negative public opinion surrounding some of these activities and therefore this may have an influence on the achieved impacts of the project.

Summary assessment scores for all four evaluation levels are presented in Table 17.

Table 17: VoGERA overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	4	4
Theme level review	4	5
GeoERA level review	4	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The project fully achieved all objectives and goals. Its overall score at GeoERA level of assessment is 4. The Project has delivered what was promised in the original proposal, but in addition it also developed a decision support tool (DST), which can be accessed and downloaded from the map viewer of the VoGERA website. Freely available DST is for Theme reviewer the main reason for the highest rating of the impacts and outcome of the Project.

Stakeholder also found the final results very significant with respect to the objectives.

3.11 EuroLithos: European Ornamental stone resources. Raw Materials

EuroLithos developed a framework of information infrastructure for ornamental stone for spatial and technical data, developed and testing prototypes, and produced guidelines for partner countries. It aimed to (Project Agreement):

- Improve knowledge-sharing across Europe through a common understanding of Europe's raw material sources and an increased understanding of Europe's construction raw material deposits as a prerequisite to supplying Europe's construction raw material needs.

- Lift knowledge from national to European levels, providing solutions for harmonized and comparable data.

- Contribute to a common understanding of European natural stone resources, their value and significance, and create a platform for further development.

- Improve the environmental performance of natural stone production due to transport and energy consumption.

- Provision of relevant information for the construction sector (including architectural and cultural heritage preservation) facilitating the conservation of Europe's national monuments, protected structures and the built environment in general.

- Provide information and guidelines on how to find and employ authentic sources, and facilitate the search for alternative "matching" sources in case the former is not available.

- Stimulation of the consolidation of the cooperation and communication between national/regional subsurface organizations and European stakeholders that deal with spatial planning in relation to Energy, Mining and Urban Areas.

- The spatial distribution of geological formations of importance to our built heritage. This alone will provide tools for spatial planning, where the weighing of significance for different land use is crucial.

- A valorisation tool for the intrinsic value of quarries and quarry landscapes.

Summary assessment scores for all four evaluation levels are presented in Table 18.

Table 18: EuroLithos overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	3
Scientific review	4	4
Theme level review	3	3
GeoERA level review	3	3

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 3 with good progress and only minor deviations, except for scientific scope that fully achieved all objectives. The Project faced challenges and delays, however, managed to achieve all the set goals (GeoERA D4.7).

One reason for the Moderate score is linked with the lack of appropriate INSPIRE terminology and the need to find solutions to bridge from widely used EN standards to INSPIRE. The long tradition in the use of natural stone by various trades and for a wide variety of applications has led to specific norms and standards that cannot currently be translated in accordance with INSPIRE. Conform terminology could not be solved to its full satisfaction by EuroLithos as it goes beyond their responsibility. The Project issued recommendations to overcome identified bottlenecks. Suggestions on the terminology and on bridging documents need to be provided via the European Commission to the relevant and mandated working groups.

Stakeholder (see also D5.1) furthermore opines that the main agents have not been engaged to a satisfactory extent in the Project - the stone industries, federations and the cities/municipalities (as one of the most important group of buyers of natural stone). Stronger bonds to stakeholder groups and more communication outside the group were expected (DRAFT, 2020).

The Scientific reviewers nevertheless claim that the goals of the project have been achieved in a satisfactory manner and, most importantly, in a sustainable ways: the project results will be regularly upgraded and republished for at least the next five years.

3.12 FRAME: Forecasting and assessing Europe's Strategic Raw Materials needs. Raw Materials

Project FRAME dealt with the strategic Critical Raw Materials (CRM) by addressing the EU Commission's concerns regarding the sustainable sourcing of crucial raw materials to the industrialised Europe facing the green transition. FRAME can be considered as a cornerstone

within the GeoERA Raw Materials Theme. FRAME worked to update and improve the concept and data used in EU programmes.

The EU have deemed critical raw materials a core topic. The Project is working to update and improve the concept and data used in EU programmes. The European Commission has already acknowledge CRM metallogenetic knowledge as crucial to a wide range of societal issues, including sustainability in the area of energy, minerals, water, environmental monitoring, health and safety of citizens, and the development of secure infrastructure (natural hazards). The mineral resources sector is the source of a significant proportion of CRM on which the society depends. It supports regional communities, creates employment, provides facilities and enhances services, including health, education and welfare, through its contribution to local, regional and national economies.

Access to strategic CRM is essential to industrial and social development and economic growth and wellbeing of Europe. Europe's geology favours exploitable ore deposits for primary sourcing of many CRM and the project highlights regions with greatest potential and thereby generate predictive targets and increase the exploration investments towards the best quality prospects. This is a key action concerning the improvement of the pan-European critical minerals deposit and mineral-based waste database, ensuring that all available European data are updated and have been checked for quality and accuracy at the national level, and to make them accessible in a seamless way to all users helping business and other stakeholders to optimize their investment. The Project is a critical look beyond the traditional CRM list, taking into account the mineral expertise present in the project consortium and member states in order to impact generally on:

- Develop an updated knowledge base based on existing and newly acquired data.

- Define the state-of-the-art with regards to these elements and minerals.

- An inventory possible secondary sources of these elements and minerals in historic mine sites.

- Develop new products that make visualization of the data more simple, e.g. maps.

- Develop new metallogenic models for CRM and strategic minerals.

- Develop predictability maps where possible.

- Disseminate the knowledge base through a wide community of potential shareholders, European, national and regional policy makers, exploration companies and the general public.

- Significantly contribute to a common spatial data platform and one-stop-shop for verified, quality minerals data.

Summary assessment scores for all four evaluation levels are presented in Table 19.

Table 19: FRAME overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	4	4
Theme level review	4	4
GeoERA level review	4	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The project fully achieved all objectives and goals. Its overall score at GeoERA level of assessment is 4.

In stakeholder's view the Project produced 'a fantastic foundation layer for further development', with a lot of data usage potential.

3.13 MINDeSEA: Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials. Raw Materials

MINDeSEA was the flagship project for marine mineral deposits in the EU. This Raw Materials project aimed at seabed mineral deposits in the European Seas and tackles the potential supply shortage of strategic metals and critical raw materials (CRM), crucial for low-carbon energy production and new technologies.

The Project (from its project description):

- Provides integrated reliable data and information of the off-shore resources, useful for economic and social agents for the selection of viable mine sites and the design of environmentally sound and efficient seabed mining systems for the future.

- Supports exploration and development of marine mineral raw materials by improving our knowledge and understanding of the occurrence of critical raw materials and base metals on submarine mineral deposits.

- Supports future marine-based mining of critical raw materials, especially cobalt (Co), tellurium (Te), niobium (Nb), rare earth elements (REEs) and platinum group elements (PGEs).

- Develops cooperation and collaboration ties between researchers in the different partner organisations and countries participating in the project, contributing towards reducing duplication of research – both in terms of data acquisition as well as resource potential modelling.

- Identifies data gaps and target areas in future projects.

Summary assessment scores for all four evaluation levels are presented in Table 20.

Table 20: MINDeSEA overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	4	4
Theme level review	4	4
GeoERA level review	4/5	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 4. The Project fully achieved all its objectives. The scientific output was commendable with several publications in high-ranking journals. The enormous dissemination and communication output by the Project is a strong surplus for the entire GeoERA Team. The Project provided an important contribution to three editions of the EU Blue Economy Report.

3.14 MINTELL4EU: Mineral Intelligence for Europe. Raw Materials

The overall aim of MINTELL4EU was to improve the European knowledge base on raw materials by updating the electronic Minerals Yearbook, by extending the spatial coverage and quality of data currently in the Minerals Inventory and by increasing the degree of harmonization, communication and interaction between existing data platforms.

Not only was the electronic minerals yearbook updated, the data were also transferred to the MIN4EU database and integrated with the mineral inventory, allowing automation and sustainability. This enables appropriate and streamlined interfaces towards end users e.g. through EGDI and RMIS (EU's Raw Materials Information System). In addition, the geographic recording of raw material data in the mineral inventory was expanded to include Balkan countries, Luxembourg and a German state.

The data quality and harmonization were addressed via education, workshops and the development of quality assurance tools. Harvesting systems to ensure correct data acquisition was already in place but was further developed.

The Project implemeneds recommendations from the EU ORAMA (Optimising data collection for Primary and Secondary Raw Materials) project including testing the use of UNFC (United Nations Framework Classification of Resources) on European mineral resource data. This should check the applicability of the classification system with regard to improved data harmonization and ultimately a Europe-wide harmonized mineral inventory. This can be used to derive decision indicators that are supported in the decision-making process and the schedule for project implementation. The project contributed to a comprehensive mineral resource data platform for the European primary and secondary mineral resources, including a user-friendly portal, providing vital information to governmental and private stakeholders, for planning and investment purposes.

Summary assessment scores for all four evaluation levels are presented in Table 21.

Table 21: Mintell4EU overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	4
Scientific review	4	5
Theme level review	3	5
GeoERA level review	4	4

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 4, as the project fully achieved all its objectives and even more (Overachiever) in scientific area and due to its contribution to the Theme. The database provided is the most reliable and up-to-date freely available (greenfield) mineral information database in Europe. The project received significant attention from the European Commission Directorate General GROW. The Theme reviewer emphasized that the Project made additional efforts to provide information on tourist mines and on the feasibility of UNFC. Several technical papers were published based on the findings of the project. The new knowledge and products allow an innovative visualization to increase the comprehensibility of the Project achievements to non-experts and is an asset on its own

3.15 GIP-P: GeoERA Information Platform project

The overall aim of the GIP-P was to support the GeoERA Projects in organizing, disseminating and sustaining their results in terms of digital data, interpretations, reports and services.

The primary impact of the GIP-P is indirect as the project's main goal was to support other GeoERA Projects. The GIP-P ensured a common access point to the GeoERA results and a harmonization of the data and information. In the past, user-friendly access to geological data and information from across Europe has been very limited. A number of European data harmonization projects successfully developed web portals, but these were never maintained after the end of the project. With the establishment of the EGDI (EuroGeoSurveys' European Geological Data Infrastructure) in 2016, the foundation for a long-term sustainable infrastructure was made. Using EGDI as the base for the GIP-P is valuable as it ensures that different stakeholders in Europe have user-friendly access to the results of the GeoERA Projects through a common access point, besides from enabling to combine these results with data from numerous previous European and regional projects. By building on EGDI the GIP-P brought additional value for scientists, decision makers and other stakeholders. This significantly increases the value of the GeoERA results. As EGDI, and the extensions to this through the GIP-P, adheres to established European and international standards, the GeoERA results are interoperable with data and information from other domains than geology like biology, land use, physical infrastructure and others. This greatly increases the impact of the GeoERA Projects' results for a broad range of stakeholders. The GIP-P/EGDI has great impact by enabling SMEs like software companies, consultants and similar to develop advanced services on top of the platform for data exchange of geoscientific data. An important example of this is 3D/4D geological models where no standard exists today making it difficult to build sustainable software for this kind of information. As EGDI originates from the EGS (EuroGeoSurveys) and is

backed by this organization, the platform can be considered sustainable also beyond the lifetime of the GeoERA programme itself.

The information platform contains a central database, a web-portal and a digital archive. The project to a high degree supports cross-domain integration through the standardisation tasks and data and information is made easily findable via a metadata system. A dedicated GeoERA instance of an EGDI map (https://data.geus.dk/egdi/?mapname=geoera) consists of approximately 600 layers, 439 records describing data sets and services and in total 50 metadata editors from Projects were involved. 7 models generated in different 3D modelling tools are stored in a generic 3D geological model database. 15 Project Vocabularies created for 6 different projects altogether contain 8386 scientific concepts including 1286 bibliographic references and a Multilingual Keyword Thesaurus with 2596 terms. Terms were translated into a total of 21 languages. A Document Repository for "unstructured" data contains currently 694 PDFs, 231 Images and 59 DOIs.

Summary assessment scores for all four evaluation levels are presented in Table 2 above.

Table 22: GIP-P overall score for four evaluation levels, on scale from 1 to 5

	Midterm	Final
Monitoring (project implementation indicators)	4	5
Scientific review	3	5
Theme level review	3 / 4	5
GeoERA level review	3 / 4	5

Source of data: Midterm Technical Review Report, April 2020. Final Technical Review Report, January 2022

Legend – Evaluation scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

GIP-P self-assessed its achievements in the Questionnaire about the extent to which the Project contributed to each of the Expected Impacts for the Information Platform Theme. Results are presented in Table 23.

Table 23: The extent to which GIP-P contributed to each of the Expected Impacts for the Information Platform Theme, score 1-5

Improved access to integrated information and knowledge on subsurface resources and potentials, including functionalities to investigate such data, contributing to the dialogue between policy domains and subsurface stakeholders in support of subsurface spatial planning and decision making	5
Improved ability of GSOs to define future actions with regards to improving key knowledge on subsurface resources, through provision of a sustainable and expandable spatial information framework	4
Improving ability for end-users to combine geospatial databases with other environmental data and information sources through standardized access	5

Source of data: Questionnaire to stakeholders.

Assessment scale: 5 – Overachiever, 4 – Fully achieved all objectives, 3 – Good progress (only minor deviations), 2 – Acceptable progress (considerable corrective action needed), 1 – Unsatisfactory progress.

The overall Project score achieved at GeoERA level of evaluation is 5 (Overachiever). The current version of the GeoERA information platform / EGDI is now probably the most comprehensive and advanced subsurface information platform, globally – not the least when talking about cross-thematic common digital multi-national harmonized subsurface data platforms.

This project surpassed expectations due to delivering more complex forms of geoscience data than expected. The project exceeded the plans by introducing free text search across all types of data in EGDI (and some technical features). IGME (project partner from Spain), together with other partners, developed an EGDI version of the system, which was also not foreseen in the proposal. During the project implementation it was decided to include a 3D model viewer to work with the 3D database. An additional deliverable was produced to explain and make recommendations about the Creative Commons (CC-BY) licence model for access to and reuse of the data.

In majority of impact indicators GIP-P surpassed also achievements in other Themes (note that GIP-P is a single project while scores for other Themes were multiple from several Projects within each Theme). Identified pattern of disparity between scores in GIP-P and in other Projects (Table 24) seems characteristic for GIP-P as primarily a cross-cutting issue (see section 2.3).

Table 24: GIP-P scores as % above (+) or below (-) average score for other three Themes, for selected impacts

Strengthen competitiveness and growth of companies	+86
Synergies with businesses: Creating new market opportunities	+64
Industrial leadership	+62
Economic impacts	+48
Project Results may qualify for Intellectual property protection	+35
Contribution to Geosciences	+29
Policy impacts	+27
Overall to H2020	+25
Longer term impacts: An increase of research funding in GeoERA	**+21**
Achieving self-sustained networks that can operate without EU funding	**+20**
Exchange of good practice	+18
Maturity score	+14
Developing common approaches	+13
Overall contribution of GeoERA Projects to ERA-NET	+9
Organisational impacts	-15
National administrative procedures and legal conditions	-18
Developing European common assessment frameworks and methodologies	-31

Sources of data: Tables 1-9, Appendix, own calculation

The assessment also notes that GIP-P is strong in several criteria in which the other three themes are particularly weak, such as competitiveness, intellectual property rights, industrial leadership, and financial sustainability.

4 MAIN FINDINGS AND RECOMMENDATIONS

The overall goal of GeoERA was to integrate the Geological Survey Organisations' (GSO's) information and knowledge on subsurface resources, and to support their sustainable use in addressing Europe's grand challenges (GeoERA, 2016). Evaluation findings on realization of these goals:

1. About **integration**: cross-country networking is assessed as Very Good, cross-cutting integration was Extraordinary successful (beyond expectations), while cross-thematic integration is moderate and asymmetrical. Overall, the goal is fully achieved at the level of the best initial expectations (Section 2.3 above).

2. About the **GSO's information and knowledge** on subsurface resources; score 5, beyond expectations. Contribution to Knowledge and services aimed at European policy makers and stakeholders is beyond expectations (Table 1, Appendix).

3. About **sustainability**: Ability to achieve self-sustained P2P networks that can operate without EU funding (Maturity score, Table 9, Appendix) is assessed with score 3,5, which is at the lower range of rating as Very Good. With the same score is assessed an increase of the amount of research funding in the domain of GeoERA (Table 6, Appendix).

4. About addressing **Europe's grand challenges**: GeoERA Projects assessed their contribution to EU Societal challenges as Very Good (score 3,6, Table 1, Appendix).

What to **recommend** at the end to the Programme that fully achieved and overachieved its initial aspirations? This question is even more justified when evaluating the Programme that is anyway not going to continue in its present form anymore. But the question is nevertheless relevant with an proposal for continuation of the Programme already submitted and presently under evaluation.

With the completion of the GeoERA Programme its main goal to deliver a Geological Service for Europe is foreseen to in a EU **Coordination and Support Action** 'Geological Service for Europe' (CSA GSE). EU CSA funds projects consisting mainly of accompanying measures or complementary activities, such as standardisation, dissemination, awareness-raising and communication, networking, coordination or support services, policy dialogue, mutual learning exercises, studies and networking and coordination between programmes in different countries. Expected outcomes and scope of a new CSA proposal (document C5-D3-CC-02-2021. File 'CSA GSE_cluster 5 draft call text, submitted to EU January 2022') refer to further strengthening cross-cutting and cross-boundary integration, with cross-thematic dimension focused more on data and information (micro level) and less on Themes (meso level). Therefore, the CSA GSE **emphasises cross-thematic integration at lower level in comparison to GeoERA**.

When also taking into account that cross-thematic integration at the Thematic level is at present the weakest integration chain in GeoERA it becomes apparent that the geological community may need to **secure additional efforts** for maintaining and further strengthening the present cross-thematic achievements between thematic fields of geosciences.

In order to further cross-thematic achievements, the geological community may wish to:

1. Take into account that it is usually harder, more complex to implement a high quality cross-thematic project than a high quality mono-thematic project. Preparation and implementation of cross-thematic projects require some additional and probably quite specific conditions, including flexible financial rules, co-management skills and in particular cross-thematic (matrical) comprehension of challenges. This evaluation recommends the GeoERA Partners to consider coordinated efforts for strengthening their cross-thematic cooperation beyond otherwise highly commendable scope of the CSA GSE. Potentials for further cross-thematic projects are already identified by GeoERA (see Matrix 3-5).

2. Take into account the essential difference between vertical and horizontal integration of knowledge or difference between **harmonisation** (cross-cutting) and **synergic** (cross-thematic) integration. Complex knowledge system need carefully maintained balance between them.

3. In order to further cross-thematic achievements, the geological community may wish to award the highest priority advance **knowledge that arises at the intersection between different geological domains** but also between geology, environment and society, between micro and macro and between nature and culture, in a partial overlap between them (Venn diagram).

4. Implement possible activities for further cross-thematic integration (GeoERA Joint Call Document no. 4 and 9):

   – Provide a common European Geological Knowledge Base Platform as a single open access gateway to the project results as well as underlying data and information collections and infrastructures of partners at national and regional level.

   – Understand the interaction between the different natural resources (GeoEnergy, Raw Materials and Groundwater).

   – Further develop common models and assessment frameworks that allow simultaneous appraisal of natural resources (GeoEnergy, Raw Materials and Groundwater) exploitation.

   – Use of the subsurface for solving integral problems such as climate change mitigation and adaptation options.

   – Develop input to integrated surface and subsurface spatial planning including optimized location of different land uses and infrastructure (transport systems, new urban development etc.).

   – Identify regional geo-hazards and geological impacts (floods, land subsidence, landslides, earthquakes etc.) related to deployment of geo-energy, groundwater and mineral resources.

Stakeholder remarked that the future society will demand a holistic view of how geoscience is connected to sustainable development. **Geoscience information for the future** should go beyond the traditional siloed, supply-driven database-oriented approaches towards integrative knowledge solutions. They are of course user-focused but they also need to transcend disciplines to be able to cope with complex social challenges beyond harmonisation of data from various geological sectors and their unified graphical presentation, use, and interpretation.

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6   APPENDICES

I. Answers to the Questionnaire for GeoERA Projects

Appendix I Table 25: The extent to which GeoERA Project contributed to European Impact, 1 to 5, or n.r.

	GE*	GW*	RM*	GIP-P*	GeoERA*	Overall**
To Knowledge and services aimed at European policy makers and stakeholders	3,7	4,5	4,3	5,0	4,4	**Exceptional**
Establishing interoperable, pan-European data and information services	4,0	3,8	4,0	5,0	4,2	**Exceptional**
To more competitive research	4,3	4,0	4,3	4,0	4,1	**Exceptional**
Developing European common assessment frameworks and methodologies	4,5	4,5	4,0	3,0	4,0	**Very Good**
To Removing obstacles for undertaking transnational coordination:	3,1	3,8	3,8	3,7	3,6	**Very Good**
o EC administrative procedures or legal requirem.	3,0	4,0	3,3	4,0	3,6	**Very Good**
o The misalignment of national thematic programme priorities	3,0	3,5	4,0	4,0	3,6	**Very Good**
o National administrative procedures, legal cond.	3,3	4,0	4,0	3,0	3,6	**Very Good**
Contribution of GeoERA Projects to ERA NET	4,1	3,9	4,2	4,4	4,1	**Exceptional**
o Developing common approaches	4,7	4,3	4,3	5,0	4,6	**Exceptional**
o Join forces to provide common answers to common problems	4,3	4,0	4,8	5,0	4,5	**Exceptional**
o Avoiding overlap and build up expertise	4,2	4,3	4,0	5,0	4,4	**Exceptional**
o Exchange of good practice	4,5	4,0	4,3	5,0	4,4	**Exceptional**
o Access to expertise from other countries	4,5	3,7	4,3	5,0	4,4	**Exceptional**
o Speaking with "one voice"	3,8	3,7	4,0	5,0	4,1	**Exceptional**
o Achieving critical mass, to ensure better use of scarce resources	3,7	4,0	4,0	4,0	3,9	**Very Good**
o Addressing specific geographical issues internationally	4,2	3,5	3,8	4,0	3,9	**Very Good**
o Addressing global issues	3,7	4,0	4,0	3,0	3,7	**Very Good**
o Influencing the national focus of research policies and instruments	3,5	3,3	4,0	3,0	3,5	**Very Good**
To selected priorities of Horizon 2020	3,4	3,1	3,6	4,0	3,5	**Very Good**
o Excellent science	3,7	3,3	3,8	4,0	3,7	**Very Good**
o Societal challenges	3,7	3,5	3,3	4,0	3,6	**Very Good**
o Digitising and transforming industry and servic.	3,3	3,3	3,8	4,0	3,6	**Very Good**
o Industrial leadership	2,8	2,3	3,3	4,0	3,1	**Moderate**
OVERALL contributed to European Impact	**3,8**	**3,8**	**3,9**	**4,1**	**3,9**	**Very Good**

Source of data: Questionnaire for GeoERA projects, December 2021. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

**Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix I Table 26: The extent to which GeoERA Project contributed to, 1 to 5, or n.r.

	GE*	GW*	RM*	GIP-P*	GeoERA*	Overall **
Policy impacts	3,8	4,0	4,0	5,0	4,2	**Exceptional**
Innovation impacts	3,8	4,3	4,0	5,0	4,3	**Exceptional**
Environmental impacts	3,8	4,0	3,7	4,0	3,9	**Very Good**
Science impacts	4,3	3,8	4,0	3,0	3,8	**Very Good**
Economic impacts	3,0	3,7	3,5	5,0	3,8	**Very Good**
Cultural impacts	3,2	3,3	3,8	4,0	3,6	**Very Good**
Health impacts	3,0	3,5	4,0	n.r.	3,5	**Very Good**
Organisational impacts	3,6	3,3	3,7	3,0	3,4	**Moderate**
Symbolic impacts	3,7	3,7	3,3	3,0	3,4	**Moderate**
Training impacts	3,4	3,3	3,3	3,0	3,3	**Moderate**
Societal impacts	2,8	4,0	3,5	3,0	3,3	**Moderate**

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

**Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix I Table 27: The extent to which your GeoERA Project contributed to any other European Impact, 1 to 5, or n.r.

	GE*	GW*	RM*	GIP-P*	GeoERA*	Overall **
Improving potentials for climate & environm. policy	3,8	4,3	3,7	4,0	4,0	**Very Good**
Enhancing innovation capacity	3,7	3,3	3,5	4,0	3,6	**Very Good**
Engaging of researchers with civil society	3,6	3,8	4,0	4,0	3,8	**Very Good**
Synergies with science education	3,8	2,7	3,3	4,0	3,4	**Moderate**
Employment	2,0	3,0	3,3	4,0	3,1	**Moderate**
Synergies with businesses	2,0	2,0	3,3	4,0	2,8	**Moderate**
Strengthen competitiveness and growth of companies	1,8	2,0	3,0	4,0	2,7	**Moderate**
OVERALL indirect European Impact	**3,0**	**3,0**	**3,4**	**4,0**	**3,3**	**Moderate**

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

** Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix I Table 28: Assess the quality of measures to maximise impact. Strategy for knowledge management and protection. The extent to which GeoERA Project, 1 to 5, or n.r.

	GE*	GW*	RM*	GIP-P*	GeoERA*	Overall**
Integrated obtained Results into knowledge base	4,5	4,0	4,0	4,0	4,1	**Exceptional**
Open access to results by other project partners	4,3	4,0	4,0	4,0	4,1	**Exceptional**
Open access of data to general public	3,7	4,0	4,0	4,0	3,9	**Very Good**
Project Results that may qualify for Intellectual property protection	2,7	2,5	3,7	4,0	3,2	**Moderate**
Overall quality of measures to maximise impact	**3,8**	**3,6**	**3,9**	**4,0**	**3,8**	**Very Good**

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

** Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix I Table 29: Assess the quality of Measures to maximise impact. How many of listed activities enabling knowledge transfer and dissemination have you accomplished, Yes, % of answers

	GE*	GW*	RM*	GIP-P*	GeoERA*
Knowledge transfer workshops with stakeholders	67	100	100	100	**92**
Knowledge sharing networks with other international stakeholders	67	100	100	100	**92**
Working structures to coordinate collaboration with other ERA-NETS	17	25	0	0	**10**
Joint events with other relevant initiatives	67	75	100	100	**86**
Knowledge exchange of funded projects	83	75	100	100	**90**
Knowledge hubs	67	50	100	100	**79**
Promotion via open access journals	100	75	100	100	**94**
Production of website content available to large public	67	100	100	100	**92**
Training activities and seminars	67	25	100	100	**73**
Appointment of special groups	17	25	75	0	**29**
Average yes response, in %	**62**	**65**	**88**	**80**	**74**

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations.

Appendix I Table 30: What do you consider the most important longer-term impacts of your involvement in GeoERA?, 1 to 5, or n.r.

	GE*	GW*	RM*	GIP-P*	GeoERA*	Overall **
New methodologies, tools, knowledge	4,7	4,3	4,3	5,0	4,5	**Exceptional**
An increase of knowledge exchange	4,3	4,0	4,0	4,0	4,1	**Exceptional**
An increase of strategic cooperation among EU MS	3,8	4,0	4,3	4,0	4,0	**Very Good**
A reduction of duplication and fragmentation of research activities	3,8	3,7	4,0	4,0	3,9	**Very Good**
A better integration of basic and applicative research	3,8	4,0	3,5	4,0	3,8	**Very Good**
More effective transdisciplinary approach	3,7	3,0	4,0	4,0	3,7	**Very Good**
An increase of the amount of research funding in the domain of GeoERA?	3,3	3,3	3,3	4,0	3,5	**Very Good**

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

** Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix I Table 31: Assessment of the success factors for the project outcomes?, 1 to 5, or n.r.

	GE*	GW*	RM*	GIP-P*	GeoERA*	Overall **
Consortium partners with different expertise	4,7	4,0	4,8	5,0	4,6	**Exceptional**
Quality of results	4,3	4,3	4,5	5,0	4,5	**Exceptional**
Internal communication	4,7	3,8	4,5	5,0	4,5	**Exceptional**
Strategy and aims of the project	4,0	4,0	4,3	5,0	4,3	**Exceptional**
The innovative research approach	4,3	4,0	4,3	4,0	4,1	**Exceptional**
Networking activities	4,0	3,5	4,3	4,0	3,9	**Very Good**
External communication	3,3	3,3	4,5	4,0	3,8	**Very Good**
Trainings or other forms of education	3,3	2,3	4,0	5,0	3,7	**Very Good**
Exogenous factors: legal, market, coincidence	2,2	2,0	4,3	2,0	2,6	**Moderate**

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

** Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix I Table 32: The extent to which Project directly contributed with its results to benefits of different groups of users/beneficiaries. 1 to 5, or n.r.

	GE*	GW*	RM*	GIP-P*	GeoERA*	Overall **
Contribution to research sector	4,2	3,5	4,0	5,0	4,2	**Exceptional**
Contribution to Geosciences	4,3	3,5	3,8	5,0	4,1	**Exceptional**
Contribution to your research team	4,5	3,5	4,3	4,0	4,1	**Exceptional**
Contribution to you personally	4,5	3,3	4,5	4,0	4,1	**Exceptional**
Contribution to your organization	4,3	3,8	4,3	4,0	4,1	**Exceptional**
Contribution to government sector	3,8	3,5	4,0	4,0	3,8	**Very Good**
Contribution to broader community	3,2	3,5	4,3	4,0	3,7	**Very Good**
Contribution to business sector	2,2	2,8	4,0	3,0	3,0	**Moderate**
OVERALL Contribution to beneficiaries	**3,9**	**3,4**	**4,1**	**4,1**	**3,9**	**Very Good**

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

** Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix I Table 33: Maturity Score, 1 to 5, or n.r.

	GE*	GW*	RM*	GIP-P*	GeoERA*	Overall **
Systematic exchange of information and good practices on existing research programmes	4,3	3,8	4,3	4,0	4,1	**Exceptional**
Identification, analysis of common strategic issues	3,8	3,5	4,5	4,0	4,0	**Very Good**
Development of joint activities between national or regional research programmes	4,0	3,3	4,3	5,0	4,1	**Exceptional**
Achieving self sustained network - P2P networks that can operate without EU funding	3,6	2,7	3,8	4,0	3,5	**Very Good**
Implementation of joint transnational research activities:	4,0	3,8	4,1	4,6	4,1	**Exceptional**
o Defining common priorities and joint research agendas	4,2	3,8	4,3	5,0	4,3	**Exceptional**
o Implementing joint research agendas	3,7	4,0	4,3	5,0	4,2	**Exceptional**
o Jointly implementing and financing calls and projects	4,2	2,8	3,8	5,0	3,9	**Very Good**
o Engaging in transnational R&D cooperation beyond the GeoERA	3,8	4,3	3,8	4,0	4,0	**Very Good**
o Mutual learning	4,2	4,0	4,5	4,0	4,2	**Exceptional**
OVERALL Maturity score	**4,0**	**3,5**	**4,1**	**4,4**	**4,0**	**Very Good**

Source of data: Questionnaire for GeoERA Projects, December 2021. Own calculations.

Legend:

*Scale for assessing impacts: 0—No Impact. 1—Negative impact. 2—Weak Impact. 3—Moderate Impact. 4—Excellent Impact. 5—Outstanding Impact, beyond expectations.

** Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix I Table 34: Leopold matrix: The extent to which Project contributed to the Expected Impacts, score 1 to 5, or n.r.

Project Impacts / Assessment Criteria		HIKE	GeoConnect3d	Hotlime	MUSE	3DGEO-EU	GARAH	Vo-GERA	HOVER	TACTIC	RESOURces	EuroLithos	MINTELL4EU	FRAME	MINDeSEA
		GE	GE	GE	GE	GE	GE	GW	GW	GW	GW	RM	RM	RM	RM
Improved ability to predict sub-surface contributi-ons to secure future energy supply based on a transnational harmonized inventory of HC solid fuel, geothermal resource, energy storage capaci.	GE	4	4	5	5	4	5	3	n.r.	2	4	n.r.	n.r.	n.r.	n.r.
Improved evaluation of potential to limit further human-caused climate change, through improved understanding of subsurf. storage capac. for CO2	GE	4	3	3	n.r.	3	5	n.r.	n.r.	2	4	n.r.	n.r.	n.r.	n.r.
Improved anticipation of poten-tial bottle-necks in exploitation of GE resour., storage capacities	GE	4	5	4	5	4	5	5	3	2	4	n.r.	n.r.	n.r.	n.r.
Improved basis for developing future research programmes	GE	4	5	5	5	4	4	3	3	2	4	n.r.	n.r.	n.r.	n.r.
More scientifically supported basis for socio-economic CB analyses, subsurface spatial planning decisions, SEA	GE	4	5	2	5	4	5	4	3	3	4	n.r.	4	n.r.	n.r.
Improving dialogue with public for discussions on GE uses	GE	3	5	4	5	2	4	3	3	2	4	n.r.	n.r.	n.r.	n.r.
Improved support for the implementation of EU water policies taking into account the exploitation of GE and raw mat.	GW	4	4	2	n.r.	2	n.r.	5	3	3	5	n.r.	4	n.r.	n.r.
Improved decision support for climate change adaptation by improved coupled climate and GW-surface water models	GW	n.r.	n.r.	3	2	2	n.r.	n.r.	2	5	4	n.r.	n.r.	n.r.	n.r.
Resource mapping to set basis for monitoring system of GW	GW	n.r.	n.r.	3	n.r.	n.r.	n.r.	n.r.	5	4	5	n.r.	n.r.	n.r.	n.r.
Improved insight in the interacttions of subsurface activities, climate change,GW abstr, floods	GW	n.r.	3	3	3	n.r.	n.r.	n.r.	2	4	4	n.r.	4	n.r.	n.r.
Assure open access to modelling others to develop new GW servi	GW	n.r.	n.r.	3	3	n.r.	n.r.	3	4	3	5	n.r.	n.r.	n.r.	n.r.
Improved global role of Europe in sustainable water managem.	GW	5	n.r.	3	2	n.r.	n.r.	4	5	4	5	n.r.	n.r.	n.r.	n.r.
Improved access to download-able hydraulic and (hydro)chem. parameters of main European aquifers and aquitards	GW	n.r.	n.r.	3	2	n.r.	n.r.	n.r.	5	n.r.	5	n.r.	n.r.	n.r.	n.r.
Developing tools for decision support on the cost-effectiveness of measures and to sustainable decision making in relation to the water-food-energy nexus	GW	5	3	3	n.r.	2	n.r.	5	4	4	4	n.r.	n.r.	n.r.	n.r.
Reinforcing synergy at internat. level in raw materials research, facilitating efficient use of natural resources	RM	n.r.	n.r.	3	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	4	5	4	4	4
Providing technical solutions to enhance the exploration, making it more efficient & optimise deposit exploration	RM	n.r.	2	3	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	4	4	2	5	4
Providing innovative solutions for mineral exploration & deve-lopment, to optimise investment	RM	n.r	3	3	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	4	4	3	4	4
Providing data/tools to facilitate reuse & recycling of mineral based waste	RM	n.r	n.r.	3	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	4	3	4	4	n.r.
Reduction of the import depend. of industry for critical raw mater	RM	n.r	n.r.	3	n.r.	n.r.	n.r.	n.r.	n.r.	n.r.	4	5	4	4	4

Source of data, Legend: the same as in Tables above.

II. Answers to the Questionnaire for GeoERA Stakeholders

Appendix II Table 35: Stakeholders on contribution of GeoERA Co-founded projects to ERA NET, score 1 to 5

	Beginning of the project	End of the project	Difference in %
Coordination, harmonisation	2,2	3,6	63
• Improving integration of basic and applicative research	2,1	3,5	65
• Avoiding overlap and build up expertise, the reduction of fragmentation and duplication of effort of both policy initiatives and research activities.	2,3	3,5	56
• Developing common approaches, such as European common assessment frameworks and methodologies and interoperable, pan-European data and information services.	2,4	4,1	74
• Providing more effective transdisciplinary research.	2,0	3,3	63
• Introducing Mutual coordination of research programs between EU, national and regional authorities.	2,1	3,4	61
Enhancing research capacities	2,1	3,2	51
• Improving access of countries to knowledge and/or research capacity from other countries.	2,4	3,6	53
• Achieving critical mass in scientific and technological capabilities of countries.	2,0	3,0	50
• Improving visibility of research area.	2,1	3,3	53
• Increasing funding of research area.	2,0	2,8	38
• Increasing the quality of research activities.	2,3	3,5	56
• Invoking clear changes in behaviour and perceptions of the benefits of transnational R&D cooperation.	2,0	3,1	56
Facilitating practical initiatives:	2,3	3,7	61
• Providing Knowledge and services aimed at regional, national, European or global policy makers and stakeholders, including innovation and technological development.	2,3	3,6	56
• Enhancing exchange of good practice.	2,3	3,8	67

Source of data: Questionnaire for Stakeholders. Own calculations.

Legend: Scale for assessing impacts: 0 (or empty)-No Impact. 1-Negative impact. 2-Weak Impact. 3-Moderate Impact. 4-Excellent Impact. 5-Outstanding Impact, beyond expectations).

Appendix II Table 36: Stakeholders on contribution of GeoERA Co-founded projects to Horizon 2020 and its Focus areas in the 2018-2020 Work Programme, score 1 to 5

	Score*	Evaluation**
Excellent science (World class science, able to develop, attract and retain research talent, with the best access to infrastructures	3,3	**Moderate**
Industrial leadership (Strategic investments in key technologies underpin innovation across existing and emerging sectors, attracting more private investment, innovative small and medium-sized enterprises)	3,0	**Moderate**
Societal challenges (answering to concerns of citizens and society; breakthrough solutions from multi-disciplinary collaborations	3,6	**Very Good**
Digitising and transforming European industry and services	3,8	**Very Good**

Source of data: Questionnaire for Stakeholders. Own calculations.

Legend:

* Scale for assessing impacts: 0 (or empty)-No Impact. 1-Negative impact. 2-Weak Impact. 3-Moderate Impact. 4-Excellent Impact. 5-Outstanding Impact, beyond expectations).

** Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

Appendix II Table 37: Participation in GeoERA led to results that would not have been possible without the scheme – Stakeholders' view, score 1 to 5

	Score*	Evaluation**
Creating new opportunities for enabling transnational R&D activit.	4,1	**Exceptional**
Overcoming fragmentation of research in Europe	4,1	**Exceptional**
Managing to attract a wider range of relevant public sector stakeholders who would otherwise be excluded	3,8	**Very Good**
Managing to attract a wide range of research beneficiaries who would otherwise be excluded (such as research, non-EU states)	3,7	**Very Good**
Leading to increase in national budgets invested in transnational R&D projects and influenced national research policy	3,6	**Very Good**
If Participation in GeoERA helped to remove obstacles for undertaking transnational coordination was it because of:		
• Helping to remove obstacles for undertaking transnational coordination of, and cooperation between, R&D programmes	4,1	**Exceptional**
• Removing the misalignment of national thematic programme priorities	3,2	**Moderate**
• More efficient national administrative procedures and legal conditions	3,0	**Moderate**
• More efficient EC administrative procedures or legal requirements	2,9	**Moderate**

Source of data: Questionnaire for Stakeholders. Own calculations.

Legend:

* Scale for assessing impacts: 0 (or empty)-No Impact. 1-Negative impact. 2-Weak Impact. 3-Moderate Impact. 4-Excellent Impact. 5-Outstanding Impact, beyond expectations).

** Scale for evaluating cumulative results: Poor (from 2,0 to 2,5), Moderate (2,6-3,4); Very Good (3,5-4,0); Exceptional (more than 4,0).

III. Monitoring data, aggregated, selected

Appendix III Table 38: Cross-border cooperation & No. of participating organisations, by Projects

	No. of organisations	No. of countries
RESOURCE	35	30
HOVER	34	29
MINTELL4EU	27	25
GIP-P	24	22
FRAME	20	20
TACTIC	20	17
GeoConnect3D	20	16
MUSE	16	15
HIKE	19	14
EuroLithos	16	14
HotLime	18	12
MINDeSEA	12	10
GARAH	8	8
3DGEO-EU	11	7
VoGERA	7	6

Source of data: GeoERA Monitoring.

Appendix III Table 39: Number of Communication and Diseminaton Activities

Activity	No. of activity
Events	232
Publications	353
Media	11
Meetings	476
Online_media	3176
Total	4248

Source of data: GeoERA Monitoring.

Appendix III Table 406: Assesment scores for Communication and Diseminaton Activities, by Projects

Projects	Assesment score
3DGEO-EU	3
GARAH	3
HotLime	3
VoGERA	3
HIKE	4
HOVER	4
TACTIC	4
RESOURces	4
MUSE	5
MINTELL4EU	5
EuroLithos	5
FRAME	5
GeoConnect3d	5
GIP-P	5
MINDeSEA	5

Source of data: GeoERA Monitoring.