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

Deliverable 4.6

COMPLETED MONITORING REPORTS BASED ON PROJECT PROGRESS REPORTS

Authors and affiliation:
Barbara Simić[1]
Jasna Šinigoj[1]
Aleksandra Trenchovska[1]

[1 GEOZS]

E-mail of lead author:
Barbara.simic@geo-zs.si

Version: 28-12-2021

Deliverable Data		
Deliverable number	D4.6	
Dissemination level	Public	
Deliverable name	Completed monitoring reports based on Project Progress Reports (2)	
Work package	WP4, Follow-up and monitoring of projects resulting from co-funded call	
Lead WP/Deliverable beneficiary	Geological Survey of Slovenia	
Deliverable status		
Submitted (Author(s))	26/12/2021	Barbara Simić
Verified (WP leader)	28/12/2021	Jasna Šinigoj
Approved (Coordinator)	28/12/2021	Joop Hasselman

GENERAL INTRODUCTION

GeoERA launched a Joint Call for Joint Research Projects [hereafter referred to as Projects] with the aim of enforcing a more integrated and efficient management and a more responsible and publicly accepted exploitation and use of subsurface resources. The Joint Call resulted in 15 GeoERA funded Projects running for three years from July 2018 until June 2021. With the Projects, GeoERA aims to achieve the objectives set in Description of work (DOW). Progress of the Projects are monitored regularly, since GeoERA's objectives depend upon the success of these. Twice per project lifetime projects submit their Project Progress Reports. This document compiles all Midterm Project Progress Reports.

EXECUTIVE REPORT SUMMARY

GeoERA work package 4, Follow-up and monitoring of projects resulting from the Joint Call, is concerned with monitoring of the Projects to ensure timely delivery and quality of implemented Project activities are in line with the strategic objectives, goals and scope of GeoERA. Administrative monitoring of the Projects is carried out by evaluating the submitted Project Progress Reports, which projects are required to submit every 18 months. The evaluation of the research part of each Project is carried out at two Review Meetings with members of Stakeholder Council. The progress of the Projects will be summarized in the Technical Review Report, which represents part of GeoERA monitoring and evaluation process for the Projects. The Technical Review Report consists of four sections, each representing one level of monitoring and evaluation of the project.
This document compiles projects' doc no 2C: Final Project Progress Reports on which the monitoring and evaluation are based. The projects follow instructions described in two documents:

- PI doc no 1 Reporting procedures and monitoring indicators; and
- PI doc no 2 Reporting templates & e-tool, with annexes

- PI doc. no. 2A Information on cumulative expenditures (in word form)
- PI doc. no. 2B Project Progress Report (in excel form)
- PI doc. no. 2C Final Project Progress Report (in excel form)
- PI doc. no. 2D Costs after Project end (in excel form)
- PI doc. no. 2E Technical Review Report (in word form)

TABLE OF CONTENTS

1 PROJECT 3DGEO-EU

1.1 Identification of the project

Project full title:	3D geomodeling for Europe
Project acronym:	3DGEO-EU
Project reference number:	GeoE.171.005
Project topic:	Geo-energy
Project specific research topic:	GE5 - ADVANCEMENTS IN DEVELOPING AND USING 3D TRANSNATIONAL GEOMODELS
Project website address:	http://geoera.eu/projects/3dgeo-eu/

Period covered	from:	01.01.2020	to:	31.10.2021

Report submission date:	19.11.2021
Project coordinator:	Stefan Knopf (BGR)

Contact person for the project:	Stefan Knopf
Tel:	+49 511 643 2744
E-mail:	Stefan.Knopf@bgr.de

1.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Bundesanstalt für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Lead
2	Ceska Geologicka Sluzba	Czech Geological Survey	CGS	Czech Republic	999546783	Project Partner
3	Geological Survey of Denmark and Greenland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Partner
4	Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg	State Office for Mining, Geology and Raw Materials Brandenburg	LBGR BRB	Germany	923483942	Project Partner
5	Landesamt für Umwelt, Naturschutz und Geologie Mecklenburg-Vorpommern	State Office for the Environment, Nature Conservation and Geology Mecklenburg-Vorpommern	LUNG	Germany	919805993	Project Partner
6	Landesamt für Bergbau, Energie und Geologie Niedersachsen	State Office for Mining, Energy and Geology Lower Saxony	LBEG	Germany	991377831	Project Partner
7	Landesamt für Geologie und Bergwesen Sachsen-Anhalt	State Office for Geology and Mining Saxony-Anhalt	LAGB	Germany	921579444	Project Partner
8	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Partner
9	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	Polish Geological Insitute	PIG-PIB	Poland	999492463	Project Partner
10	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
11	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner

1.3 Publishable summary

The project 3DGEO-EU has mainly dealt with methods for the harmonization of geological data and 3D geomodels across international borders. It tackles an important issue, as geodata and 3D subsurface information is often inconsistent across borders. Adjoining geomodels for example quite often do not fit across borders, i.e. exhibit border discontinuities like a different depth of a geological horizon. Such inconsistencies hamper reliable assessments of cross-border subsurface potentials.

The reasons for cross-border inconsistencies are e.g. different definitions of stratigraphical horizons, heterogeneous geological base data, different levels of geological exploration, or different approaches and methods used by the Geological Survey Organizations (GSO) on both sides of a border. Yet, cross-border issues are not the only difficulties to be faced when producing reasonable 3D geomodels of the subsurface. Therefore the project has also investigated selected geomodeling topics regarding (i) the visualization of uncertainties of geological 3D models, (ii) regarding modeling of geological faults, and (iii) regarding optimized workflows for 3D reconstruction of the subsurface.

In 3DGEO-EU, 11 national and regional GSO from 7 countries have worked together and strived to find some solutions helping to overcome cross-border differences and aspire towards achieving best methods and (optimized) workflows for cross-border harmonization and 3D geomodeling, which could be applied in other regions and geological settings in Europe. That is an important goal, as the harmonization of geological data and 3D geomodels across borders is an important step towards the future goal of creating a consistent database for pan-European assessments of resource potentials and possible conflicts of use. Consistent and reliable assessment results across borders can only be achieved if the used geological basic information (e.g. geomodels) is consistent across borders as well.

The general approach of the project was to set-up international cross-border pilot areas (work packages 1-3) that served as showcases to develop and test methods for the cross-border harmonization of geological 3D models. Accompanying the work in the pilot areas and to support cross-border harmonization, three additional work packages (4-6) have investigated selected geomodeling topics like the visualization of uncertainties of geological 3D models, modeling of geological faults, or the optimization of 3D subsurface reconstructions. Furthermore, work package 7 governed the interactions with the GeoERA Information Platform project (GIP-P), thus managed all kinds of communication and data exchange between 3DGEO-EU and GIP-P, and was responsible to upload results (spatial data) to EuroGeoSurvey's web portal EGDI (European Geological Data Infrastructure).

The main research and technical work happened in the work packages 1-6:

Cross-border pilot areas:

- WP1 Pilot area in onshore Dutch-German cross-border region
- WP2 Pilot area in onshore German-Polish cross-border region
- WP3 Pilot area in offshore cross-border North Sea region between the Netherlands, Germany and Denmark

Selected geomodeling topics:

- WP4 Uncertainty in geomodels
- WP5 Faults
- WP6 Optimizing reconstructions of the subsurface to reduce structural uncertainty in 3D models

Following the first project phase (Months 1 -18), where cross-border partners defined the areal extent of pilot/work areas, covered the inventory of existing geodata, 3D models, and concepts, and especially evaluated the differences across borders and developed their strategies for the modelling and harmonization work, in the second project phase (Months 19 – 40) for most work packages the actual harmonization work and the generation of harmonized geomodels and maps really took off. As a consequence, 3DGEO-EU is a project where most deliverables (26 of 35) have been finalized in the second project phase.

In the following, some WP-specific information on activities and results of the second project phase is briefly presented:

WP1 “Harmonization of Cenozoic and Mesozoic layers in the northern onshore Dutch-German cross-border region for assessment of underground usage” delivered a harmonized onshore cross-border 3D model of the northeastern part of the Netherlands and the German state of Lower Saxony. The model contains 10 main Cenozoic and Mesozoic horizons. As another result, 2D maps depicting the distribution, depth and thickness of three Cenozoic layers were developed. Furthermore, a decision support map of the Rupel Formation was generated, showing the thickness and distribution of this barrier between deeper saltwater and freshwater, to be used for decisions of underground usage to protect the freshwater bodies of pollution with saltwater. An overview of the work, results and lessons learned is presented in a “Final Report incl. lessons learned”.

WP2 “Cross-border harmonization of selected horizons and structures in the Polish-German border region” had already finished a first harmonized model of a pilot area in the border region of Brandenburg and Poland (Gorzów-block) during the first project phase. In the second project phase another harmonized cross-border model was generated in the border region of Mecklenburg-Western Pomerania and Poland (Szczecin trough). Both models represent the final harmonized German-Polish 3D model that covers an area of about 14.000 km2. The harmonization methods, workflows and results are described in two deliverables reports.

Furthermore, in cooperation with WP6, gravimetric data were harmonized and a detailed joint Bouguer map was developed for an extended model area. In addition, a petrophysical model of the rock densities for the modelled strata based on well logs and core data was developed. The information was used in gravimetric modelling in co-operation with WP6, and documented in deliverable 6.3.

WP3 “North Sea area NL-DE-DK” continued a broad harmonization approach, addressing various potential sources of model inconsistencies. In the second project phase, the challenges and limitations encountered in harmonizing (litho-)stratigraphic units across borders were addressed for certain stratigraphic levels, and detailed log-correlations as a way for harmonization were presented and discussed. The seismic stratigraphic and interpretational concepts applied by the participating GSO´s were compared further in detail for the first time and, when possible, existing disparities were harmonized across borders. Building upon the findings from the previous deliverables, a harmonized time horizon model for the Entenschnabel region was constructed and presented, and the corresponding harmonization steps like seismic re-interpretation in the border regions were described. The establishment of a transnational velocity model for the time-depth conversion in the study area was a further essential step to ensure successful harmonized cross-border 3D models in WP3. Finally, a consistent, harmonized depth model of the Entenschnabel region and a fault model of a segment of the Coffee Soil Fault was constructed as well as concepts for defining structural elements across borders were presented and discussed. The aforementioned work and results are documented in several deliverable reports.

WP4 “Uncertainty in geomodels” continued in the second project phase to investigate different uncertainties that are inherent in large scale geological models from Geological Survey Organizations (GSOs), and how they could be quantified. The outcome of this task has been covered in a report on the sources of uncertainty. Afterwards, the visualization methods that are really needed in order to visualize potential uncertain models coming from GSOs have been selected from the wide range of available methods. Considering those selected methods, the requirements of the European Geoscience Date Infrastructure (EGDI) for visualizing regional geological models with uncertainty have been captured in a deliverable report, together with a prototypical example implementation. Finally, as an example, an uncertainty analysis has been done for a geological model from work package 3 (North Sea). This publicly available example data set (deliverable 4.4) can be used in the future to test and showcase methods and implementations.

WP5 “Faults” was an interface to the GeoEnergy project HIKE. As a standard task it communicated the requirements and specifications of the HIKE Fault Database to the 3DGEO-EU modeling work packages. Furthermore, it was involved in the harmonization work of faults within the pilot areas of WP1-3. The main activity during the second project phase was to collect and analyze methods and best practices for fault modelling work, which were executed within various 3DGEO-EU work packages and partners. The outcome of this task and the entire WP has been described in a main deliverable report that provides an

overview of best practices for fault modelling and data management. This report may act as a reference for future fault modelling projects.
WP6 “Optimizing reconstructions of the subsurface to reduce structural uncertainty in 3D models” has focused on potential field geophysics (particularly gravimetrics) and classic structural geology techniques (like balanced cross sections) as quick, cost-effective and efficient methods for 3D modeling, especially useful for the harmonization of cross-borders regions or regions with scarce and heterogeneous subsurface information or areas where the access to the subsurface information is restricted. The work followed on from the first project phase, with all products to be finalized and delivered in the second project phase.
As a main result, WP6 proposes an optimized workflow for 3D reconstruction based on gravimetric, structural and petrophysical information. This workflow is based on a deep synthesis, discussion and feedback process among many members of the 3DGEO-EU project team and the GeoERA Energy community. The deliverable report on this workflow is a comprehensive and practical instruction manual on common procedures used by some European Geological Surveys (and some universities).
The proposed workflow has been applied and tested in two case-studies, one in the South western Pyrenees, and in cooperation with WP2 a second one in the Northern German/Polish border region, aiming to aid in the harmonization. The main results in the SW Pyrenees are the building of a robust Bouguer anomaly map and especially the construction of a 3D model for the region that integrates structural and stratigraphic elements. A comprehensive deliverable report describes the new and previously available data, methods and procedures used to build the 3D model of the south western Pyrenees. The main result in the Northern Polish/German border region is the harmonization of a cross border Bouguer anomaly map. The outcome of this case study is described in a deliverable report as well.
WP7 “Information Platform Interface” acted as an interface to the GeoERA Information Platform project (GIP-P). As a standard task it organized the communication between the 3DGEO-EU partners and GIP-P. Especially in the second project phase, WP7 has managed the data transfer as well as editing the metadata of the data products created by the different work packages. This included the management of the data testing process (especially 3D-data), the upload of the final 2D/3D-datasets to EGDI and the creation of the corresponding metadata. Furthermore, a deliverable report on data exchange was completed, providing an overview of the technical details of the geo-data produced by 3DGEO-EU that was transferred to the GeoERA Information Platform.
WP8 “Project Management and Coordination” provided daily operational management, communication, and monitoring of project progress. In the second project phase, WP8 organized two 3DGEO-EU project meetings (due to COVID-19 only virtual meetings) and 20 regular Project Board meetings, thus constantly monitoring project progress. The minutes documents from those and other meetings of project wide concern that were staged during the entire project time (M1 – M40) have been compiled as a confidential deliverable 8.1 “Minutes of meetings”. Furthermore, WP8 was responsible for the Final Project Progress Report (D8.4) and a public summary report (D8.5) with an overview of the work and main results of the project.

Altogether, despite of delays caused by the COVID-19 pandemic, the partners completed all tasks and deliverables within the timeframe of the project (01.07.2018 – 31.10.2021). The technical/scientific results are all publicly available, either via the GeoERA 3DGEO-EU webpage or via the EGDI portal.

1.4 Project contribution to GeoERA project

The overall objectives of GeoERA "is to contribute to the optimal use and management of the subsurface. GeoERA will … aim to support 1) a more integrated and efficient management and 2) more responsible and publicly accepted, exploitation and use of the subsurface."
3DGEO-EU aimed to contribute to these objectives as it tested and developed methods and workflows needed for generating harmonized cross-border 3D geomodels of the subsurface. The partners put a lot of effort into the project, following a path from the first project phase (Months 1 -18), where partners defined the areal extent of pilot/work areas, covered the state-of-the-art in the areas and for selected geomodeling topics, i.e. an inventory of existing geodata, 3D models, concepts and methods, then evaluated the state-of-the-art (e.g. differences across borders), and on this basis developed strategies for the modelling and harmonization work, which partly included field campaigns to acquire gravity data (south western Pyrenees), then to the second project phase (Months 19 – 40) with a focus on the actual harmonization work and the generation of harmonized 3D geomodels and maps. Altogether, the partners of 3DGEO-EU have accomplished many products, i.e. more than 20 technical/scientific reports and several digital data sets (e.g. harmonized 3D geomodels and 2D maps) for various work areas. The partners gained experience and increased their knowledge level on the tackled research issues, which enables the project partners to communicate valuable lessons learned.
Thus, 3DGEO-EU has contributed to the overall objectives of GeoERA, as the project results have increased the knowledge concerning ways and means to harmonize underlying geological base data, which is necessary for all kind of consistent and reliable subsurface assessments and thus eventually for planning of the optimal use and management of the subsurface.
The results of 3DGEO-EU mainly aim at experts from European Geological Survey Organizations and the scientific community, thereof especially the geomodeling community, who can build upon the results and carry on to create harmonized 3D geomodels in other areas of Europe as well. By this way, the 3DGEO-EU results can help to achieve the future goal of creating a consistent database for pan-European assessments of subsurface resources. Therefore, in the end stakeholders, decision makers, politics and the public will also have a benefit from those technical expert results of 3DGEO-EU.

This project relates to the GeoEnergy Specific Research Topic (SRT) GE5 "Advancements in developing and using 3D transnational geomodels". The results of 3DGEO-EU contribute to some aspects of the SRT GE5 scope, for example:
- The gained knowledge on methods and workflows for the harmonization of geological data and 3D geomodels has advanced the state-of-the-art towards an integrated and applied 3D modeling.
- The gained knowledge on methods and workflows and the demonstration of cross-border harmonization can help to enhance the reliability of 3D geomodels for future cross-border resource assessments.
- The achieved workflows and solutions in the field of model harmonization are applicable to other countries, regions and organizations as well.
- The generated harmonized cross-border 3D geomodels in different European pilot areas can be used as examples and keystones for further transnational developments.

1.5 Work progress and achievements during the period

Work package 1: Harmonization of Cenozoic and Mesozoic layers in the northern onshore Dutch-German cross-border region for assessment of underground usage

For generation of the harmonized cross-border 3D model NLS3D, criterias, a methodology, and a procedure for harmonization were compiled. Harmonized NLS3D model (D1.2) consist of 10 Cenozoic and Mesozoic layers, from which three thickness maps for Cenozoic units (D1.3) were derived. To improve quality of two horizons on Lower Saxony side these were remodeled (D1.3). Potential Cenozoic geothermal reservoirs and parameters of these were investigated (Task 1.4). A cross-border decision support map, showing distribution and depth of base of a geological barrier between freshwater resources and deeper saltwater was derived from NLS3D (D1.4). An overview of the work, results and lessons learned is presented in D1.5 "Final Report incl. lessons learned". All results are communicated with and uploaded to EGDI via WP7.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Inventory report	LBEG	Report	PU	M6	Completed	Review completed with Midterm report.
D1.2	NLS3D: A harmonized 3D model	TNO	3D model	PU	M24	Completed	
D1.3	Maps of Cenozoic layers	LBEG	Digital data	PU	M33	Completed	
D1.4	Map of hydraulic barrier	LBEG	Digital data	PU	M34	Completed	
D1.5	Final report incl. lessons learned	LBEG	Report	PU	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1	Kick-off Seminar	M3	Completed	Review completed with Midterm report.
2	State-of-the-Art and inventory in pilot areas documented	M12	Completed	Review completed with Midterm report.
3	Mid-Term Seminar	M18	Completed	Review completed with Midterm report.
4	Harmonized crossborder 3D geomodels in Pilot areas	M39	Completed	
5	Final Seminar	M40	Completed	
6	Best practice and lessons learned for cross-border harmonization documented	M40	Completed	

Work package 2: Cross-border harmonization of selected horizons and structures in the Polish-German border region

First, the available datasets along both sides of the Polish-German border (well and seismic data, results of gravimetric and magnetic surveys) and the results of former cross-border projects (starting from first co-operations in the 1970s) were evaluated. The evaluation was summarized in the State of the Art Report (deliverable D2.1, submitted in M9). To complete the databases numerous wells, seismic sections and maps were digitized from the partners. Additionally the possibilities and restrictions of data exchange in both countries were analyzed and discussed. Methods were developed to overcome legal restrictions in sharing of primary data and to handle with heterogenous distribution of data from different sources and data gaps. Thus, the workflow of cross border harmonization was mainly based on interpreted data (modelled surfaces and structures, which were obtained using seismic reflection horizons and well markers). In a next step, comparison and harmonization of these geological and geophysical interpretations were done (lithologs, seismic stratigraphy, velocity models). A harmonized model of the pilot area 1 (border region of Brandenburg and Poland) was finalized in M18 (deliverable D2.3a). The model covers the major litho-stratigraphic boundaries from the base of the Zechstein to the base of Cenozoic in an area of >7,000 km². Construction of a similar harmonized model of the pilot area 2 (border region of Poland and Mecklenburg-Western Pomerania), was finished in M37 (deliverable D2.3b). Merging of both models resulted in an harmonized 3D model of about 14,000 km². It comprises eight horizons, one salt diapir and numerous faults. Most faults penetrate the Mesozoic cover. They often mark graben and halfgrabens. Subordinate, fault sets occur at the base of Zechstein. All methods, harmonization workflows and results were described in the deliverable D2.2. Furthermore, compiling, digitizing and processing of gravimetric data were completed for both pilot areas in order to test its applicability to fine-tune data-poor parts of the models (in cooperation with WP6, see D6.3). A full project description and lessons to be learned were provided in the Final Report (deliverable D2.4, submitted in M40).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	State of the Art	LBGR	Report	PU	M9	Completed	Review completed with Midterm report.
D2.2	Documentation methods, workflows and results	LUNG	Report	PU	M39	Completed	
D2.3a	Harmonized 3D geomodel pilot area 1)	LBGR	3D model	PU	M18	Completed	Review completed with Midterm report.
D2.3b	Harmonized 3D geomodel pilot area 2)	LUNG	3D model	PU	M39	Completed	
D2.4	Final report incl. lessons learned	LUNG	Report	PU	M40	Completed	

Work package 3: North Sea area NL-DE-DK

Work package 3 (WP3) of the GeoERA research project ”3D Geomodeling for Europe (3DGEO-EU)” aims to integrate existing national (and regional) geomodels into a harmonized, consistent cross-border geomodel of the North Sea area between the Netherlands, Germany and Denmark. The Netherlands Organization for Applied Scientific Research (TNO, NL), the Geological Survey of Denmark and Greenland (GEUS, DK) and the Federal Institute for Geosciences and Natural Resources (BGR, GER) are responsible for the cross-border harmonization in this pilot area.
In the second period of the project (Jan 2020-Oct 2021) the following deliverables have been produced:
D3.4: Lithostratigraphic/ chronostratigraphic correlation profiles through the study area.
D3.5: Harmonized seismic stratigraphic concepts - A base for consistent structural interpretations.
D3.6: Harmonized time model of the Entenschnabel region.
D3.7: A harmonized cross-border velocity model.
D3.8: Harmonized depth models and structural framework of the NL-GER-DK North Sea.
D3.9: Final report incl. lessons learned. This report summarizes the results of the WP3 study, discussing the best practices and lessons learned, all leading to recommendations how to generate Pan-European 3D-models.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	State of the art report	TNO/GEUS/BGR	Report	PU	M12	Completed	Review completed with Midterm report.
D3.2	Generalized cross-border 3D depth model of (a part of) the Entenschnabel region	TNO/GEUS/BGR	Digital data (3D depth model) + Supporting document	PU	M10	Completed	Review completed with Midterm report.
D3.3	Harmonized stratigraphic chart for the North Sea area NL-DE-DK	TNO/GEUS/BGR	Report	PU	M18	Completed	Review completed with Midterm report.
D3.4	Lithostratigraphic/ chronostratigraphic correlation profiles through the study area	TNO/GEUS/BGR	Report	PU	M23	Completed	
D3.5	Harmonized seismic stratigraphic concepts - A base for consistent structural interpretations	TNO/GEUS/BGR	Report	PU (confidential until 01.01.2021)	M29	Completed	
D3.6	Summary of the harmonization work on time model for seismic interpreted main horizons incl. main fault planes	TNO/GEUS/BGR	Digital data (3D TWT model) + Report	PU	M35	Completed	

D3.7	Harmonized cross-border velocity model	TNO/GEUS/BGR	Report	PU	M34	Completed	
D3.8	Harmonized structural 3D models	TNO/GEUS/BGR	Digital data (3D depth model) + Report	PU	M39	Completed	
D3.9	Final report incl. lessons learned	TNO/GEUS/BGR	Report	PU	M39	Completed	

Work package 4: Uncertainty in geomodels

During the second half of the project we investigated and discussed where the different uncertainties that are inherent in the large scale geological models from Geological Survey Organizations (GSOs) are coming from, and how they could be quantified. This has been captured in the Deliverable 4.2, the report on the sources of uncertainty. Based on this report, it was possible to narrow down the wide range of available methods for uncertainty visualization that have been described in Deliverable 4.1 – the report on the state of the art in uncertainty visualization – to a smaller set of visualization methods that we really need in order to visualize potential uncertain models coming from GSOs. These requirements of the European Geoscience Date Infrastructure (EGDI) for visualizing regional geological models with uncertainty have been captured in Deliverable 4.3, together with the description of a prototypical implementation that showcases how some basic methods could be implemented by the EGDI 3D viewer using Javascript. Finally an uncertainty analysis has been done for the geological model from Work Package 3 of the 3DGEO-EU project, which can be used in the future to test and showcase methods and implementations. This is provided as Deliverable 4.4.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	State of the art in uncertainty visualization	BGR	Report	PU	M12	Completed	Review completed with Midterm report.
D4.2	Sources of uncertainties in geomodels	BGR	Report	PU	M38	Completed	
D4.3	Uncertainty visualization requirements for EGDI	BGR	Report	PU	M39	Completed	
D4.4	Example data sets/geomodels containing uncertainty information	BGR	Gocad, VTK; including documentation	PU	M39	Completed	

Work package 5: Faults

This work package focusses on consistent cross-border fault mapping- and characterization in the 3DGEO-EU pilot areas and is acting as an interface to the GeoEnergy project HIKE. WP5 communicates the requirements and specifications of the HIKE Fault Database to the 3DGEO-EU modelling work packages. Besides the harmonization work of faults within the pilot areas of WP1-3, the main activity during the second period of the project (Jan 2020-Oct 2021) was the writing of the main report D5.1 titled "Methods, bottlenecks, best practices and accompanying descriptions to faults in 3D models". This report provides a more complete overview of best practices for fault modelling and data management and may act as a reference for future fault modelling projects.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1	Methods, bottlenecks, best practices	LAGB	Report	PU	M36	Completed	

Work package 6: Optimizing reconstructions of the subsurface to reduce structural uncertainty in 3D models

This period has strongly conditioned the WP development. Gravimetric acquisition restarted in March 2020 (we already had about 10% delay caused by early snow in November previous year) and it had to be interrupted again. The severe mobility restrictions and accommodation difficulties during 2020, caused by the COID-19 pandemic, significantly delayed the acquisition of the planned data nearly one year over the expected agenda as well as precluding the accomplishment of key forecasted in-person meetings (with WP2). The complete post-processing and the final Bouguer anomaly map was finalized in April 2021 (expected in June 2020). In addition, other personal problems (force majeure) of part of the IGME staff seriously affected the modeling agenda during 2021. In any case, we were able to fulfill the project agenda and arriving to the expected scientific and technical targets by doing (part of the team) a remarkable personal effort. During 2021, some scientific communications were done as well as the publications of some papers derived from the results from the project.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D6.1	Report on a 3D model of the South western Pyrenees	IGME	Report	PU	M40	Completed	
D6.2	3D model of the South western Pyrenees; digital files	IGME	Digital data	PU	M40	Completed	
D6.3	Report on harmonization procedure with gravmag in East GER/ West Poland border	PGI, LBGR, LUNG, IGME	Report	PU	M40	Completed	
D6.4	Optimized 3D reconstructions workflows	IGME, with all WP6 partners	Report	PU	M40	Completed	

Work package 7: Information Platform Interface

The content of the activities carried out by work package 7 was as expected. The main fields of activity were to organize the communication between the 3DGEO-EU partners and the Geo-Information Platform (GIP) and to manage the data transfer as well as editing the metadata of the data products created by the different WPs. This includes the management of the data testing process (especially 3D-data), the upload of the final 2D/3D-datasets to EGDI and the creation of the corresponding metadata in MIcKA. In addition to the mentioned tasks the deliverable “Data exchange report” (D.7.2) will be completed on schedule. It provides an overview of the geo-data produced by 3DGEO-EU which was published via the GeoERA-Information Platform (GIP) project and some results and conclusions from this process.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D7.1	Technical requirements for project data and results	LAGB	Report	PU	M12	Completed	Review completed with Midterm report.
D7.2	Data exchange report	LAGB	Report	PU	M40	Completed	

Work package 8: Project Management and Coordination

The daily operational management by the Project lead was carried out as planned. That involved, among other things, communication with partners and WP leads, GeoERA Executive Board, Monitoring team and other projects, monitoring of 3DGEO-EU project progress (together with Project Board members), the organization and coordination of face-to-face and virtual meetings, and the final check and approval of all project deliverables and the subsequent upload to the GeoERA Monitoring Share Point. For all Project Board and Project meetings, minutes documents were produced and then stored on the GeoERA 3DGEO-EU Intranet, allowing all partners to keep up to date with project progress.
In the second Project phase, WP8 organized the annual 3DGEO-EU project meeting 2020, the final project meeting 2021 (due to COVID-19 both only virtual meetings) and 20 regular Project Board meetings. The minutes documents from those and other meetings of project wide concern that were staged during the entire project time have been compiled as a confidential deliverable 8.1 “Minutes of meetings”. WP8 also coordinated the contributions of 3DGEO-EU for the GeoERA Webinar series (9 - 13 November, 2020). Furthermore, WP8 completed the Final Project Progress Report (D8.4) and a public summary report (D8.5) with an overview of the work and main results of the project. For more information on project management, see also sheet "7. Project management".

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D8.1	Minutes of meetings	BGR	Document	CO	M1 - M40	Completed	
D8.2	Project Data Management Plan	BGR	Document	PU	M6	Completed	Review completed with Midterm report.

D8.3	Midterm Project Progress Report	BGR	Report	CO	M19	Completed	Review completed with Midterm report.
D8.4	Final Project Progress Report	BGR	Report	CO	M40	Completed	
D8.5	Summary of results	BGR, with contributions of WP leads	Report	PU	M40	Completed	

1.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	

1.7 Communication and dissemination activities

	ABSTRACTS	INTERNAL PROJECT MEETING	LINKEDIN	MEETING WITH OTHER GEOERA PROJECTS	NEWSLETTER	POSTER	SCIENTIFIC PUBLICATION	Total
MEETINGS		26		6				32
ONLINE_MEDIA			2					2
PUBLICATIONS	11				5	5	6	27
Total	**11**	**26**	**2**	**6**	**5**	**5**	**6**	**61**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
MEETINGS	374										374
ONLINE_MEDIA		1600									1600
PUBLICATIONS	4329	1241									5570
Total	**4703**	**2841**									**7544**

1.8 Project management

Monitoring of project progress was carried out together with the Project Board members. An important way of communication with the Project board members were regular monthly Project Board meetings (virtual, at first WebEx, then Skype). The progress of the work packages and the status of upcoming deliverables were reported by the WP leads (or co-leads) during the meetings. Furthermore, the Project Lead informed on and discussed general project issues (e.g. requests from the GeoERA Executive Board, requirements from GIP-P, possibilities to present results in conferences) with the Board members. For each meeting, a minutes document was created and stored on the GeoERA 3DGEO-EU Intranet, allowing all 3DGEO-EU partners to keep up to date with project progress.
Communication between Project Lead and the entire consortium was mainly done with e-mails. Yet, once a year a face-to-face 3DGEO-EU project meeting ("Project Assembly") was intended, with overview presentations of project status and room for discussions among partners and work packages. After having a first project meeting in October 2019 in Hannover (Germany), in the second project phase (M19 – M40) however, due to the COVID-19 pandemic, those meetings had to become virtual meetings: In November 2020 on two days the annual 3DGEO-EU project meeting, and in October 2021 the final project meeting. For all project meetings, the minutes and all presentations were stored on the GeoERA 3DGEO-EU Intranet.
One important activity during the second project phase was to amend the 3DGEO-EU Project Plan twice. The necessary amendments were discussed and prepared during several Project Board meetings over periods of several months, before the project internal voting process could be started to get the approval of the 3DGEO-EU Project Assembly on the suggested amendments of the Project Plan. One main reason for the amendments was the necessity to react to the effects of the COVID-19 pandemic on the project work, which caused significant delays (e.g. due to a lockdown in Spain in the Spring of 2020, planned field activities in the Pyrenees had to be cancelled). The project duration of 3DGEO-EU was thus prolonged by 4 months to M40 (October 2021).
On the level of work packages, the WP leads organized communication between WP partners themselves. Next to mails and phone, WP leads also used virtual meetings and (before COVID-19) face-to-face meetings (work meetings and workshops) for communication and WP coordination.
The cooperation with other GeoERA projects in the second project phase mainly concerned the projects GIP-P and HIKE. The cooperation between 3DGEO-EU and GIP-P and HIKE was organized in WP7 (Interface to GIP-P; following requirements for data delivery) and WP5 (Interface to fault data base of HIKE; delivery of fault data to the database) respectively.

1.9 General description of the cooperation over the duration of the project

The 11 partners of the 3DGEO-EU consortium worked together very well, as they were connected in various combinations as participants of 7 technical work packages (WP), that were partly interlinked. Therefore, the exchange of knowledge, opinion, and data among partners was ensured. All WP leads and co-leads acted as members of the 3DGEO-EU Project Board, thus were involved in decision-making and monitoring of progress. Eight out of eleven project partners were represented in the Project Board.
The areas of jurisdiction for those partner institutions that were involved in cross-border harmonization are related to regions of the Central European Basin System. In addition, a few partner countries are not situated within this area, and therefore those partners (e.g. CGS, IGME) provided valuable contributions to the project, as they brought in experiences from work in different types of sedimentary basins and structural settings. That was a clear benefit of having transnational partners from different European regions.
In the following, the input of each project partner for 3DGEO-EU is briefly described (in an order of increasing participant number):

BGR (project lead) solely executed project management and coordination (WP8) and participated in 5 out of 7 technical work packages. Main participation was for WP3 “North Sea area NL-DE-DK” (Co- lead of WP), where BGR was involved in the preparation of all WP3 deliverables (reports and geomodels); for some as lead participant. Furthermore, BGR had the lead for WP4 “Uncertainty in geomodels” and was lead participant for all WP4 deliverables. In addition, BGR was also involved in a lesser scale to WP5, WP6, and WP7 and contributed to the WP5 deliverable report.
CGS participated in WP 4 “Uncertainty in geomodels” and contributed e.g. as authors for the D4.2 deliverable report. The participation of CGS was important, because the involved geologists from CGS could bring in experiences from dealing with uncertainties in different types of sedimentary basins and structural settings, comparing to the cross-border pilot areas of WP1-3.
GEUS participated in 4 out of 7 technical work packages. Main participation was for WP3 “North Sea area NL-DE-DK” (Co- lead of WP), where GEUS was involved in the preparation of all WP3 deliverables (reports and geomodels); for some as lead participant. Furthermore, GEUS was also involved in a lesser scale to WP4, WP5, and WP7.
LBGR participated in 4 out of 7 technical work packages. Main participation was for WP2 “Cross-border harmonization of selected horizons and structures in the Polish-German border region” (Main lead in 1st project phase), where LBGR was lead participant for two WP2 deliverables (a report and a harmonized 3D geomodel for WP2 pilot area 1). Furthermore, LBGR was also involved in a lesser scale to WP4, WP5, and WP6, and contributed to the WP5 deliverable report and to the D6.3 report.
LUNG participated in 4 out of 7 technical work packages. Main participation was for WP2 (Main lead in 2nd project phase), where LUNG was lead participant for three WP2 deliverables (two reports and a harmonized 3D geomodel for WP2 pilot area 2). Also, LUNG provided a harmonized overall model for WP2 pilot areas 1 and 2. Furthermore, LUNG was involved in a lesser scale to WP4, WP5, and WP6, and contributed to the WP5 deliverable report and to the D6.3 report.
LBEG had the lead for WP1 “Harmonization of Cenozoic and Mesozoic layers in the northern onshore Dutch-German cross-border region for assessment of underground usage”, where LBEG was involved in the preparation of all five WP1 deliverables (reports, geomodel, maps); for four as lead participant.
LAGB participated in 4 out of 7 technical work packages. It had the lead for WP7 “Information Platform Interface” and was lead participant for the two WP7 deliverables. LAGB had also a prominent role in WP5 “Faults”, as it was lead participant for the comprehensive WP5 report. Furthermore LAGB was involved in WP4 and WP6, and contributed to the D4.2 report and to the D6.4 report.
TNO participated in 4 out of 7 technical work packages. Main participation was for WP3 “North Sea area NL-DE-DK” (lead of WP), where TNO was involved in the preparation of all deliverables (reports and geomodels); for some as lead participant. TNO had also the lead for WP5 “Faults” and was involved in the preparation of the WP5 deliverable report. Furthermore, TNO was one of two partners in WP1, where TNO was involved in the preparation of WP1 deliverables; one as lead participant (geomodel). TNO was also involved in WP4 and contributed to the D4.2 report.
PGI participated in 5 out of 7 technical work packages. Main participation was for WP2, where PGI was involved in the preparation of all WP2 deliverables (reports and geomodels). Furthermore, PGI was involved in a lesser scale to WP4, WP5, WP6, and WP7, and contributed to the WP5 deliverable report and to the D6.3 report.
IGME participated in 5 out of 7 technical work packages. Main participation was for WP6 “Optimizing reconstructions of the subsurface to reduce structural uncertainty in 3D models” (lead of WP), where IGME was lead participant for all WP6 deliverables (reports, geomodel, maps). Furthermore, IGME was involved in a lesser scale to WP2, WP4, WP5, and WP7, and contributed to the D4.2 report and to the WP5 deliverable report. Also, IGME brought in experiences from working in different types of sedimentary basins and structural settings, comparing to the cross-border pilot areas of WP1-3.
GEOINFORM had a small participation (0,605 person months in total) in 3 out of 7 technical work packages (WP4, WP5, WP6), and provided feedback to specific topics of those WPs.

Finally, all WPs and thus most project partners contributed to the general D8.5 summary of results report.

1.10 Impact statement

The Project lead has completed the online impact questionnaire on 30.10.2021.

1.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontractiong	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. BGR	592.136,35	343,10	0,00	148.119,86	740.599,31	29,70%	219.958,00	520.641,32
2. CGS	4.620,92	0,00	0,00	1.155,23	5.776,15	29,70%	1.715,52	4.060,63
3. GEUS	183.445,35	1.158,50	0,00	46.150,96	230.754,81	29,70%	68.534,18	162.220,63
4. LBGR	58.271,36	0,00	0,00	14.567,84	72.839,20	29,70%	21.633,24	51.205,96
5. LUNG	141.605,83	11.414,71	0,00	38.255,14	191.275,68	29,70%	56.808,88	134.466,80
6. LBEG	356.193,48	319,68	0,00	89.128,29	445.641,45	29,70%	132.355,51	313.285,94
7. LAGB	168.868,58	22.500,57	0,00	47.842,29	239.211,44	29,70%	71.045,80	168.165,64
8. TNO	92.544,22	103,68	0,00	23.161,98	115.809,88	29,70%	34.395,53	81.414,34
9. PIG-PIB	85.718,82	0,00	0,00	21.429,71	107.148,53	29,70%	31.823,11	75.325,41
10. IGME-Sp	157.687,29	14.791,85	8.877,06	43.119,79	224.475,99	29,70%	66.669,37	157.806,62
11. GEOINFORM	1.739,64	0,00	0,00	434,91	2.174,55	29,70%	645,84	1.528,71
					2.375.706,98		705.584,97	1.670.122,01

Date:	19.11.2021
Person responsible:	Stefan Knopf

2 PROJECT EUROLITHOS

2.1 Identification of the project

Project full title:	European Ornamental Stone Resources
Project acronym:	EuroLithos
Project reference number:	GeoE.171.017
Project topic:	Raw materials
Project specific recearch topic:	RM2 – CONSTRUCTION MATERIAL
Project website address:	www.eurolithos.org
Period covered from:	01.01.2020 to: 31.10.2021
Report submission date:	19.11.2021
Project coordinator:	Tom Heldal
Contact person for the project:	Tom Heldal
Tel:	4799091739
E-mail:	tom.heldal@ngu.no

2.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	NORGES GEOLOGISKE UNDERSØKELSE	Geological Survey of Norway	NGU	Norway	999466758	Project Lead
2	LABORATORIO NACIONAL DE ENERGIA E GEOLOGIA I.P	The National Laboratory of Energy and Geology	LNEG	Portugal	994187921	Project Partner
3	Sveriges Geologiska Undersökning	Geological Survey of Sweden	SGU	Sweden	995575991	Project Partner
4	*Instituto Geológico y Minero de Espana*	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
5	Institouto Geologikon kai Metalleftikon Erevnon	Institute of Geology and Mineral Exploration	IGME-Gr	Greece	925968015	Project Partner
6	Regione Emilia Romagna (Servizio Geologico, Sismico e dei Suoli della Regione Emilia Romagna)	Geological, seismic and soil survey, Emilia Romagna Region	SGSS	Italy	999482375	Project Partner
7	Regione Toscana	Regional geological survey	RT	Italy	998823842	Project Partner
8	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
9	Geologische Bundesanstalt	Geological Survey of Austria	GBA	Austria	998164145	Project Partner
10	Institutul Geologic al României	Geological Institute of Romania	IGR	Romania	998906874	Project Partner
11	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner

12	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner
13	Istituto Superiore per la Protezione e la Ricerca Ambientale	Italian Institute for Environmental Protection and Research	ISPRA	Italy	997905349	Project Partner
14	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
15	Ministry of Agriculture, Natural Resources and Environment of Cyprus	Cyprus Geological Survey Department	GSD	Cyprus	999434845	Project Partner
16	Administration Des Ponts et Chaussees Direction; Service Géologique du Luxembourg	National geological survey	SGL	Luxemburg	983408408	Project Partner

2.3 Publishable summary

Ornamental stone is today a raw material produced with great skills all over Europe, SME's and larger enterprises exploiting the vast diversity of European natural stone resources. Today's European stone industry is not only large and important but also highly dispersed throughout Europe, making a backbone industry for particularly rural areas. In Italy alone, there are more than 1000 stone quarrying enterprises and the sector in total employed more than 50 000 in 2011.
Ornamental stone has contributed significantly in shaping our rural and urban landscapes, through its use in our built heritage from different historical periods. Ornamental stone is today a raw material produced with great skills all over Europe, exploiting the vast diversity of European natural stone resources. Yet, the actual use of local and regional stone resources in Europe is decreasing, and so is the knowledge of the resources, traditions and skills. However, the need for sustainable building materials has once again put ornamental stone on the front page; stone production demands less energy and causes less carbon footprints than many other non-organic construction materials.
EuroLithos is founded on the idea that increased knowledge of the geology, quality and history of use of natural stone in Europe will stimulate both more sustainable use of stone resources in Europe for the benefit of SME's and our cultural heritage, and a sound land use management for the safeguarding of ornamental stone deposits.
Yet, such information has until now been scattered, diverse and not harmonised, and did not exist at a European level.

Objectives and results
In the context of the GeoEra partnership, the best way of contributing to meet this challenge is a ornamental stone information platform, providing documentation, databases and recommendations covering the most important aspects of natural stone resources in Europe; partly, by feeding existing solutions, and partly by adding new ones. Or, said with simpler words, put the ornamental stone resources on the map.
This main challenge was broken down to a series of objectives
1) Identify and define: a descriptive framework for natural stone resources in Europe;
Partner countries have together, and under the lead of WP3 and WP4, agreed upon and developed a common terminology and data framework on how to describe stone resources in a harmonized way (D3.1, D3.2, D4.2, D6.2, and project vocabulary).
2) Collect and characterize: following the framework, carry out an inventory of natural stone resources in partner countries;
All the partner countries have done an inventory of their resources and characterized key properties related to them, such as unique name(s), commodity type, lithology, colour and denomination of origin. A total of 1219 unique stone resources / resource areas were characterized and harmonized in this way, and displayed on a particular map on EGDI.
3) Make an atlas: template and trial versions for a geological atlas on natural stone on a European and country level linked to databases and directories

The results in Objective 2 is a significant part of the atlas, where the spatial data are linked to more detailed information (directory). In addition, country atlases in a printable pdf-format have been compiled; representative coverage for 5 countries, partial coverage for 1 country and coverage for one region. The template for country atlases was given in D3.3. This deliverable also contains the link to country atlases.

4) Make a directory: database of stones and their properties

When the format and template of the directory was agreed upon among the partners (WP4), the partners (those who had enough budget in the project) started making the directories of their own countries. It was decided to make the directory as standardized reports uploaded to EGDI in pdf-format as non-structured data. It was considered to make a structured version database, but a) there are no good and approved standards for interoperable data regarding much of these data, b) the timeline of the project was not sufficient for developing such. More than 300 such directory reports were uploaded to EGDI and linked to atlas/inventory. These are easily accessed from the inventory map.

5) Identify heritage values: producing guidelines for assessing heritage values to natural stone

Ornamental stone resources and their safeguarding for the future do not only depend on their present economical value. In a part of the world with more than 4000 years of stone quarrying and use, such resources may be associated with a complicated mix of values to society, including architectural, archaeological and historical, on different scales. Thus, Eurolithos tried to explore such non-economic values through a series of case studies, and make a concentrated guideline as a tool for local, regional and national authorities needing to view such resources in a more holistic way than just economy. D5.2 – D5.4 is the guidelines, containing internal links to case studies.

6) Communicate and collaborate: stakeholder interaction and communication, building networks for continuation

Eurolithos has had fairly good interaction with some stakeholders, including national stone federations, stone companies, some national building authorities and some heritage authorities. The project still needs more interaction with European level stakeholders. One experience is that it is difficult to get a good general and high-level stakeholder interaction when there is a project in progress, much easier to communicate good results. Thus, NGU will guaranty to keep updates and network alive for at least five years after GeoEra closure.

7) Integrate and distribute: harmonize and provide data to the forthcoming solutions provided by RM1 and IP1

Although many needs of adjusting INSPIRE standards were promoted in the project, the time frame did not make that possible. However, there has been revealed serious weaknesses in the INSPIRE, for instance that same codes appear in different codelists with different definitions. This created much problems in the project. Within this difficult framework, Eurolithos has manuevered within the existing framework and harmonized as far as possible.

8) Promote and disseminate: promoting natural stone information platform to stakeholders

Eurolithos has promoted results and “stories” on several platforms: web-site, newsletter, facebook and twitter. In addition, contributing to the “did you know’s” on the geoera platform, and participating in related meetings, conferences and congresses.

9) Maintenance and continuation: secure long-term life and growth of EuroLithos solutions

The future of Eurolithos data depends on a) national delivery to harvesting system in Min4EU, b) uploading of “ID-cards” reports to EGDI, and c) maintaining inventory map with new data and links to b). The national delivery to Min4EU will evolve to better and better solutions, covering the partner countries and others that will participate. This action will continue after GeoEra. Uploading “ID-cards” has been established as a decentralized system (each country), and it is easy to continue for the partner countries, and almost as easy for new countries, since the uploading procedure is described in D4.2. For the inventory map, NGU will take the responsibility for five years to provide at least annual updates.

2.4 Project contribution to GeoERA project

EuroLithos addresses several aspects of the RM2 scope. Below, we have summarized the scopes, Eurolithos response, and results so far:

1) Develop inventories in conjunction with the Information Platform: Propose and deliver contribution to the IP central database, web-portal and digital archive, propose and deliver standardized spatial information tailored for Natural Stone resources to the EGDI.

Results: Eurolithos has delivered 1219 unique European ornamental stone resources in partner countries with basic characteristics in shape of a map to EGDI

2) Information of Europe's exploitation sites and prospective areas of ornamental stone deposits and provide a visualization which can be used for land-use planning: Country and regional case studies addressing one or several: spatial distribution of geological units of importance for natural stone production (provinces), quarries and quality, use and heritage. Close liaison with H2020 projects MINATURA2020 and MinLand.

Results: Spatial distribution of ornamental stone resources will partly be available through Min4EU, partly by Eurolithos directory (non-structured delineation of resources).

3) Explore the applicability and interoperability of standard codes among partners for harmonised reporting of resources: Natural stone will be addressed as a case study in the RM1 WP UNFC. EuroLithos will provide an assessment of codes and propose a G-axis coding for UNFC. Results so far: Case study on UNFC will be ready M24 under the Mintel4EU project.

Results: Eurolithos has delivered a case study to the Mintell4EU project on UNFC (D6.3).

4) Ensure data coherence within a given raw material and among GeoERA partner countries: From EN standards and INSPIRE, demonstrate the adaptability of classification and standards and provide guideline for data description and coherence for natural stone.

Results: In EuroLithos, se have evaluated the existing INPIRE standards, and conclude that they are not satisfactory nor in harmony with EN12440. We will adapt to existing standards on the short term, provide proposals of change and a guideline for translating data.

5) Provide appropriate input to SRT RM1: Assess and provide guideline for input of spatial data, and demonstrate through data delivery for selected partner countries.

Results: deliveries to EGDI has been provided with guidelines.

6) Provide advice on how forecasting for the demand of these materials can be improved so that policy formulation and government resource management can be enhanced and capital investment by industry can be prioritised:

Results: For natural stone, such generic forecast studies will have little impact. EuroLithos will instead provide advice on how government authorities can improve their resource management through collaboration through a more holistic vie, i.e. for improving both heritage management and SME conditions. In EuroLithos, we have provided guidelines on how to valorize and evaluate non-economic values.

7) Provide readily accessible information and easy to use decision making tools for the public and local authorities, respectively.

Results: Providing guidelines and best practices for different aspects of importance to natural stone management, and provide easy accessible and readable atlases aimed at raising the interest and awareness of natural stone production, history and use.

2.5 Work progress and achievements during the period

Work package 1: Project Management

WP 1 has two main tasks: T1.1 project consortium meetings, and T1.2 Management and reporting. In addition to the kick-off meeting, consortium meeting was held early M13, according to plan. D1.1, D1.2 and D1.3 were delivered according to plan. Project midterm review meeting was completed M21. Following project assemblies were held M27 and M38.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Cumulative expenditures report 1	NGU	Report	Administrative	M6	Completed	Review completed with Midterm report.
D1.2	Project progress report	NGU	Report	Administrative	M18	Completed	Review completed with Midterm report.
D1.3	Cumulative expenditures report 2	NGU	Report	Administrative	M18	Completed	Review completed with Midterm report.
D1.4	Project review meeting presentation 1	NGU	Presentation	Administrative	M21	Completed	Review completed with Midterm report.
D1.5	Cumulative expenditures report 3	NGU	Report	Administrative	M24	Completed	
D1.6	Final project progress report	NGU	Report	Administrative	M40	Completed	
D1.7	Project review meeting presentation 2	NGU	Presentation	Administrative	M39	Completed	

Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M1	Kick-off meeting	M1	Completed	Review completed with Midterm report.
M4	Annual meeting 2019	M12	Completed	Review completed with Midterm report.
M6	Annual meeting 2020	M24	Completed	minutes
M8	Results available through GeoEra platform	M40	Completed	Availability
M9	Final meeting	M40	Completed	minutes
M10	Scientific publication	M43	Pending	

Work package 2: Dissemination and communication

Eurolithos has been active on our website (www.eurolithos.org), facebook and twitter. Social media reached clearly more people than the web, facebook c. 3000 visitors. Facebook and twitter shows clear peaks when new products were published, the latter varying from 20 to 550.
We emailed five issues of Eurolithos Newsletter to our 44 partners plus associates and 140 stakeholders. We plan to send one more when our scientific volume is published. Several public institutions, interest

groups and enterprises reposted our newsletter on their web and social media platforms. We will make a specific, EuroLithos volume of papers by the end of the project, as a part of Geological Survey of Norway Bulletin series.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	Project web site	NGU	website	general	M9	Completed	Review completed with Midterm report.
D2.2	Stakeholder Newsletter	NGU	newsletters	general	M40	Completed	Review completed with Midterm report.
D2.3	Printed atlases	NGU	booklets	general	M40	Completed	As pdf
D2.4	Scientific volume	NGU	book	scientific	M43	Pending	Drafts delivered

Work package 3: Atlas of European Ornamental Stones

The goal of WP3 is to develop a first edition of an Atlas of European Ornamental Stones and to integrate this into the GeoEra Information Platform. The Atlas will identify, collect and harmonize existing available data on the provenance of European Ornamental Stone resources. Focus will be on the geology, available resources, prospective areas, quarrying sites and competing land uses. D3.1, D3.2 and D3.3 have been completed. Country atlases were completed for Portugal, Greece, Slovenia, Norway, Cyprus, Italy and the region Emilia-Romagna. In addition, and integrated product (WP3 and WP4) was compiled, a map of unique stone types in the partner countries. The map contain basic information about denomination, origin, commodity, lithology and link to directory in WP4. There are 1219 entries on the map. The map will be uploaded regularly and NGU will take the responsibility next five years.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	Framework for the Atlas	LNEG	Report	Professional	M12	Completed	Review completed with Midterm report.
D3.2	Country and European-level Atlas templates	LNEG	Report	Professional	M27	Completed	
D3.3	Country-level atlases	LNEG	Publication	General	M40	Completed	

Milestone no.	Milestone name	Delivery date from Contract	Progress	Means of verification
M3	Requirements for the IP	M9	Completed	Review completed with Midterm report.
M5	Prototype portal	M32	Completed	
M7	Case studies completed	M32	Completed	

Work package 4: Directory of Ornamental stone properties

The main objective of this WP is to develop a European "identity card" for ornamental stone, providing basic information regarding their composition, physical properties and "performance in use" criteria. The "identity card" will form the core of a European directory (or database) of ornamental stone properties. D4.1 discussed the content of the directory and the use of technical information and standards. D4.2 Provided template for directory with guidelines for uploading those. Approx. 350 directory reports have been uploaded to EGDI by partners. They are all available from map link (unique stone map, WP3).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Working version of the directory containing information from selected countries	HSGME	Database	Professional	M40	Completed	
D4.2	Guideline for using the Directory	HSGME	Guideline	General	M40	Completed	350 directories uploaded

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M3	Requirements for the IP	M9	Completed	Review completed with Midterm report.
M5	Prototype portal	M32	Completed	
M7	Case studies completed	M32	Completed	

Work package 5: Ornamental stone heritage

Work package 5 aims at establishing tools to assess the non-economic value of dimensional stone resources. This will contribute to better maintenance of stone-built heritage, better conditions for SME's and better protection of stone resources in land-use planning. The work will address three aspects of stone heritage: the intrinsic value of stone quarries and quarry landscapes, the value of stones from their use in stone-built heritage, and the traditional crafts. The core of the work package is a selection of case

studies illustrating best practice, and a finally guidelines for improving practices. D5.1 gave and overview of case studies. In the project proposal, 6 case studies were planned. D5.1 describes 12, whilst 9 were completed, thus achieving some more than demanded. D5.2, D5.3 and D5.4 were compiled in one document.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1	Case study collection	HGI-CSG	Report	Professional	M18	Completed	
D5.2	Best practices and guideline: How to assess values of stone types, quarries and quarry landscapes	HGI-CSG	Guideline	General	M40	Completed	
D5.3	Best practices and guideline: How to do inventories of links between stone resources and built heritage	HGI-CSG	Guideline	General	M40	Completed	
D5.4	Best practices and guideline: how to approach crafts for value assessments	HGI-CSG	Guideline	General	M40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M2	Case studies selected	M3		
M3	Requirements for IP	M9	Completed	Review completed with Midterm report.
M5	Prototype portal	M32		
M7	Case studies completed	M24		

Work package 6: Link to information platform

This work package (WP6) will secure the integration of the information structure generated by EuroLithos with the Information Platform (IP). Specifically, WP6 will identify and discuss requirements in close dialogue with the IP team and ensure that the principles and guidelines provided by the IP-project is followed and implemented. Finally, WP6 will assess the use of UNFC geology axis for ornamental stone resource classification. Requirements for IP were compiled in D6.1, and UNFC study in D6.3. D6.2 was not finished; the purpose of this was primarily to test better harvesting of ornamental stone data from national databases. This process has been delayed in GeoEra in total, and the possibility for testing from NGU databases has just opened and will be carried out in December. Another issue is unsolvable INSPIRE

problems, i.e. the existence of similar names with different definitions in the INSPIRE codelists. For example, “granite” means commodity all hard rocks in one codelist, and correct lithological definition in another. Consequently, data structure as given in the project vocabulary could not be used. A revision of the min4EU harvesting model with “dimension-stone” as separate commodity group was accepted and fulfilled.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D6.1	Definitions and requirements for the IP	NGU	Report	Professional	M9	Completed	
D6.2	Evaluation of IP prototypes	NGU	Report	Professional	M32	In delay	see text
D6.3	Application of UNFC for ornamental stone resources	NGU	Report	Professional	M29	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M3	Requirements for IP	M6	Completed	Review completed with Midterm report.

2.6 Deviations

Has the project partnership identify any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	
Withdrawal of Partner Regione Toscana RT	Part of budget transferred to GSD	No	Small change to budget corrected and approved in amendment 1
Delay of deliverables: D2.1 Website from M6-M9	Change of web platform	No	
Delay of deliverables: D2.2 Newsletter from M6-M9	All 6 newsletter will be measured as 1 deliverable M36	No	
Delay of deliverables: D6.1 from M6-M9	The original deadline was not realistic	No	
Milestone M3 reached M12	None, case studies were due to start M12	No	3 more case studies than originally proposed, but no change to workplan
D6.2 delayed/not fullfilled	None, it was not possible to do this work before this autumn, therefore one went straight to final harvesting per nation.	No	

2.7 Communication and dissemination activities

	ABSTRACTS	CONGRESS	FACEBOOK	INTERNAL PROJECT MEETING	MAGAZINE	MEETING	MEETING WITH OTHER GEOERA PROJECTS	MEETING WITH OTHER PROJECTS	NEWSLETTER	NON SCIENTIFIC PUBLICATION	OTHER	POSTER	RADIO, TV	SCIENTIFIC PUBLICATION	SEMINAR	TWITER	WEBINAR	WEBSITE	WORKSHOP	YOUTUBE	Total
EVENTS		11													3		3		2		19
MEDIA					1								2								3
MEETINGS				7		6	6	1			2										22
ONLINE_MEDIA			5								1					2		13		1	22
PUBLICATIONS	1								5	10	1	2		11							30
Total	**1**	**11**	**5**	**7**	**1**	**6**	**6**	**1**	**5**	**10**	**4**	**2**	**2**	**11**	**3**	**2**	**3**	**13**	**2**	**1**	**96**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	51750	535	110	10	32	23	64	2	510		53036
MEDIA		265000									265000
MEETINGS	429	6			1	55	1	1	4	6	503
ONLINE_MEDIA	10320	15615	950	910	1010		300		900	21000	51005
PUBLICATIONS	10650	4650	1000	970	1090	190	50	100	1000	100	19800
Total	**73149**	**285806**	**2060**	**1890**	**2133**	**268**	**415**	**103**	**2414**	**21106**	**389344**

2.8 Project management

Meetings: Three regular project meetings in the project have been arranged until M18: Kick-off in Brussels (M1), workshop in Athens (M9) and Project Assembly meeting in Trondheim (M13). After that there has been digital consortium meetings autumn 2020 and 2021. Thematic workshops and WP Lead meetings are additional and have been arranged ad hoc when needed.
Collaboration between WP3, WP4 and WP 6 became more inter-connected and close than anticipated (more difficult to distinguish activities from each other). However, we see this as a positive aspect resulting in a connected webmap of unique stone types and directory.
Collaboration with other GeoERA projects: there have been weekly meetings since covid started in the RM theme (project leads and theme coordinator). This has resulted in updated communication
Use of budget: approximately 100% of the adjusted budget has been spent.
Amendments: Regione Toscana withdrew from the GeoERA consortium. The (small amount of) funding was transferred to GSD, as given in amendment 1. Deliverable 2.1, 2.2 and 6.1 where three months late, and changes/explanations are given in amendment 2.

2.9 General description of the cooperation over the duration of the project

Some partners have only a small amount of the budget, others more. The least expected contribution for the partners has been delivery of key data on their country's ornamental stone data, set in a harmonized way. All partners have fulfilled this work. For more well-funded partners, more was expected, such as directory of unique stone resources, national atlases and case studies. We consider also this to have worked well, and that contributions from partners align well with budget spent.
Best achievements of the collaboration: The perhaps most valuable result of this project is not the actual deliverables, but the products resulting from them. We will emphasize the Ornamental stone map, with 1219 unique stone types from the partner countries, and 375 integrated links to directory reports. All partners have made a great work for compiling this map. Some partners (those who had budget for it) did great efforts in compiling all these directory reports. This work required much internal standardization in the project, and all partners contributed constructively. Other good achievements are case studies, enlightening different aspects of ornamental stone resources in different countries, and 7 atlases. Both case studies and atlases will evolve to a published special scientific volume.
Challenges: one challenge has been the discussion about standards, content of datainfrastructure and liaison with other GeoEra projects became more time-demanding than anticipated, and it also revealed unsolvable INSPIRE problems with consequences for ornamental stone. Covid19 has of course affected the project as the rest of the society, most of all reducing "togetherness" and "horizontal" thinking and networking. It has also reduced the active collaboration with stakeholders and put limits on fieldwork for case studies.

2.10 Impact statement

"Improved 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":
Eurolithos has developed a common platform for sharing knowledge in a harmonized way across Europe. The combination of min4EU harvesting from national databases, the unique stone maps and the directory collectively make the start of a system that can continue to grow after the project end. Partners and other countries can continue to upload stone type "ID-cards" to the directory, or upload new versions without loosing links. NGU will regularly upgrade and republish map for at least the next five years. We believe this is the first real attempt of creating a solid knowledge platform on ornamental stone.

“Contribution to environmental friendly raw materials production”: by providing the information infrastructure on ornamental stone, Eurolithos will hopefully stimulate more use of locally/regionally sourced stone in a European market. The highest CO2 emissions regarding stone is related to transport, and future regulations will necessarily turn more focus towards European sources. We believe that Eurolithos came at the right time, and that this knowledge platform will continue to grow and become more and more used. Eurolithos also provides tools in the shape of guidelines that can be applied for better and more sustainable management of such resources.
“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”: Eurolithos is the start of a comprehensive knowledge system, containing key information about traditional stone types, also those of mostly historical interest, and will so far represent the best tool for this sector. The guidelines and case studies will also be of help.

2.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontracting	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. NGU Norway / Project Lead	88.746,88	2.978,27	0,00	22.931,29	114.656,44	29,70%	34.052,96	80.603,48
2. LNEP Portugal	40.789,97	1.014,00	0,00	10.450,99	52.254,96	29,70%	15.519,72	36.735,24
3. SGU Sweden	10.965,76	0,00	0,00	2.741,44	13.707,20	29,70%	4.071,04	9.636,16
4. IGME Spain	29.748,52	9.216,95	0,00	9.741,37	48.706,83	29,70%	14.465,93	34.240,90
5. HSGME Greece	51.985,86	0,00	0,00	12.996,47	64.982,33	29,70%	19.299,75	45.682,57
6.SGSS Italy	11.599,58	5.319,03	0,00	4.229,65	21.148,26	29,70%	6.281,03	14.867,23
7. GeoZS Slovenia	32.084,84	0,00	0,00	8.021,21	40.106,04	29,70%	11.911,50	28.194,55
8. GBA Austria	26.202,00	0,00	0,00	6.550,50	32.752,50	29,70%	9.727,49	23.025,01
9. IGR Romania	23.684,36	91,48	0,00	5.943,96	29.719,80	29,70%	8.826,78	20.893,02
10. SRDE-GeoInform Ukraine	17.420,51	0,00	0,00	4.355,13	21.775,64	29,70%	6.467,36	15.308,27
11. GSI Ireland	63.681,20	0,00	0,00	15.920,30	79.601,50	29,70%	23.641,65	55.959,85
12. ISPRA Italy	23.094,42	0,00	0,00	5.773,61	28.868,03	29,70%	8.573,80	20.294,22
13. HGI-CGS Croatia	57.114,42	0,00	0,00	14.278,61	71.393,03	29,70%	21.203,73	50.189,30
14. GSD Cyprus	28.424,00	0,00	0,00	7.106,00	35.530,00	29,70%	10.552,41	24.977,59
15. SGL Luxembourg	2.275,00	0,00	0,00	568,75	2.843,75	29,70%	844,59	1.999,16
	507.817,32	**18.619,73**	**0,00**	**131.609,26**	**658.046,31**		**195.439,75**	**462.606,55**

Date:	30.11.2021
Person responsible:	Tom Heldal

3 PROJECT FRAME

3.1 Identification of the project

Project full title:	Forecasting and Assessing Europe's Strategic Raw Materials needs
Project acronym:	FRAME
Project reference number:	GeoE.171.010
Project topic:	Raw materials
Project specific research topic:	RM4 – FORECASTING AND ASSESSING EUROPE'S STRATEGIC RAW MATERIALS NEEDS
Project website address:	http://geoera.eu/projects/frame/
Period covered from:	01.01.2020 to: 31.10.2021
Report submission date:	12.11.2021
Project coordinator:	Daniel de Oliveira
Contact person for the project:	Daniel de Oliveira
Tel:	+351 21 092 4618
E-mail:	daniel.oliveira@lneg.pt

3.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Laboratorio Nacional de Energia e Geologia I.P.	The National Laboratory of Energy and Geology	LNEG	Portugal	994187921	Project Lead
2	Bundesanstalt für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Partner
3	Bureau de Recherches Géologiques et Minières	The French Geological Survey	BRGM	France	999993662	Project Partner
4	Ceska Geologicka Sluzba	Czech Geological Survey	CGS	Czech Republic	999546783	Project Partner
5	Eesti Geoloogiakeskus (non-funded partner)	Geological Survey of Estonia	EGT	Estonia	996572763	Non-funded partner
6	Sveriges Geologiska Undersökning	Geological Survey of Sweden	SGU	Sweden	995575991	Project Partner
7	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner
8	Geologian Tutkimuskeskus	Geological Survey of Finland	GTK	Finland	999432614	Project Partner
9	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
10	Institouto Geologikon kai Metalleftikon Erevnon	Institute of Geology and Mineral Exploration	IGME-Gr	Greece	925968015	Project Partner
11	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
12	Magyar Bányászati és Földtani Szolgálat	Mining and Geological Survey of Hungary	MBFSZ	Hungary	967592364	Project Partner
13	Norges Geologiske undersokelse	Geological Survey of Norway	NGU	Norway	999466758	Project Partner

14	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	Polish Geological Insitute	PIG-PIB	Poland	999492463	Project Partner
15	Institut Royal des Sciences Natueelles de Belgique	Geological Survey of Belgium – Royal Belgian Institute of Natural Sciences	RBINS-GSB	Belgium	998437006	Project Partner
16	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	Geoinform	Ukraine	947331392	Project Partner
17	Institutul Geologic al României	Geological Institute of Romania	IGR	Romania	998906874	Project Partner
18	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
19	Istituto Superiore per la Protezione e la Ricerca Ambientale	Italian Institute for Environmental Protection and Research	ISPRA	Italy	997905349	Project Partner
20	Geologische Bundesanstalt	Geological Survey of Austria	GBA	Austria	998164145	Project Partner

3.3 Publishable summary

Introduction - Europe shows an inevitably growing and accelerating consumption of mineral commodities. Presently, the question whether supply to meet these demands is adequate or not, cannot be answered with any certainty because secure supply is a matter of knowing the resources and the ability to exploit them with respect to sustainability.

It is well established and broadly accepted by now that non-energy minerals underpin our modern economy. They are essential for manufacturing and renewable “green” energy supply. Most of the environmental technologies and applications (e.g. wind turbines, photovoltaic cells, electric and hybrid vehicles) allowing energy production from renewable resources will use, so called, high-tech metals (e.g. Rare Earth Elements (REE), Platinum Group Elements (PGE), niobium, lithium, cobalt, indium, gallium, vanadium, tellurium, selenium) that were derived or refined from minerals, which Europe is strongly import dependent on. More specific, industrial trends, particularly clean and carbon-reducing technologies, are disrupting traditional metal sectors, with a robust drive in the development of battery-raw material metals. We need to calculate the volumes of critical and potentially strategic metals (e.g. cobalt, niobium, vanadium, antimony, PGE and REE) and minerals that are currently not extracted in Europe. We further need to understand how high-tech elements are mobilised, where they occur and why some are associated with specific major industrial metals.

The high import dependence of strategic (STR) and critical raw materials (CRM) has a serious impact on the sustainability of the EU manufacturing industry. This problem can only be solved by more intense and advanced exploration for new mineral deposits on land and the marine environment. Seafloor mineral resources receive growing European interest with respect to the exploration potential of REE, cobalt, selenium, tellurium and other high-tech metals.

Many critical minerals and metals may be collected through recycling of mining related waste materials. However, even with the important contribution from recycling to secure resource efficient supply it will still be necessary to extract primary mineral deposits, focusing on applying new technologies for deep exploration and mining, turning low- grade ores to exploitable resources and reducing generation of mining wastes and large tailings by converting them to exploitable resources and solving environmental footprint and land-use challenges.

As well as the dependence on extra-EU supply concerns, the production of many materials is reliant on a few countries. This concentration of supply also poses concern as these few countries dominate supply of individual or several materials: Brazil (niobium), USA (beryllium), South Africa (platinum), DRC (cobalt) and China (REE, antimony, magnesium, and tungsten). Twenty countries are the largest suppliers of the CRM contributing with 90% of supply. All major suppliers of the individual critical raw materials fall within this group of twenty countries. At the same time all are predicted to experience demand growth, with

lithium, niobium, gallium and heavy rare earth element forecast to have the strongest rates of demand growth, exceeding 8% per year for the rest of the decade. In addition, Russia is known to have an active programme on materials stockpiles and export restrictions, China has from time to time tightened the export quotas for REE ostensibly to secure internal supply, and the US has long had a stockpile for strategic defense materials.

There is a need on exploration focus by challenging more effective CRM exploration and better understanding of their metallogenetic setting and mineral potential. Discovery of new STR and CRM resources needs enhanced information on surface and subsurface geology, new concepts of mineral resource potential, particularly in underexplored areas of limited geological knowledge and projects facilitating the need to span the geosciences and be truly multidisciplinary. The question about "where are undiscovered critical mineral resources likely to exist, and how much undiscovered mineral resource may be present" needs to be answered. All of the processes involved in the formation of a CRM deposit type, a good understanding of why CRM mineral deposits occur where they do, ore exploration models and resource assessment studies, make significant steps to be taken. Irrespective of the CRM exploration potential level, better understanding of the geology and metallogeny, and delivery of high-quality CRM maps may lead to new or little-known types of CRM ore deposits and ore-forming systems. In addition, future CRM exploration will likely need to focus increasingly on blind deposits. The European Union has recognized these challenges and has reacted since 2008 with its Raw Materials Initiative, following Communications (COM(2008) 699 final; COM(2011) 25 final;) and the List of Critical Raw materials. Many National Geological Surveys have supported the European Commission in identifying potential bottlenecks on CRM as well as providing information how to overcome physical shortages. However, all these activities are punctual, on individual basis and hence, not lasting. The rationale of FRAME can be outlined as follows:

Unlike "more common metals" such as copper, zinc, lead and iron, many CRM do not form the main commodity (-ies) produced from operating mines, but are instead recovered as by-products ('companion metals') of the primary ores at some stage during processing. Europe has a rich and diverse mineral endowment including CRM, and a map showing the distribution of selected CRM deposits of Europe, based on the ProMine database was published by EGS's Mineral Resources Expert Group during 2016 and an updated version base on the new CRM list was delivered in December 2017. Despite these efforts, there is still need for a more comprehensive pan-European identification and compilation of mineral potential and metallogenic areas of CRM. Such metallogenic areas can be defined by the presence of mineral occurrences and deposits, past and active mines, previous and ongoing exploration activities, favourable bedrock geology, geophysical signatures, geochemistry and predictive/prospectivity mapping. Understanding that mineral exploration is the process by which mineral resources essential to society are discovered and is the initial wealth-creating process of the mining value chain (Porter, 1985) is a fundamental concept. The outdated idea of a single prospector wandering around inspecting altered outcrops, and perhaps occasionally finding an ore deposit, has now given rise to geoscientists using multidisciplinary tools being specifically tailored to specific commodities and even refined for the specific type of deposit sought is now the norm (Wood and Hedenquist, 2019). Even so, the rate of finding of ore deposits has fallen since 2005 despite considerable increases in exploration budgets (Schodde, 2017).

Even though some will argue that ambitious climate policies, as well as economic development, education, technological progress and less resource-intensive lifestyles, are crucial elements for progress towards the UN Sustainable Development Goals (Soergl, 2021), one thing to remember is that the world is increasingly technology driven [today's technologies utilize virtually the entire periodic table (Nuss and Ciuta, 2018)] and the demand for mineral resources is only set to increase (e.g., EU Commission 2018; Carrara et al., 2020) in light of the objectives of central government agencies (e.g., EU Commission) and the planned programmes to reduce greenhouse gas emissions by utilizing larger amounts of "green" energy generating technologies (e.g., the now well-known EU Green Deal).

New research into mineral intelligence must, however, be dissociated from the pressures of these above concepts but it must be methodical, generate homogenized data and be available for interpretation and reinterpretation if needed.

Mineral Intelligence - FRAME delivered what it promised at the beginning of the project. The cohesive team of researchers understood the tasks ahead and worked towards common goals. The unexpected pandemic situation was another giant hurdle to overcome during on-going research, which FRAME did so successfully.

In the field of mineral intelligence, FRAME has contributed significantly even though we are still only barely scratching the surface. The deeper-lying deposits are still waiting to be found and metallogenic models can only be further strengthened with additional data and significant, focused investment in research, and new data collection, compilation, homogenization, interpretation, disclosure, and dissemination.

While projects need not innovate every time, the FRAME Team believes that this project has placed a set of innovative and unique data sets and looked at known in a different light regarding their potential and the possible existence of satellite ore bodies.

Results achieved – While many are the feats achieved in the project, the following stand out:

- FRAME updated and completed, where possible, ProMine, Minerals4EU (M4EU), EURARE and European Geological Data Infrastructure (EGDI) datasets on rare earth elements, graphite, cobalt, lithium, phosphor, niobium and tantalum in collaboration with the other work project packages (WP4, WP5 and WP6);
- Close cooperation with non-consortium members in the Mineral Resources Expert Group of EuroGeoSurveys to supply extra data;
- WP3 focused to present the metallogenetic maps – i.e., areas of similar lithological and metallogenic characteristics for the several types of elements dealt with in the project. These were broken down by areas, e.g., Fennoscandian Shield, Caledonian Orogeny, Variscan province, etc.
- Bilateral collaboration between FRAME and MINDeSEA projects on exploration potential areas and mineralisation in Europe because of the huge potential in sea-bed deposits and the fact that a unified picture of the metalliferous potential of Europe should focus on both land and sea;
- Production of land-Sea maps containing phosphate, cobalt,
- Predictability mapping using both Cell Based Association and Fuzzy Weight of Evidence methods;
- Acquisition of new mineralogical and geochemical data on selected phosphate deposits and occurrences;
- A synthetic study about the chemistry of apatite and igneous phosphate deposits in Europe;
- Development of a procedure to prepare and analyze phosphate deposits to provide internally consistent geochemical data at a European level;
- The study suggests that Lower Palaeozoic sedimentary phosphorites (and probably the Jurassic ones; to be confirmed) are the most promising targets regarding their REE content;
- Provision of new approximate numbers on resources in REE of phosphate deposits/district in Europe, e.g., the Kodal deposit (Norway), the Bjerkreim-Sokndal intrusion (Norway), the Northern Norrbotten district (Sweden), the carbonatite-related Siilinjarvi deposit (Finland), the phosphatic chalk of the Mons basin (Belgium) and the Salento Peninsula (Italy);
- Compilation of new and more complete data from national databases regarding the occurrences of lithium, cobalt and graphite;
- Classification of the Li-type deposits into brine, hard-rock, magmatic Li, Magmatic-hydrothermal Li and sedimentary-hydrothermal Li;
- Separation of the European graphite deposits are of the so-called flake and amorphous types;
- The Frame project, for the first time, compiled in an aggregated form, the occurrences, geology and potential for Lithium Cobalt and Graphite and for the first time it was possible to make clusters of deposits and metallogenetic provinces for most of Europe;
- FRAME looked at the “Conflict Minerals”, namely Nb-Ta ahead of the EU legislation on this matter;
- FRAME carried out a comprehensive characterization of the European and African Nb-Ta deposits;
- New petrographic and quantitative mineral chemical analyses have allowed the identification of different Nb-Ta minerals - Ta-enriched cassiterite, columbite-(Fe), columbite-(Mn), tantalite-(Fe), tantalite-(Mn), tapiolite (s.l.), wodginite, ixiolite, microlite minerals, Nb-bearing rutile, Ta-Nb-bearing rutile and Ta-rich rutile (“strüverite”);

- Detailed information on the CRM potential was collected from 160 mine sites and specific case studies were undertaken in a dozen old mines;
- Specific, joint studies by PGI (Polish Geological Survey) and CGS (Czech Geological Survey) in the St. Leopold historical mine in Gierczyn (Poland);

3.4 Project contribution to GeoERA project

FRAME is one of the cornerstones of the GeoERA Raw Materials theme. This project handles the Critical Raw Materials in a follow up of the EU Commission's constant concerns regarding the sustainable sourcing of crucial raw materials to industrialised Europe, the contribution to the Circular Economy (reducing waste and using secondary raw materials), the Battery Alliance and the Decarbonisation of the economy. FRAME is conceived beyond the scope of the time frame of the project. Hence, it focuses equally on a new EU law out on the 1st of January 2021 – the Conflict Minerals Regulation, which aims to help stem the trade in four minerals – tin, tantalum, tungsten and gold (3TG) - which sometimes finance armed conflict or are mined using forced labour.
This overall philosophy of research in FRAME fulfils the main objective of GeoERA, which is to contribute to the optimal use and management of the subsurface. GeoERA that will aim to support 1) a more integrated and efficient management and 2) more responsible and publicly accepted, exploitation and use of the subsurface.

3.5 Work progress and achievements during the period

Work package 1: Coordination/Lead

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Description of work	LNEG	R	CL	M5	Completed	Review completed with Midterm report.
D1.2	Ethical requirements (consent procedures, protection of personal data) M	LNEG	R	CL	M5	Completed	Review completed with Midterm report.
D1.3	Terms of reference (governance)	LNEG	R	CL	M5	Completed	Review completed with Midterm report.
D1.4	Management report (submission of consolidated report to the European Commission)	LNEG	R	CL	M18	Completed	
D1.5	Management report (submission of consolidated report to the European Commission)	LNEG	R	CL	M36	Completed	
D1.6	Final Report	LNEG	DEC	PU	M40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M1	Kick-off meeting	M1	Completed	Review completed with Midterm report.
M2	dissemination of progress achievements	M6,M12,M18,M24,M30,M36	Completed	Review completed with Midterm report.
M3	Final Meeting	M36	Completed	

Work package 2: Communications, Dissemination and Exploitation

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	Communication strategy	LNEG	R	CL	M1	Completed	Review completed with Midterm report.
D2.2	Visual identity (Logo, Templates, Project site, etc.)	LNEG	DEC	PU	M1	Completed	Review completed with Midterm report.
D2.3	Collection of Information materials (Leaflet, Website, Media kits etc.)	LNEG	DEC	PU	M6	Completed	Review completed with Midterm report.
D2.4	Organization of events:	LNEG	DEC	PU	M16	Completed	Review completed with Midterm report.
D2.4.1	Workshop	LNEG	DEC	PU	M16	Completed	Review completed with Midterm report.
D2.5	Triannual newsletters	LNEG	DEC	PU	M4, 8, 12, 16, 20, 24, 36	Completed	
D2.6	Final newsletter	LNEG	DEC	PU	M40	Completed	

Milestones							
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**			
M2.1	Report on Communication strategy	M1	Completed	Review completed with Midterm report.			
M2.2	Visual identity, logo design	M2	Completed	Review completed with Midterm report.			
M2.3	Digital newsletters delivery to consortium	M4, 8, 6, 12, 16, 20, 24, 30	Completed	Review completed with Midterm report.	Note: All GeoERA FRAME newsletters are available in www.frame.lneg.pt		
M2.4	Events documentation	M18, 40	Completed				

M2.5	Final digital newsletter delivery to consortium	M40	Completed				

Work package 3: Critical and Strategic Minerals Map

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	Producing a report describing the methodology used for the identification and selection process of the CRM to be included in the metallogenetic map	SGU	R	CL	M3	Completed	Review completed with Midterm report.
D3.2	Providing a data platform, digital version of metallogenic map and related description report highlighting the endowment and exploration potential of CRM in Europe	SGU	DEC	CL	M28	Completed	
D3.3	Producing a predictivity map outlining the CRM exploration potential areas and the major prospective minerals belts	SGU	R	PU	M32	Completed	
D3.4	Providing CRM data and intelligence to EURMKB (RM1) and the GeoERA information platform	SGU	R	PU	M37	Completed	
D3.5	Prospectivity maps of CRM in Europe	SGU	R	PU	M38	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M3.1	Methodology for collecting CRM data from primary (land and marine) and secondary sources	M4	Completed	Review completed with Midterm report.
M3.2	Metallogenetic map of CRM in Europe	M29	Completed	
M3.3	CRM and STR predictivity and mineral exploration potential map	M38	Completed	

Work package 4: Critical Raw Materials associated with phosphate

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Overview of the phosphate deposits and occurrences in Europe under the form of a database and map(s)	RBINS-GSB	R	PU	M9	Completed	Review completed with Midterm report.
D4.2	New mineralogical and geochemical data on samples from phosphate deposits/occurrences (+ host black shales). These samples should be as numerous and as widely geographically distributed as possible, and coming from different types of deposits	RBINS-GSB	R	CL	M20	Completed	
D4.3	Detailed metallogenic studies of key phosphate deposits. The selection of deposits aims to be as representative as possible of the phosphate deposits encountered in Europe	RBINS-GSB	R	PU	M30	Completed	
D4.4	Development of a procedure to prepare and analyse phosphate deposits with the objective to provide internally consistent geochemical data at a European level for this type of mineralization	RBINS-GSB		External	M34	Completed	
D4.5	Providing Phosphate data and intelligence to EURMKB (RM1) and the GeoERA information platform	RBINS-GSB	R	PU	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M4.1	Partners identify the case studies/regions (key phosphate/black shale deposits) to study	M4	Completed	
M4.2	Partners (1) approve the list of samples to investigate in order to provide D4.2, (2) decide where the analyses will be carried out, and analyses to perform	M8	Completed	
M4.3	Final report and end of the WP	M35	Completed	

Work package 5: Energy critical elements

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1	Provide mineral potential and prospectivity maps of key mineral provinces in Europe with deposits of, or potential for, energy critical elements	NGU	R	PU	M28	Completed	

	(natural graphite, lithium, cobalt) in collaboration with WP 3						
D5.2	Develop and/or review models for the formation of natural graphite, lithium and cobalt in Europe	NGU	R	PU	M32	Completed	
D5.3	Report: Energy critical metals and minerals in Europe; occurrence, types, characteristics, formation, and future potential for European production	NGU		PU	M34	Completed	
D5.4	Map of Cobalt, Graphite, Lithium deposits (including deposits where cobalt is a significant byproduct)	NGU	R	PU	M36	Completed	
D5.5	Relevant Metallogenic maps	NGU	R	PU	M36	Completed	
D5.6	Provide INSPIRE-compliant harmonised data on deposits and prospects of natural graphite, lithium and cobalt for the EURMKB (RM1)	NGU	O	CL	M36	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M5.1	Establish an overview of known European prospects and deposits of natural graphite, hard rock lithium and cobalt as a working base for WP5	M4	Completed	Review completed with Midterm report.
M5.2	Report on occurrence, types, characteristics, formation, and future potential for the production of natural graphite, lithium and cobalt from European sources	M32	Completed	
M5.3	Map of Cobalt, Graphite, Lithium deposits (including deposits where cobalt is a significant byproduct)	M36	Completed	
M5.4	Relevant Metallogenic maps	M36	Completed	

Work package 6: Conflict Minerals

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D6.1	A report on the distribution and systematics of Nb-Ta mineralisations in Europe, including a case study. This will include new INSPIRE compliant data of selected Nb-Ta deposits that will be available for integration into the EURMKB (RM1) and the GeoERA Information Platform	SGU	R	PU	M35	Completed	
D6.2	A report outlining recommendations for future	SGU		external	M32	Completed	

	exploration in Europe for Nb-Ta						
D6.3	A discussion and draft outlining the possibilities for relieving European import dependence and improvement of conditions for Nb-Ta production in central Africa	SGU	R	PU	M36	Completed	
D6.4	Providing Nb-Ta mineralisations in Europe data and intelligence to EURMKB (RM1) and the GeoERA information platform	SGU	R	PU	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M6.1	Selection of key areas and occurrences/deposits to study	M6	Completed	Delivery of report
M6.2	Regional overview of the distribution and systematics of Nb-Ta in Europe	M35	Completed	Delivery of report
M6.3	Recommendations for future exploration of Nb-Ta in Europe	M32	Completed	Delivery of report

Work package 7: Historical mining sites revisited

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D7.1	Report 1: Potential target areas identified / Overview concerning potential and criteria	BGR	R	PU	M8	Completed	Review completed with Midterm report.
D7.2	Template for content of case studies to ensure consistent data collection in line with requirements of the GeoERA Information Platform	BGR	OTHER	PU	M10	Completed	Review completed with Midterm report.
D7.3	Report 2: Case studies	BGR	R	CO	M24	Completed	
D7.4	Report 3: Final Report	BGR	DEC	CO	M33	Completed	
D7.5	Site info in raw materials data bank and GeoERA IP	BGR	DEC	PU	M37	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M7.1	Partners approve criteria to identify sites/regions for case studies and to identify the set of case studies	M4	Completed	Review completed with Midterm report.
M7.2	Technical data migration test phase	M38	Completed	
M7.3	Final report	M33	Completed	
M7.4	End of the WP	M40	Completed	

Work package 8: Link to Information Platform

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D8.1	Deliver, in conjunction with the central GeoERA Information Platform a norm for data format and delivery	LNEG	R	CL	M13	Completed	Review completed with Midterm report.
D8.2	Implement IT equipment infrastructure capable of interacting with internal system requirements to ensure delivery and increase the reliability of data and information to the EURMKB	LNEG	OTHER	CL	M24	Completed	
D8.3	Assist in the data planning for the raw materials under study	LNEG	OTHER	CL	M6-40	Completed	
D8.4	Final compilation of data and delivery to central GeoERA IP	LNEG	DEC	CL	M40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M8.1	Report on the data normative and format requirements	M18	Completed	
M8.2	Report on on prototype results	M24	Completed	
M8.3	Report of data and intelligence delivery to GeoERA IP	M40	Completed	

3.6 Deviations

Has the project partnership identify any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Yes	The pandemic situation impacted FRAME in two specific WP's: WP4 – closed laboratories prevented more analytical data being generated WP7 – limited or no circulation of persons severely limited field trips to historic mine sites

3.7 Communication and dissemination activities

	ABSTRACTS	BLOG	CONGRESS	EXHIBITION	FACEBOOK	INTERNAL PROJECT MEETING	LEAFLET	LINKEDIN	MEETING	MEETING WITH OTHER GEOERA PROJECTS	NEWSLETTER	NEWSPAPER	NON SCIENTIFIC PUBLICATION	OTHER	PITCH EVENT	SCIENTIFIC PUBLICATION	SEMINAR	TWITER	WEBINAR	WEBSITE	WORKSHOP	YOUTUBE	Total
EVENTS			5	1										3	1		3		4		5		22
MEDIA								1															1
MEETINGS						1			1	5											1		8
ONLINE_MEDIA		14			3			1				1		1				14		20		2	56
PUBLICATIONS	16						1				16		1	10		17							61
Total	**16**	**14**	**5**	**1**	**3**	**1**	**1**	**2**	**1**	**5**	**16**	**1**	**1**	**14**	**1**	**17**	**3**	**14**	**4**	**20**	**6**	**2**	**148**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	45540	160	43	10	3		5	35		25000	70796
MEDIA	50										50
MEETINGS	366			1			2				369
ONLINE_MEDIA	6000	248086		4							254090
PUBLICATIONS	147135	6100	1	1	1	1	1	1	1	147601	300843
Total	**199091**	**254346**	**44**	**16**	**4**	**1**	**8**	**36**	**1**	**172601**	**626148**

3.8 Project management

• Maintaining an open communication channel between project coordinator, WP leaders and consortium members,
• A close quarters, open dialogue stream with the GeoERA Raw Materials Theme coordinator, Antje Wittenberg, and Monitoring Team
• Fomenting the interaction between WP's; essential for the success of FRAME, as well as between FRAME and the other Raw Materials projects namely, MindeSea, Eurolithos, Mintell4EU, GIP-IP and Hike
• Opening a communication highway between FRAME and the Mineral Resources Group (MREG) of EuroGeoSurveys (EGS). This has been particularly useful in getting countries that do not belong to the consortium to deliver data. This close interaction with MREG and EGS is clearly a benefit and has already been instrumental in achieving a complete map of the Energy Critical Elements,
• This interaction with EGS and MREG has resulted in meetings of the MREG group having a B2B meeting with the GeoERA RM projects. The formula has been applied in Rome (Nov. 2018), Trondheim (May 2019) and Madrid (November 2019) and has been successful and is seen as essential to discuss project details
• Maintaining an open dialogue with the EU Commission and its constituent DG's,
• Maintaining an active visual presence of FRAME in social media and the project website as well as pitching FRAME in congresses, public events and workshops,
• Maintaining an up to date Deliverable and Milestone plan.

3.9 General description of the cooperation over the duration of the project

/

3.10 Impact statement

The objectives set out initially and the subsequent results obtained in the FRAME project were presented in several event types ranging from scientific fora/meetings/congresses, seminars, webinars and workshops where the interest shown was high. Given the expertise, enthusiasm and dedication of the participating consortium members and the link to EGS members through MREG, FRAME made a significant and successful attempt to further unlock the mineral potential for a renewed raw materials sector in Europe as a driver for domestic raw material value chains. Of the points to highlight, the following stand out: 1- FRAME represented a cohesive taskforce of scientists working together for common pan-European goals to mitigate the dependency of mineral resources from non-European sources; 2-FRAME created innovation in mineral prospectivity science with favourability mapping implementation; 3- FRAME recognised the importance and the recognition and establishment of metallogenic provinces for the strategic CRM; 4- FRAME produced comprehensive mineral deposits maps of the occurrences of REE, P, Li, Co, C, Nb and Ta in Europe; 5- FRAME made a significant review of Nb-Ta mineral deposits in Europe and in Africa; 6- FRAME increased by 60% the available data on battery critical elements (Li, Co, C) in Europe by interacting with MREG members; 7- FRAME undertook and accomplished comprehensive phosphate mineralization indices in Europe; 8- FRAME added unpublished geochemistry data of phosphate deposits; 9- FRAME made a review of the CRM (REE) deposits in Europe; 10- FRAME had a revitalized look at selected old mine sites; 11- FRAME augmented and updated pan-European data sets, namely EGDI; 12- FRAME worked together with the other Raw Materials projects, within the GeoERA Raw Materials topic, and produced composite maps in conjunction with them, one example being the land-sea EU cobalt mineralization. (A strong network was established among the FRAME, MINDeSEA, Mintell4EU and GIP-P projects to facilitate on-going support); 13- Together with GIP-P and MINTELL4EU projects implemented important issues in a global context of the overall system of information, which included a- FRAME integrated results through the EGDI Portal (metadata, structured and unstructured

data (EU-MKDB architecture), and b- FRAME was instrumental in the improvement of the present harvesting system and its quality assurance.
FRAME has made sure that a “lighter scientific side” of the project results were also presented to the general public through the dissemination of short and informative Facebook, LinkedIn, Twitter and newsletter issues.
Because it is still too early to tell, FRAME expects the results achieved to disseminate quickly after the end of the project, reaching more of the scientific community, the policy makers and strengthening its presence amongst the academic and civil societies.

3.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontracting	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. LNEG	152.958,39 €	12.027,72 €	- €	41.246,53 €	206.232,64 €	29,70%	61.251,09 €	144.981,55 €
2. BGR	99.770,74 €	1.226,51 €	- €	25.249,31 €	126.246,56 €	29,70%	37.495,23 €	88.751,33 €
3. BRGM	68.151,67 €	1.192,90 €	- €	17.336,14 €	86.680,71 €	29,70%	25.744,17 €	60.936,54 €
4. CGS	22.057,25 €	2.850,67 €	- €	6.226,98 €	31.134,90 €	29,70%	9.247,07 €	21.887,83 €
5. GSE	- €	- €	- €	- €	- €	0,00%	- €	- €
6. SGU	126.033,83 €	2.621,70 €	- €	32.163,88 €	160.819,41 €	29,70%	47.763,37 €	113.056,05 €
7. GSI	90.610,00 €	- €	- €	22.652,50 €	113.262,50 €	29,70%	33.638,96 €	79.623,54 €
8. GTK	24.871,35 €	183,27 €	- €	6.263,66 €	31.318,28 €	29,70%	9.301,53 €	22.016,75 €
9. HGI-CGS	9.560,93 €	- €	- €	2.390,23 €	11.951,16 €	29,70%	3.549,50 €	8.401,67 €
10. IGME-Gr	20.940,00 €	904,70 €	- €	5.461,18 €	27.305,88 €	29,70%	8.109,84 €	19.196,03 €
11. IGME-Sp	94.859,54 €	19.192,78 €	3.988,16 €	28.513,08 €	146.553,55 €	29,70%	43.526,41 €	103.027,15 €
12. MBFSZ	10.927,69 €	- €	- €	2.731,92 €	13.659,61 €	29,70%	4.056,90 €	9.602,71 €
13. NGU	62.181,00 €	27.736,24 €	- €	22.479,31 €	112.396,54 €	29,70%	33.381,77 €	79.014,77 €
14. PIG-PIB	24.576,93 €	- €	- €	6.144,23 €	30.721,16 €	29,70%	9.124,19 €	21.596,98 €
15. RBINS-GSB	126.643,79 €	- €	- €	31.660,95 €	158.304,74 €	29,70%	47.016,51 €	111.288,23 €
16. Geoinform	36.456,48 €	- €	- €	9.114,12 €	45.570,60 €	29,70%	13.534,47 €	32.036,13 €
17. IGR	94.131,74 €	- €	- €	23.532,93 €	117.664,67 €	29,70%	34.946,41 €	82.718,26 €
18. GeoZS	40.485,18 €	2.593,99 €	- €	10.769,79 €	53.848,97 €	29,70%	15.993,14 €	37.855,82 €
19. ISPRA	12.647,58 €	- €	- €	3.161,90 €	15.809,48 €	29,70%	4.695,41 €	11.114,06 €
20.GBA	12.058,00 €	- €	- €	3.014,50 €	15.072,50 €	29,70%	4.476,53 €	10.595,97 €
	1.129.922,08 €	**70.530,48 €**	**3.988,16 €**	**300.113,14 €**	**1.504.553,86 €**		**446.852,50 €**	**1.057.701,37 €**

Date:	12.11.2021
Person responsible:	Daniel de Oliveira

4 PROJECT GARAH

4.1 Identification of the project

Project full title:	Geological Analysis and Resource Assessment of selected Hydrocarbon systems
Project acronym:	GARAH
Project reference number:	GeoE.171.002
Project topic:	Geo-energy
Project specific research topic:	GE1 - FOSSIL ENERGY, ENERGY SECURITY AND CLIMATE ACTION
Project website address:	http://geoera.eu/projects/garah/
Full Period covered from:	01-01.2020 to: 31.12.2021
Report submission date:	12.12.2021
Project coordinator:	Peter Britze (GEUS) between 01072018 and 01072021. From this date and hereafter Niels Schovsbo (GEUS) has been the Project coordinator
Contact person for the project:	Niels Schovsbo
Tel:	4591333759
E-mail:	nsc@geus.dk

4.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Geological Survey of Denmark and Greenland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Lead
2	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
3	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Partner
4	Bureau de Recherches Géologiques et Minières	The French Geological Survey	BRGM	France	999993662	Project Partner
5	Bundesanstalt für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Partner
6	UK Research and Innovation	British Geological Survey	NERC (UKRI)	United Kingdom	906446474	Project Partner
7	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner
8	Norwegian Petroleum Directorate	Norwegian Petroleum Directorate	NPD	Norway	0	Non-funded partner

4.3 Publishable summary

The main achievement of the GARAH project is a harmonized, scientifically based, geological analysis and assessment of the conventional and unconventional offshore hydrocarbon resources in the North Sea as well as an assessment of the gas-hydrate distribution beneath the European continental shelf (Geological Analysis and Resource Assessment of selected Hydrocarbon systems (GARAH) – GeoERA). This contributes to sustainable and affordable energy resources and energy security. The analysis and assessment of hydrocarbons has focused on two areas:

(i) in Europe's major petroleum province – the North Sea a "Geological analysis and resource assessment of North Sea petroleum systems", Work Package 2.
This research includes the assessment of conventional and unconventional oil and gas resources in the most important hydrocarbon basin in Europe. The result enables the remaining resource to be better understood and managed and has identified options for multiple and alternative uses of the subsurface as producing conventional fields come off-line.
The assessment of the conventional resources is made quantitatively based on a harmonization of the national reserve and resource estimations for each country, and qualitatively following a play-based approach. In addition, the assessment of the unconventional resources is made following a Monte Carlo simulation approach known as the "EUOGA method".
The harmonization of the national conventional assessments shows that more than 14 billion cubic meter oil equivalents (o.e.) have been produced in the North Sea and that significant additional reserves and resources remain. The reserves amount to at least 2,900 x 10^6 m3 o.e. and the contingent resources are estimated to be at least 1,500 x 10^6 m3 o.e. Following the national agencies, it is estimated that the prospective yet-to-find resources are 1,900 x 10^6 m3 o.e.
The qualitative assessment of hydrocarbon resources in the North Sea has resulted in the construction of a total of 13 major conventional play maps. This represents the first North Sea-wide cross-border mapping of potential hydrocarbon accumulations. The maps represent a major achievement assisting future regional planning of the North Sea subsurface both in terms of oil and gas development as well as for alternative use and renewable energy projects. A considerable yet-to-find resource potential also exists within unconventional plays in the North Sea. Ten potentially prolific oil plays have been identified with a yet-to-find resource potential (P50) of 6,648 x 106 m3 oil and nine shale gas plays have yet-to-find resource potential of 9,344 x 109 m3 natural gas. The yet-to-find unconventional resources are mainly distributed in the UK and Norwegian North-Sea sectors, with minor resources also in the Netherlands sector. Additionally, conventional and unconventional hydrocarbon resources were assessed with a detailed 3D basin and petroleum system model, regionally covering the cross-border area of the Danish, German and Dutch Central Graben.

(ii) with a pan-European view, "Hydrate assessment in the European continental margin and related risks". Work Package 3.
The assessment of gas-hydrates resources in the European continental margin represents an information gap of pan-European interest. GARAH has improved the understanding of the potential role that gas-hydrates may play in the future EU energy mix, as the results constitute a base-line for future projects pertaining the improvement of the European model of the gas hydrate stability zone (GHSZ), related hazards, and potential for geological storage of CO2. All the analytical data were generated to a common European Geological Data Infrastructure (EGDI) database. During the last years of the project, the main activities and results achieved in WP3 have been the (i) collection of available data focused on hydrate research in a pan-European area and (ii) the definition of the data model structure of the pan-European hydrate-related GIS. The main impact of this results has been to extend the existing EGDI structure to enable incorporation, maintenance, and dissemination of outcomes.
Alternative Use/Risk/Hazard

In addition to the regional analyses, a catalogue evaluating the multiple-use of hydrocarbon reservoirs, as integrated or alternative use of the subsurface, together with an appraisal on potential hazards, has been developed. This catalogue includes options on CO2 storage (CCS and CCUS), H2 storage, underground natural gas storage, and geothermal energy. In addition, potential for conversion of oil & gas facilities for new natural habitats (“rigs-to-reefs"), windmill parks and energy islands are catalogued. The hazards catalogue focuses on potential new risks and environmental impacts associated with continued exploitation of the subsurface for energy in the North Sea. This evaluation is based on a review of recent literature. We also examine gas hydrates and their geohazards.

4.4 Project contribution to GeoERA project

WP2 (North Sea Petroleum Systems) has defined the range of petroleum systems in the North Sea and populated a harmonized database detailing the oil and gas resource present in the UK, Dutch, German, Danish and Norwegian sectors. The work package has provided a harmonized assessment of the conventional and unconventional resources adapting EUOGA methodology for the offshore North Sea area. The WP2 also demonstrated the advantages of 3D model assessment in a pilot study area.
WP3 (addressing knowledge gaps in the hydrate assessment in the European continental) developed a harmonized model for a pan-European gas hydrate data infrastructure. A GIS-database has been developed that includes key gas hydrate observations along the whole European continental margin.
This has fed into an assessment of hazard associated with effective closure of mature fields, including multiple and alternative use of assets and infrastructure.
The developed catalogue of alternative usage and associated hazards and risks of the offshore subsurface is a contribution to offshore climate mitigation strategies, for carbon capture (CCS, CCUS), hydrogen and other energy storage, and even for offshore geothermal energy. This contributes to further enable the European community to strategically develop the most efficient, sustainable, and climate-friendly use of the subsurface. The alternative use catalogue is complimented by a risk and geohazard catalogue associated with the use of the subsurface (existing and future) as well as with the gas hydrate resource mapped and assessed as part of the GARAH project. Gas hydrates pose potential geohazards that can trigger events such as tsunamis. In addition, there is increased awareness that global warming may lead to increasing disintegration of gas-hydrates and permafrost, thereby releasing large volumes of methane, a strong greenhouse gas.

4.5 Work progress and achievements during the period

Work package 1: Main Project Coordination

Coordination of weekly meetings and minutes
Preparation of annual meetings.
Incorporated project plan amendments
Established the Annual Project Progress Report (D1.5)
Preparing Final project report (D1.6)
Preparing Final Project presentation (D1.7)
Preparing FPPR review

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Dissemination and Exploitation Plan	GEUS	Report	Public	M3	Completed	Review completed with Midterm report.
D1.2	Project data management plan	GEUS	Report	Public	M6	Completed	Review completed with Midterm report.
D1.3	Annual progress report 2018	GEUS	Report	Public	M8	Completed	Review completed with Midterm report.
D1.4	Midterm Project Progress Report	GEUS	Report	Public	M19	Completed	
D1.5	Annual progress reports 2020	GEUS	Report	Public	M32	Completed	
D1.6	Final Project report	GEUS	Report	Public	M40	Completed	
D1.7	Project review with EU stakeholders – Formal presentation	GEUS	Report	Public	M40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS1	Kick-off meeting/ seminar	M1	Completed	Review completed with Midterm report.
MS2	Data review & Characterization method agreed	M6	Completed	Review completed with Midterm report.
MS4	Midterm progress report	M19	Completed	Review completed with Midterm report.
MS6	Annual project meeting/seminar 2020	M32	Completed	
MS13	Annual project meeting/seminar 2021	M40	Completed	
MS15	Presentation of the GARAH findings	M40	Completed	
MS15	Presentation of the GARAH findings	M40	Completed	

Work package 2: North Sea Petroleum Systems

Based on existing data and knowledge from the WP-partners WP2 has harmonized a cross-border overview of the North Sea petroleum systems and assess their resource potential. The main focus for the conventional assessment has been a harmonizing of the resource assessments published by the individual countries and synchronizing 13 major conventional play maps that represent the first North Sea-wide mapping of the where hydrocarbon accumulations are likely to be located. The maps thus represent a major step in planning of the future use of the North Sea subsurface both in terms of licences rounds, alternative use and risking. This process has allowed to identify potential underexplored play systems and define new play concepts. The harmonization of the national conventional assessments shows that more than 14 billion cubic meter oil equivalents have been produced in the North Sea and that significant additional reserves and resources remain. The reserves amount to at least 2,900 x 10^6 m^3 o.e. and the

contingent resources are estimated to be at least 1,500 x 10^6 m3. Following the national agencies, it is estimated that the prospective yet-to-find resources are 1,900 x 10^6 m^3 o.e. The unconventional assessment has identified ten potentially prolific unconventional oil plays in the North Sea have been identified with a yet-to-find resource potential (P50) of 6.6 x 10^9 m^3 oil, and nine gas plays have a yet-to-find resource potential of 9,344 x 10^9 m^3 gas. The assessment of the unconventional resources is made following a Monte Carlo simulation approach known as the "EUOGA method".
In WP 2D a detailed 3D basin and petroleum system model (BPSM) covering the Danish, German, and Dutch Central Graben area was constructed for calculation of conventional and unconventional petroleum resources. In close cooperation the GARAH and 3DGEO-EU projects' participants delineated the area of interest and the stratigraphic framework of the model. The construction of a single model of the pilot study area highlighted the different interpretations and stratigraphic concepts of each country. Nevertheless, we were able to harmonize the data across borders and reach a comprehensive volume model. All results e.g., maturity or transformation ratio maps can now be extracted from the model without breaks at country borders.
A catalogue of the multiple-use (or sequential-use) potential and impacts of hydrocarbon reservoirs to further enable the European community to understand the most efficient, sustainable, and climate-friendly use of the subsurface has been made. The alternative use catalogue is complimented by a risk and geohazard catalogue associated with the use of the subsurface (existing and to come) as well as with the gas hydrate resource mapped and assessed as part of the GARAH project.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	Data base & harmonization report	GEUS	Report	Public	M10	Completed	Review completed with Midterm report.
D2.2	Petroleum system report and GIS maps	BGS/TNO/ GEUS	Report	Public	M35	Completed	
D2.3	Resource assessment „EUOGA"	GEUS/TNO	Report	Public	M38	Completed	
D2.4	Resource assessment 3D pilot Unconventional	BGR/GEUS	Report	Public	M32	Completed	
D2.5	Resource assessment 3D pilot Conventional	BGR/GEUS	Report	Public	M38	Completed	
D2.6	Alternatives + risks	BGS/IGME	Report	Public	M40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS2	Data review & Characterization method agreed	M6	Completed	Review completed with Midterm report.
MS5	Pilot 3D Unconventional assessment	M32	Completed	By delivery 2.4
MS8	Inventory of the North Sea petroleum systems	M35	Completed	By delivery 2.2
MS9	Pilot 3D Conventional assessment	M38	Completed	By delivery 2.5
MS10	Resource assessment of the North Sea	M38	Completed	By delivery 2.3
MS14	Catalogue of Hazards and alternative usage	M40	Completed	By delivery 2.6

Work package 3: Knowledge gaps Gas Hydrates

During 2020 and 2021, activities have been focused on Task 3B and Task 3C. Task 3B (definition of data model structures and data loading) were finalised in June 2020. The deliverable D3_2 contains a list of the available hydrate related-data of interest to be incorporated into the GIS of WP3. Hydrate-related information of GIS of GARAH WP3 has been grouped in four geological groups: (A) Geological & geochemical evidence/indicators, (B) Geophysical indicators, (C) Fluid flow seabed indicators, (D) Oceanographic variables & geological constrains. A group with cultural data has been defined with relevant geographical and political marine information. Source data, accessibility/use, size, typology and state have been specified. From June 2020 the work has focussed on the Task 3C integration of results documented in the delivery 3.3 that present a pan Eropean gas hydrate overview. Critical knowledge gaps have been identified and a Susceptibility assessment of seafloor areas affected by hydrate dissociation has been made. In addition, the potential safe geological storage of CO2 as mixed gas hydrates: the "deep offshore" storage option is presented and discussed.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	Collection data report on available Hydrates data	BGS/IGME	Report	Public	M9	Completed	Review completed with Midterm report.
D3.2	Hydrates GISdatabase	IGME	GIS	Public	M27	Completed	By delivery 3.2
D3.3	Gas Hydrate overview report	IGME	Report	Public	M39	Completed	By delivery 3.3

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS2	Data review & Characterization method agreed	M6	Completed	Review completed with Midterm report.
MS7	Hydrate GIS data base	M27	Completed	By delivery 3.2
MS11	Gas Hydrate overview	M39	Completed	By delivery 3.3

Work package 4: Knowledge data base

Interactions with the GeoERA-IP project has been maintained to execute the parts of the Project Data Management Plan relating to IP and EDGI and to enable an efficient and consistent uptake and embedding of project results into the GeoERA-IP.
Communicating the requirements of the project to GeoERA-IP and vice versa have been made to ensure that the guidelines and standards provided by GeoERA-IP are properly implemented in the WP's 2 and 3 processes.
Meetings have been held with GIP to discuss requirements and prototype development and data input to GIS-I has been made as the results became available.
A GeoERA Information Platform (web portal) for the GARAH project has been made. The project web site include:
Web map services and web feature services
A metadata database
A digital archive for reports and unstructured data

Multilingual keyword thesauri
Code list repositories
In addition, the GARAH project also has added functionality that shows bibliographic references for a given feature.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Preliminary data selection, IP guidelines, QA procedures	GEUS	Report	Public	M6	Completed	Review completed with Midterm report.
D4.2	Description of Extensions - EGDI	GEUS	Report	Public	M30	Completed	
D4.3	Assist in HC planning	GEUS	Report	Public	M30	Completed	
D4.4	Online available results	GEUS	Report	Public	M39	Completed	
D4.5	Data input to IP	GEUS	GIS data	Public	M1	Completed	Review completed with Midterm report.
D4.5	Data input to IP	GEUS	GIS data	Public	M39	Completed	LINK

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS3	Preliminary data selection, IP guidelines and QA procedures	M6	Completed	Review completed with Midterm report.
MS12	All data in IP EGDI data base	M1	Completed	LINK
MS12	All data in IP EGDI data base	M39	Completed	LINK

4.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	

4.7 Communication and dissemination activities

	CONGRESS	INTERNAL PROJECT MEETING	MEETING	MEETING WITH OTHER GEOERA PROJECTS	NEWSLETTER	RESEARCHGATE	SCIENTIFIC PUBLICATION	WORKSHOP	Total
EVENTS	9							2	11
MEETINGS		27	3	3					33
ONLINE_MEDIA						1			1
PUBLICATIONS					4		4		8
Total	**9**	**27**	**3**	**3**	**4**	**1**	**4**	**2**	**53**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	2765		110								2875
MEETINGS	465			200			10				675
ONLINE_MEDIA	100										100
PUBLICATIONS	310		440								750
Total	**3640**		**550**	**200**			**10**				**4400**

4.8 Project management

In the second half of the GARAH project the GARAH project management board had bi-monthly virtual meetings, where the progress in the GARAH study is discussed and assessed; From spring 2020 the meeting frequency was increased to every month. On work package level, several informal virtual meetings, together with emails has formed the basis for close communication.
Until now, the group had WP and Board meetings physically in Madrid (Oct. 2018) and Edinburgh (Oct. 2019). An annual meeting planned to be carried out in Ljubljana in Spring 2020 was cancelled due to Covid-19 travel restrictions. A meeting planned for Orleans in autumn 2021 was also cancelled due to COVID-19 restrictions. Instead, these meetings were carried as virtual workshops.
Close cooperation between 3DGEO-EU and GARAH on a 3D pilot study area in the North Sea has been maintained by key persons working on both projects. This is also the case for the close collaboration between the GARAH project and the HIKE project.
Integration and close cooperation between GARAH and the GIP have been established early on, facilitated due to the technical staff working on both projects.

4.9 General description of the cooperation over the duration of the project

In the GARAH project, the partners of the geological surveys have been essential to achieve the task objectives and providing the necessary the national data covering the North Sea area as well as data on gas hydrates along European margins. For the gas hydrate assessment, we succeeded in collecting data from additional countries and research networks e.g the database provided by the COST Migrate network and the EdmoNet community, which resulted in an almost complete Pan-European spatial coverage.

4.10 Impact statement

The GARAH project has registered more than 30 events, meetings, online media posts etc. and has reached more than 4000 people . The majority of the reached (>4000 estimated) is the research community where 3 peer review journals, 10 abstract and one report has been prepared and presented. Estimated 500 policy makers have been reached especially in the start of the project as the latter half has seen a dramatic drop in people reached due to the Covid-19 pandemic that has limited meetings.
The impact of the GARAH assessment of selected hydrocarbon systems and its reported total resource base, and especially the new unconventional resource estimate is that it may extend field life and postpone abandonment phase as the unconventional plays occur typically where production is already taking place. In addition, understanding the current and potential resource may also support the shift from coal to domestic gas and will naturally feed into planning and policy (particularly licensing of areas for exploration) by member states, as well as commercial exploration strategies. Our mapping of remaining knowledge gaps will impact and inform academic research or programs of exploration sponsored by member states. The combined assessment of the resource base also has value for decarbonising energy in the subsurface of the North Sea, with potential for providing storage space for carbon dioxide or alternative energy carriers like hydrogen or production of e.g., blue hydrogen.
The construction of a single 3D BPSM model of the pilot study area highlighted the different interpretations and stratigraphic concepts of each country. It is expected that it will impact and encourage further harmonization across country borders without interpolation and extrapolation artefacts caused by cross-border misalignments of geological features. Furthermore, the 3D model impact future assessments of conventional and unconventional resources as the calculated volumes from the 3D model allowing for much better resource planning as well as spatial planning of the subsurface. Additionally, we

expect that the 3D model will impact the r planning of alternative usages e.g., storage of CO2 and other gases.

The GARAH gas hydrate study has demonstrated that gas hydrates in the European continental margins have been insufficiently studied from a global scope. There are critical knowledge gaps to be solved in the short to medium term. So far, WP3 has built an infrastructure of knowledge to be used as a baseline in future scientific projects. Understanding gas hydrates constitutes a unique scientific project with new data acquisition and a pan-European scope to tackle important issues such as:

The impact of our catalogue of the multiple-use (or sequential-use) potential is to further enable the European member states to understand the most efficient, sustainable, and climate-friendly use of the subsurface. The alternative use catalogue is complimented by a risk and geohazard catalogue associated with the use of the subsurface (existing and future) as well as with the gas hydrate resource mapped and assessed as part of the GARAH project. Also, the gas hydrates pose potential geohazards related to its sensitive nature that can trigger events such as tsunamis. In addition, as evidence mounts for sustained global warming, there is increased awareness of the relative importance of methane emitted to greenhouse warming. We know that the pressure and temperature conditions of the gas hydrate stability and the global distribution of gas hydrate make it susceptible to the key perturbations associated with global warming, namely relative changes in sea level (pressure) and increases in ocean temperatures. This is especially observed in several sites in the Arctic region and may also pose a long-term environment hazard within the GARAH study area.

4.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontractiong	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. GEUS	225.595,41	1.160,92	0,00	56.689,08	283.445,41	22,50%	63.769,93	219.675,49
2. IGME-Sp	69.913,69	14.092,91	0,00	21.001,65	105.008,25	22,50%	23.624,90	81.383,35
3. TNO	27.773,41	210,56	0,00	6.995,99	34.979,96	22,50%	7.869,84	27.110,12
4. BRGM	13.427,40	0,00	0,00	3.356,85	16.784,25	22,50%	3.776,14	13.008,11
5. BGR	66.729,78	230,00	0,00	16.739,95	83.699,73	22,50%	18.830,88	64.868,85
6. NERC (UKRI)	49.823,28	243,22	0,00	12.516,63	62.583,13	22,50%	14.080,03	48.503,09
7. GEOINFORM	0,00	0,00	0,00	0,00	0,00	22,50%	0,00	0,00
					586.500,73		**131.951,71**	**454.549,01**

Date:	12.11.2021
Person responsible:	Niels Schovsbo

5 PROJECT GEOCONNEC^{3}D

5.1 Identification of the project

Project full title:	Cross-border, cross-thematic multiscale framework for combining geological models and data for resource appraisal and policy support
Project acromyn:	GeoConnect^{3}d
Project reference number:	GeoE.171.009
Project topic:	Geo-energy
Project specific research topic:	GE6 - ENABLING SUBSURFACE MANAGEMENT AND DECISION SUPPORT
Project website address:	http://geoera.eu/projects/geoconnect3d6/

Period covered from: 01.01.2020 to: 31.10.2021

Report submission date:	31.10.2021
Project coordinator:	Renata Barros

Contact person for the project:	Kris Piessens
Tel:	+32 02 788 76 34
E-mail:	kpiessens@naturalsciences.be

5.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Institut Royal des Sciences Natueelles de Belgique	Geological Survey of Belgium – Royal Belgian Institute of Natural Sciences	RBINS-GSB	Belgium	998437006	Project Lead
2	Vlaams Planbureau voor Omgeving	0	VPO	Belgium		Project Partner
3	Vlaamse Instelling voor Technologisch Onderzoek VITO, affiliated or linked to VPO	0	VITO	Belgium	999645238	Third Party
4	Federalni Zavod Za Geologiju Sarajevo	Geological Survey of Federation of Bosnia and Herzegovina	FZZG	Bosnia and Herzegovina	947831524	Project Partner
5	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
6	Ceska Geologicka Sluzba	Czech Geological Survey	CGS	Czech Republic	999546783	Project Partner
7	Bureau de Recherches Géologiques et Minières	The French Geological Survey	BRGM	France	999993662	Project Partner
8	Bundesanstalt für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Partner
9	Bayerisches landesamt fur Umwelt	Bavarian Environment Agency - Geological Survey (Associated partner)	LfU	Germany	923455230	Project Partner

10	Magyar Bányászati és Földtani Szolgálat	Mining and Geological Survey of Hungary	MBFSZ	Hungary	967592364	Project Partner
11	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner
12	Administration Des Ponts et Chaussees Direction; Service Géologique du Luxembourg	National geological survey	SGL	Luxemburg	983408408	Project Partner
13	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Partner
14	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	Polish Geological Insitute	PIG-PIB	Poland	999492463	Project Partner
15	Institutul Geologic al României	Geological Institute of Romania	IGR	Romania	998906874	Project Partner
16	Geological Survey of Serbia	Geological Survey of Serbia	GSS	Serbia	919767678	Project Partner
17	Statny Geologicky ustav Dionyza Stura	State Geological Institute of Dionyz Stur	SGUDS	Slovakia	995391982	Project Partner
18	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
19	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner
20	Geologischer Dienst Nordrhein-Westfalen	0	NRW	Germany		Non-funded partner

5.3 Publishable summary

The uses the subsurface will only increase and diversify with the continued transition of the energy industry, and therefore the management of the subsurface is a pressing issue. The GeoConnect³d project developed and tested a new methodological approach to prepare and disclose geological information in a more useful and understandable way for policy support and subsurface management. This innovative bottom-up approach introduced two concepts to increase the geological understanding of an area and are aimed at providing a coherent geological context for evaluating subsurface applications and resolving subsurface management issues. The first new concept is the structural framework as a means of joining existing models of different scale and resolution to clarify the importance of geological surfaces, such as faults, contacts, lineaments, unconformities etc., in a way that makes the geology understandable to stakeholders involved in subsurface management. The second concept is that of geomanifestations. These specific expressions of geological processes are important sources of information for improving geological understanding.

The methodology was developed using the Roer-to-Rhine region and the Pannonian Basin, two areas extending over many countries in which geological settings and degree of implementation of subsurface exploitation and management differ greatly. The approach was also tested in two smaller one-country pilot areas in Germany and Ireland, and in a broader pan-European context. The resulting integrated model brings together results from all different case studies and is composed of spatial data, available in the EGDI viewer, and linked vocabulary with definitions and relations between all elements and databases with further relevant geological information. These results were critically evaluated by project partners, both involved or not in the construction of the structural framework and geomanifestation databases. It has been concluded that the GeoConnect³d approach allows the integration of complex cross-thematic research, and is beneficial to achieve cross-border harmonisation. The novel elements of geomanifestations and the use of semantic relations facilitate the communication of geological features of the subsurface. The GeoConnect³d methodology is sucessful to gather, harmonise and disclose geological knowledge to a wide range of stakeholders.

5.4 Project contribution to GeoERA project

GeoERA objectives:
1) A more integrated and efficient management of the subsurface, and
2) More responsible and publicly accepted, exploitation and use of the subsurface.

Geo-energy objectives:
1) Establishing state-of-the-art methodologies for harmonised mapping and assessment of potential resources and capacities;
2) Improving the interoperability of geological datasets that underpin such assessments, and
3) Implementing scientific intelligence and information into the policy domain considering relevant cross-thematic links to groundwater and mineral resources.

GeoConnect³d contributions to these objectives:
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 more transparent for a diverse public, including those with limited previous knowledge about geology. The methodology entails a redefinition of the structural framework model and the introduction of geomanifestations, with semantic definitions at its core to facilitate harmonisation and standardisation across borders and themes. Furthermore, developing this methodology was not the final goal of the project. The ambition of GeoConnect³d has been to disseminate these results in order to show its potential to support the management of the subsurface for geo-energy and other uses, and to demonstrate how awareness of the opportunities and limits of the subsurface is critically important by developing several use cases.

The structural framework is therefore a direct answer to the first geo-energy objective. It has already proved successful to beyond the current state-of-the-art, e.g. by being applicable to areas that span contrasting geological units (cf. Roer-to-Rhine case study). It does this by taking an alternative approach to harmonisation by introducing global semantic models, identifying 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.

The GeoConnect³d methodology developed can also a useful tool to improve the interoperability of geological information, the second geo-energy objective. The methodology ensures existing and new information is gathered in a structured way, clearly separated into spatial data, data attributes and semantic data, three pillars that are interlinked. This structure can be well embedded in current computer systems, and its clear structure also leaves open the option for automatisation in the future, so that information can be frequently updated and does not become obsolete.

The structural framework is also a frame of reference for other geological datasets. GeoConnect³d focusses on data that test or complement the geological models and geological understanding that they represent, and refers to such data as geomanifestations. This concept, besides inspiring geological curiosity and having great potential as a way to communicate with policy makers, is also part of the structural framework methodology and therefore brings together and discloses structured data about a variety of themes such as groundwater (as e.g. springs), mineral resources (as e.g. mineral occurrences), hazards (as e.g. earthquakes), and other subsurface processes (e.g. karstification). This is an important contribution to the third geo-energy objective, and to the first GeoERA objective.

GeoConnect³d also tackled the public awareness about subsurface exploitation and use (the second GeoERA objective) during its whole duration, with material that outlives the project. The project blog was a powerful tool in which articles with accessible language were posted frequently, and attracted the public's attention to several topics such as subsurface management, policy challenges, geothermal

energy, mineral resources, geophysical methods to investigate the subsurface, among many others. These articles were widely diffused using the project's social media channels (Twitter, Facebook, LinkedIn), which all continued to attract more followers until the very last month. And, as one of the preferred blog topics, the concept of geomanifestations has been succesful to attract the public's interest, linking geological wonders all around Europe with more technical discussions about e.g. subsurface processes and exploitation. GeoConnect³d also launched a YouTube channel, in which videos from public online presentations are hosted. Additionally, GeoConnect³d led two outreach initiatives aimed at a broader, non-specialised public, as part of the project's final stakeholders event together with MUSE and other external partners (Geoscience, Policy and Society): the GeoStar Challenge, to promote the understanding of past and present geological processes hidden beneath the ground by looking at their expressions reflected at the surface (also known as geomanifestations); and the virtual field trips, showing a selection of geosites that unveil and help the understanding of the potential of the subsurface. These are described in detail in Deliverable 2.1.

The ultimate goal of GeoERA was to be the first step in creating a Geological Service for Europe. In the CSA-GSE proposal, the structural framework methodology was taken up as the basis of the workpackage on geological mapping and modelling, in particular to define the geological vocabulary concepts needed at European level by the geological community, and to create the first pan-European lithotectonic map. It will also serve to the cross-thematic pilots where applied research results will be geologically framed, which can be seen as an extension of the GeoConnect³d efforts of crossing thematic boundaries with other GeoERA projects. This proves that the structural framework methodology developed by GeoConnect³d, as well as the spirit of cross-thematic and multi-resource thinking, have passed scrutinisation and are on their way to be integrated and adopted as a new and fundamental elements of the future Geological Service for Europe.

5.5 Work progress and achievements during the period

Work package 1: Project Management Plan

WP1 partners were responsible for overseeing the overall development of the project. The Project Management Board (PMB) had meetings every two weeks via WebEx and monitored closely the progress of the project.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Minutes of virtual (monthly) and physical (annual) meetings of the PMB	RBINS-GSB	Report	Project	M1	Completed	Review completed with Midterm report.
D1.1	Minutes of virtual (monthly) and physical (annual) meetings of the PMB	RBINS-GSB	Report	Project	M40	Completed	
D1.2a	First and final version of the project Data Management Plan	VITO	Report	Project	M6	Completed	Review completed with Midterm report.

D1.2b	First and final version of the project Data Management Plan	VITO	Report	Project	M40	Completed	
D1.3	Dissemination and Exploitation Plan	RBINS-GSB	Report	Project	M6	Completed	Review completed with Midterm report.
D1.4	Mid-term Project Progress and Monitoring Report	RBINS-GSB	Report	GeoERA	M19	Completed	Review completed with Midterm report.
D1.5	Project Final Report	RBINS-GSB	Report	H2020	M40	Completed	
D1.6 a	Cumulative Expenditure Report 2018,2019,2020	VITO	Report	GeoERA	M6	Completed	Review completed with Midterm report.
D1.6 b	Cumulative Expenditure Report 2018,2019,2020	VITO	Report	GeoERA	M18	Completed	Review completed with Midterm report.
D1.6 c	Cumulative Expenditure Report 2018,2019,2020	VITO	Report	GeoERA	M30	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M1 a,b,c,d	Outlook presentation of the project on the kickoff GeoERA meeting Kick-off project workshop Kick-off workshop R2R case study Kick-off workshop Pannonian Basin case study	M1	Completed	Review completed with Midterm report.
M4 a	First and second technical joint GeoERA-GE workshop	M9	Completed	Review completed with Midterm report.
M4 b	First and second technical joint GeoERA-GE workshop	M29	Completed	Review completed with Midterm report.
M6 a,b	Presentation of progress, results and highlights of the project on the mid-term GeoERA Review Meeting Mid-term project workshop	M21	Completed	Video of webinar, presentation
M10	Presentation of progress, results and highlights of the project on the final GeoERA Review Meeting	M43	Pending	

Work package 2: Interface package & Methodology

WP2 partners were responsible for: 1) the development of the structural framework methodology, resulting in the report M3 that was circulated among all partners and launched via a presentation/Q&A WebEx session in June 2019, 2) the first version of the regional structural framework, 3) the overall structure for collection and storage of geomanifestations data and 4) monitoring the interactions between GeoConnect³d and other GeoERA projects and collaborations outside of GeoERA. For 2 and 3, short reports were presented to the GeoERA Monitoring Team.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	Intra- and inter-thematic exchange logbook	TNO	Report	GeoERA	M1	Completed	Review completed with Midterm report.
D2.1	Intra- and inter-thematic exchange logbook	TNO	Report	GeoERA	M40	Completed	
D2.2	Report (in conjunction with IP) on agreed requirements for data I/O and visualization of results	TNO&RBINS-GSB	Report	H2020 (EGDI)	M6	Completed	Review completed with Midterm report.
D2.3	Report on fault property requirements (in conjunction with GE4-HIKE)	TNO	Report	H2020 (EGDI)	M6	Completed	Review completed with Midterm report.
D2.4	Report and publication(s) on the two-step framework-geomanifestation methodology	RBINS-GSB	Report	Project	M27	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M2	Launch of the GeoConnect³d website	M4	Completed	Review completed with Midterm report.
M3	Structure and guidelines for annotated structural framework methodology	M9	Completed	Review completed with Midterm report.
M5 a,b	First version regional structural framework Structure for a data management system for geomanifestations	M14	Completed	Review completed with Midterm report.

Work package 3: Roer-to-Rhine

WP3 partners were responsible for the construction of the R2R structural framework-geomanifestations model. Workshops (mostly online) were organised to encourage internal collaboration between WP3 partners.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	Scientific publication of R2R results (submitted)	RBINS-GSB	Publication	Open access	M35	Completed	
D3.2	Minutes of the workshop on subsurface management and planning	VPO&VITO	Report	Project	M36	Completed	
D3.3	Report on ways to disclose essential subsurface data and information to different stakeholders	VPO&VITO	Report	Project	M40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M7 a,b	Inventory of available geomanifestations for the R2R and Pannonian Basin case studies	M23	Completed	Report
M8 a	R2R and Pannonian Basin regional workshops on subsurface management and planning	M25	Completed	Minutes, videos of webinars
M8 b	R2R and Pannonian Basin regional workshops on subsurface management and planning	M29	Completed	Minutes, videos of webinars

Work package 4: Pannonian Basin

WP4 partners were responsible for the construction of the Pannonian Basin structural framework-geomanifestations model. Workshops (mostly online) were organised to encourage internal collaboration between WP4 partners.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Horizon and voxel 3D model, 3D fault plane surfaces of the main deformation zones in harmonisation with the stratigraphic model horizons	MBFSZ	Geological model	H2020	M29	Completed	

D4.2	A joint report on geomanifestations with their physical, spatial- and temporal (4D) analysis, validation of the 3D structural-geological model of the Pannonian basin based on their identification and evaluation of their relevance for spatial management at pilot areas. Only interpreted data will be included	MBFSZ & GeoZS	Report	H2020	M33	Completed	
D4.3	A scientific article on geomanifestations in the Pannonian Basin (IF paper, submitted)	MBFSZ & PB partners	Publication	Open access	M35	Completed	
D4.4	Report on the workshop results	MBFSZ	Report	GeoERA	M31	Completed	
D4.5a	Report on the benchmark methodology and the results of indicator calculations and evaluations	MBFSZ	Report	H2020	M40	Completed	
D4.5b	Applied (traffic-light) model	MBFSZ	Data model	H2020	M38	Completed	

Work package 5: Sharing the case studies

WP5 partners were responsible for the evaluation of the structural framework-geomanifestation results of all areas. Online meetings were organised to encourage internal collaboration between all project partners.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1	State of the art of subsurface planning and management, and avenues for improvement	PGI	Report	H2020	M24	Completed	
D5.2 a	Lessons learnt from Molasse Basin pilot (GeoERA: GE3-HotLime WP6/Task 6.3) - feeding into the HotLime Final Report	LfU	Report	GeoERA, H2020	M34	Completed	

D5.2 b	Lessons learnt from Irish case pilot	GSI	Report	GeoERA, H2020	M35	Completed	
D5.2 c	Lessons learnt from R2R case	VITO	Report	GeoERA, H2020	M36	Completed	
D5.2 d	Lessons learnt from Pannonian Basin case	MBFSZ	Report	GeoERA, H2020	M37	Completed	
D5.3	Overall conclusions and recommendations	BRGM	Report	H2020	M40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M9	Subsurface management workshop with panEuropean outreach	M36	Completed	Video of webinar, copies of presentations

5.6 Deviations

Has the project partnership identify any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of GeoConnect³d, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. The detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. The detailed list of changes is part of the project documentation in the Project plan History of changes.	No	No
The Deliverable D1.4 Mid-term Project Progress was erroneously scheduled for M17 (30.11.2019) in the original proposal.	The change from delivery in M17 from M19 (in line with the plan of all other GeoERA projects) was included in the amendment to the project plan from 19.12.2019.	No	No

The Deliverable D3.1 was originally foreseen as a publication of the R2R structural framework and geomanifestations model. Due to the inevitable delays due to COVID-19 pandemic, the results necessary for the development of this deliverable were fullt achieved late in the project's timeline, leaving a period too limited to produce and submit the high-quality publication we aspire. On the other hand, early in the project WP3 partner RBINS-GSB has dedicated special focus to geomanifestations in the form of CO2-rich groundwater springs in the AOI. This has led to a collaboration with external partners, namely the University of Liège and Spadel, and the publication of a review and reassessment of available data, as well as ways forward to a model that considers subsurface interactions and the role of faults (limits in the structural framework).	The change from a structural framework publication to one more focused on geomanifestations was included in the amendment to the project plan from 24.09.2021. This publication is an important milestone for the project and helps to demonstrate the importance of integrative models such as the structural framework to understand local geological features. Moreover, it fulfils the original objective of D3.1 to disseminate the project's results to the scientific community.	No	No
WP4 partner GEOINFORM had difficulties to fulfill GeoERA obligations and had their participation, and therefore budget, reduced.	The coordination of WP4 lead MBFSZ to acquire necessary data in a timely manner. Budget shift from Geoinform to RBINS-GSB approved by the Project Management Board and included in the amendment to the project plan from 03.02.2020.	No	No
Difficulties to communicate with WP3 partner SGL, which resulted in no data delivered on time to contribute to the structural framework-geomanifestations model. The partner underspent their budget.	Coordinator RBINS-GSB did continuous contact attempts, mostly without success. Other WP3 partners partially covered the Luxembourg area in a more general scale. The GeoERA Coordination was informed.	No	SGL's GeoConnect³d budget has been decreased by 14,250 EUR and made available to other GeoERA partners.
WP5 partner GSI overspent their budget, which is well justified by the completeness of their results delivered to the project.	The GeoERA Monitoring Team was informed.	No	GSI's budget has been increased by 52,455.11 EUR through internal transfers and from other partners.

5.7 Communication and dissemination activities

	ABSTRACTS	BLOG	FACEBOOK	INTERNAL PROJECT MEETING	LINKEDIN	MEETING WITH OTHER GEOERA PROJECTS	ORAL PRESENTATION	OTHER	POSTER	RESEARCHGATE	SCIENTIFIC PUBLICATION	TWITER	WEBINAR	WEBSITE	WORKSHOP	YOUTUBE	Total
EVENTS													9		2		11
MEETINGS				7		3		1									11
ONLINE_MEDIA		94	1		1					1		2		1		3	103
PUBLICATIONS	11						10	1	7		3						32
Total	**11**	**94**	**1**	**7**	**1**	**3**	**10**	**2**	**7**	**1**	**3**	**2**	**9**	**1**	**2**	**3**	**157**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	20	706	25	7	290	13		4	45	172	1282
MEETINGS	122										122
ONLINE_MEDIA	1048	277719	35	10	44	10	10	10	41		278927
PUBLICATIONS	5026		5		55				10	2051	7147
Total	**6216**	**278425**	**65**	**17**	**389**	**23**	**10**	**14**	**96**	**2223**	**287478**

5.8 Project management

The management of GeoConnect³d was led by the coordinator RBINS-GSB. A Project Management Board (PMB) was established at the beginning of the project and had WebEx meetings every two weeks (with few meetings skipped in case no quorum would be achieved) to assess the progress of GeoConnect³d. The reports and slides of these meetings are presented in the Deliverable 1.1.

Communication and cooperation between project partners was promoted through workshops and meetings, which shifted from mostly presential in the first half of the project to online on its second half. Cooperation with other projects was promoted throughout the duration of GeoERA by the project coordinator RBINS-GSB and WP2 partners. The final version of Deliverable 2.1 describes in details all intra- and inter-thematic interactions between GeoConnect³d and other GeoERA projects, as well as interactions and collaborations developed beyond GeoERA.

5.9 General description of the cooperation over the duration of the project

GeoConnect³d was focused on developing and testing new methodology, and because of this it was a highly collaborative project that successfully brought together geological surveys all around Europe. The majority of partners were actively involved in all or part of the naturally evolving discussions throughout the project, starting from the development of the methodology (mostly WP2 and WP3 partners), followed by the application of the methodology for data collection and discussions about needed adaptations of the methodology (WP3, WP4 and WP5 pilots), and ending with the evaluation of results and conclusions/recommendations (WP5, WP3 and WP4 partners). Collaborations between neighbouring countries were especially fruitful for WP4, which achieved an integrated cross-border stratigraphic horizon 3D model covering eight countries (Hungary, Slovakia, Ukraine, Romania, Serbia, Bosnia-Herzegovina, Croatia, Slovenia) and as a strucutral framework the first detailed cross-border map of the Pannonian Basin basement. Also for WP3, the collaboration between Belgium and the Netherlands, which had already constructed together a cross-border 3D geological model, took the harmonisation of geological information one step further based on the structural framework, and linking it across geological domains. Moreover, the majority of partners were commited to the external communication and dissemination about the project and its results by participating in the project blog, which stimulated knowledge exchange between different partners and countries. In conclusion, the transnational collaboration in GeoConnect³d was extremely valuable for exchange of expertise, harmonisation of geological information, and sharing of geological knowledge.

Below a summary of the input of each participant:
RBINS-GSB: coordination, reporting, communication and dissemination lead, development of the methodology, lead of the pan-European structural framework and contributor to the structural framework of R2R, contributor to the collection of geomanifestation data for R2R, evaluation of future application of results.
VPO: development of the methodology, lead of geomanifestation data collection for R2R, WP3 deliverables lead, part of the WP5 evaluation committee, main authors of various blogs.
VITO: development of the methodology, contributor to the structural framework of R2R, contributor to the collection of geomanifestation data of R2R, main authors of various blogs.
FZZG: contributor to the collection of horizon and 3D model, structural framework and geomanifestation data for the Pannonian Basin, main authors of various blogs.
HGI-CGS: contributor to the collection of horizon and 3D model, structural framework and geomanifestation data for the Pannonian Basin, main authors of various blogs.
CGS: contributor to the state of the art study of subsurface planning and management, part of the WP5 evaluation committee, main author of various blogs.

BRGM: contributor to the state of the art study of subsurface planning and management, WP5 evaluation committee lead, contributor to communication and dissemination events, main author of various blogs.
BGR: development of the methodology, part of the WP5 evaluation committee.
LfU: development of the structural framework of Bavaria, part of the WP5 evaluation commitee, main author in various blogs.
MBFSZ: lead of horizon and 3D model and structural framework data collection for the Pannonian Basin, contributor to the collection of geomanifestation data for the Pannonian Basin, main authors of various blogs.
GSI: development of the structural framework of Ireland, part of the WP5 evaluation committee, main author in various blogs.
SGL: small participation in the discussions about structural framework and geomanifestation data of R2R.
TNO: development of the methodology, contributor to the Dutch part of the R2R structural framework and geomanifestation data, exchange logbook caretaker, main authors of various blogs.
PIG-PIB: lead of the state of the art study of subsurface planning and management, part of the WP5 evaluation committee, main author of various blogs.
IGR: contributor to the collection of horizon and 3D model and structural framework data for the Pannonian Basin, main authors of various blogs.
GSS: contributor to the collection of horizon and 3D model and structural framework data for the Pannonian Basin, part of the WP5 evaluation committee, main author of various blogs.
SGUDS: contributor to the collection of horizon and 3D model and structural framework data for the Pannonian Basin, main author of various blogs.
GeoZS: contributor to the collection of horizon and 3D model and structural framework data for the Pannonian Basin, lead of the collection of geomanifestation data for the Pannonian Basin, part of the WP5 evaluation committee, main authors of various blogs.
GEOINFORM: contributor to the collection of horizon and 3D model and structural framework data for the Pannonian Basin, main authors of various blogs.
GD NRW: development of the methodology, contributor to the structural framework of R2R.

5.10 Impact statement

GeoConnect³d had the ambition to generate impact by 1) setting new standards for integrating cross-border and cross-thematic geological information, 2) providing a backbone to assess conflicts and synergies between subsurface uses through an approach that integrates data and knowledge from different geological disciplines, and 3) making it easier for the European GSOs to provide input to policy, allowing for the proper uptake of geological information in future societal planning. We believe the structural framework-geomanifestations methodology was succesful to meet these goals.

Having the methodology developed and tested by multiple partners in different countries and, therefore, geological settings, resulted in a robust workflow to gather and integrate geological information that can easily be followed through guidelines (D2.4) and templates. The methodology is being adopted for the continuation of GeoERA (CSA) since it has been demonstrated to be an efficient way to work cross-borders towards harmonised outputs. The methodology has also been used to teach MSc-level students in Belgium about regional geology, with their results being incorporated to the pan-European and Roer-to-Rhine structural frameworks.

We also demonstrated that the resulting model can improve the ability to predict subsurface potential e.g. thermal anomalies in groundwater and groundwater springs within the structural framework to identify sweet spots of geothermal potential, or geomanifestations of CO2-seeps that provide information on subsurface processes involving CO2 migration and are therefore relevant to improve understanding of storage potential. Moreover, the cross-thematic character of the resulting model facilitates the assessment of potential conflicts and synergies in subsurface uses. Other results of the project such as

the multiple use indicator to evaluate geothermal aquifers (D4.5a) and the traffic-light model (D4.5b) are useful tools generated at the end of the project to be promoted beyond its duration.

The scientific impact of GeoConnect³d can be estimated by the frequent presentations in international conferences (21 oral or poster presentations, most accompanied by published abstracts), as well as 2 peer-reviewed publications on the topic of groundwater-related geomanifestations as indicators of complex subsurface processes and interactions. All material is open-access. To reach beyond the scientific community of stakeholders, GeoConnect³d organised 2 interactive online workshops: a mid-term webinar series discussing the subsurface space as a cross-thematic issue (including geoheritage, groundwater and geothermal energy as sub-themes); and a final workshop as part of the Geoscience, Policy and Society event, to showcase the structural framework-geomanifestations results and its potential applications. These events have reached a total of >250 unique participants summed, attracting the attention of geological surveys, universities/research centers, private sector and governmental institutions.

GeoConnect³d also believed that the key to highlight the importance of geology in policy is to highlight its importance to our society. To this extent, we made science communication as a core task of the project, using different media to reach the most varied possible audience. Especially social media (Twitter, Facebook) and the project blog brought the subjects of the project (geo-energy, subsurface uses and interactions, subsurface management, geodata etc.) in a more accessible language to the general public. These efforts resulted in outstanding outreach and engagement (>1,000 followers on social media, >230,000 blog post reads) and interest in the project. We believe the community we built is a strong legacy that will likely contribute to the interest of the follow-up of GeoERA.

5.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontracting	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. RBINS-GSB	204.385,25	0,00	0,00	51.096,31	255.481,57	29,70%	75.878,03	179.603,54
2. VPO	37.319,09	0,00	0,00	9.329,77	46.648,86	29,70%	13.854,71	32.794,15
3. VITO	164.760,45	3.515,41	0,00	42.068,97	210.344,83	29,70%	62.472,41	147.872,41
4. FZZG	15.063,96	0,00	0,00	3.765,99	18.829,95	29,70%	5.592,50	13.237,45
5. HGI-CGS	26.329,98	67,00	0,00	6.599,25	32.996,23	29,70%	9.799,88	23.196,35
6. CGS	5.984,80	0,00	0,00	1.496,20	7.481,00	29,70%	2.221,86	5.259,14
7. BRGM	52.005,81	0,00	0,00	13.001,45	65.007,26	29,70%	19.307,16	45.700,11
8. BGR	13.403,83	0,00	0,00	3.350,96	16.754,79	29,70%	4.976,17	11.778,62
9. LfU	79.542,29	0,00	0,00	19.885,57	99.427,86	29,70%	29.530,07	69.897,78
10. MBFSZ	84.345,21	0,00	0,00	21.086,30	105.431,51	29,70%	31.313,16	74.118,35
11. GSI	96.962,70	0,00	0,00	24.240,68	121.203,38	29,70%	35.997,40	85.205,97
12. SGL	4.415,36	0,00	0,00	1.103,84	5.519,20	29,70%	1.639,20	3.880,00
13. TNO	48.132,02	101,08	0,00	12.058,28	60.291,38	29,70%	17.906,54	42.384,84
14. PIG-PIB	17.973,46	0,00	0,00	4.493,36	22.466,82	29,70%	6.672,65	15.794,18
15. IGR	27.566,24	0,00	0,00	6.891,56	34.457,79	29,70%	10.233,97	24.223,83
16. GSS	2.976,00	0,00	0,00	744,00	3.720,00	29,70%	1.104,84	2.615,16
17. SGUDS	18.203,50	0,00	0,00	4.550,88	22.754,38	29,70%	6.758,05	15.996,33
18. GeoZS	33.994,83	8,20	0,00	8.500,76	42.503,79	29,70%	12.623,62	29.880,16
19. GEOINFORM	1.978,80	0,00	0,00	494,70	2.473,50	29,70%	734,63	1.738,87
20. NRW - non-funded	23.393,68	0,00	0,00	5.848,42	29.242,10	0,00%	0,00	29.242,10
					1.173.794,08		**348.616,84**	**825.177,24**

Date:	30.11.2021
Person responsible:	Renata Barros

6 PROJECT GIP-P

6.1 Identification of the project

Project full title:	GeoERA Information Project
Project acronym:	GIP-P
Project reference number:	GeoE.171.014
Project topic:	Information platform
Project specific research topic:	IP1 - DEVELOPMENT OF AN INFORMATION PLATFORM TO SUPPORT MANAGEMENT AND PROVISION OF DATA FOR THE THREE OTHER THEMES
Project website address:	https://geoera.eu/projects/gip-p/
Period covered from:	01.01.2020 to: 31.10.2021
Report submission date:	30.11.2021
Project coordinator:	Jørgen Tulstrup (GEUS)
Contact person for the project:	Jørgen Tulstrup
Tel:	4550926411
E-mail:	jtu@geus.dk

6.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	De nationale geologiske undersøgelser for Danmark og Grønland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Lead
2	Bundesanstalt Für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Partner
3	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Partner
4	Sveriges Geologiska Undersökning	Geological Survey of Sweden	SGU	Sweden	995575991	Project Partner
5	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
6	Ceska Geologicka Sluzba	Czech Geological Survey	CGS	Czech Republic	999546783	Project Partner
7	Bureau de Recherches Géologiques et Minières	The French Geological Survey	BRGM	France	999993662	Project Partner
8	UK Research and Innovation	British Geological Survey	NERC (UKRI)	United Kingdom	906446474	Project Partner
9	Istituto Superiore per la Protezione e la Ricerca Ambientale	Italian Institute for Environmental Protection and Research	ISPRA	Italy	997905349	Project Partner
10	Geologian Tutkimuskeskus	Geological Survey of Finland	GTK	Finland	999432614	Project Partner
11	Norges Geologiske undersokelse	Geological Survey of Norway	NGU	Norway	999466758	Project Partner

12	Institut Royal des Sciences Natueelles de Belgique	Geological Survey of Belgium – Royal Belgian Institute of Natural Sciences	RBINS-GSB	Belgium	998437006	Project Partner
13	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner
14	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
15	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner
16	Institutul Geologic al României	Geological Institute of Romania	IGR	Romania	998906874	Project Partner
17	Geologische Bundesanstalt	Geological Survey of Austria	GBA	Austria	998164145	Project Partner
18	Regione Emilia Romagna (Servizio Geologico, Sismico e dei Suoli della Regione Emilia Romagna)	Geological, seismic and soil survey, Emilia Romagna Region	SGSS	Italy	999482375	Project Partner
19	Magyar Bányászati és Földtani Szolgálat	Mining and Geological Survey of Hungary	MBFSZ	Hungary	967592364	Project Partner
20	Bayerisches landesamt fur Umwelt	Bavarian Environment Agency - Geological Survey (Associated partner)	LfU	Germany	923455230	Project Partner
21	Laboratorio Nacional de Energia e Geologia I.P.	The National Laboratory of Energy and Geology	LNEG	Portugal	994187921	Project Partner
22	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	Polish Geological Insitute	PIG-PIB	Poland	999492463	Project Partner
23	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
24	Islenskar Orkurannsoknir	Iceland GeoSurvey	ISOR	Iceland	993296006	Project Partner

6.3 Publishable summary

The GIP-P was established with the aim of setting up an information system to support the other GeoERA projects (GSPs) in organising, standardising, disseminating and safeguarding their results (background data, digital maps, geological models, reports, etc).
Instead of each GeoERA project creating their systems to display maps using web-GIS, creating databases, etc., the GIP-P has done this in a standardised way thereby delivering achievements and results from GeoERA in a much more cost effective, standardised and sustainable way.
The GIP-P had 3 purposes: 1) Supporting the GSPs in reaching their specific goals, 2) Ensuring that the results from the whole GeoERA programme will be more accessible and standardised across GSPs and thereby supporting the overall aim of GeoERA to deliver solutions to cross-thematic issues and 3) Ensuring sustainability and accessibility of the digital results from GeoERA in the long term.
The technical platform for the GIP-P was chosen to be the already existing European Geological Data Infrastructure EGDI (www.europe-geology.eu). During the GIP-P this platform has been substantially further developed in three main areas: 1) Increasing the data content of the platform. It now contains geospatial data for the 14 GeoERA projects in addition to 23 other projects. The total number of map layers has been increased by approx. 600, 2) Extending the capabilities of the EGDI with a 3D geological database and visualisation, a project vocabulary based on Linked Data technology, a document repository and related search system, a general search system connected to all parts of EGDI, an upload system, and

an eLearning module with user guides, etc., and 3) Extending the functionality of the web-GIS, metadata system, central database, harvesting systems and other elements of EGDI.
The GIP-P has had strong focus on mapping the requirements of the GSPs to ensure that all these were fully described and understood by the developers. It has been an iterative process where feedback from the developers have been used to adjust the requested capabilities from the GSPs. WP2 was dedicated to this and also to define which technical extensions were needed to the EGDI in order to fulfil the needs of the GSPs.
To ensure as high a degree of standardisation as possible with regard to scientific classifications and other semantic topics WP3 analysed the data from all the GSPs and came up with suggestions for standards.
WP4 was dealing with establishing Project Vocabularies and Multilingual Keyword Thesauri for ensuring the highest possible interoperability and documentation of the scientific terms and concepts.
Development of the identified necessary extension to the EGDI platform was carried out by WP6 (user oriented functionality) and WP7 (backend functionality), and WP5 described possible future architectures for the system.
To support users in preparing and uploading data for the EGDI platform, WP8 developed user guides, videos and other material and ran a help desk.
The value of the results has been increased through the work of WP10 which includes guidance to the GSPs about Creative Commons licenses.
WP9 was working on finding solutions for the long-term sustainability of the EGDI platform and has been very much involved in the definition and writing of a proposal for a Geological Service for Europe (GSE). EGDI will be a central infrastructure in such a GSE.
Finally, W11 has disseminated the results of the GIP-P through blog posts on the GeoERA website, videos, webinars, and other channels.

6.4 Project contribution to GeoERA project

The overall aim of GeoERA – to integrate European Geological Surveys' information and knowledge on subsurface energy, water and raw material resources to contribute to sustainable use and management of the subsurface – has to a very high degree been supported by the GIP-P. Not only has the information and knowledge generated in the other GeoERA projects been made useful for all relevant stakeholders like national and regional policy makers, industry, science, SMEs and consultants by making it standardised and interoperable at a pan-European level. It has also been made easily accessible through a single point of access – the user friendly EGDI platform – and through the fact that for instance all data shown on the maps are also accessible through web map services (INSPIRE compliant in many cases). In this way the GIP-P has substantially contributed to the overall ambition of making the GeoERA results FAIR.
The scope described for projects under the GeoERA Programme Specific Research Topic "IP1 - DEVELOPMENT OF AN INFORMATION PLATFORM TO SUPPORT MANAGEMENT AND PROVISION OF DATA FOR THE THREE OTHER THEMES" has to a high degree been fulfilled in the GIP-P. The platform contains the following elements to support the other GeoERA projects:

- a central database to store geospatial data as GeoPackages (or similar GIS formats), tabular data as well as 3D geological models,
- a web-portal giving end users easy access to all results,
- an archive for other digital products like reports, images, spreadsheets,
- a project vocabulary based on Linked Data technologies for organisation of new terms, and for supporting specialised functionalities like the HIKE knowledge sharepoint,
- a metadatabase with ISO and INSPIRE compliant metadata information coupled to a multilingual Keyword Thesaurus about all geospatial results,
- a free text search system giving the user the possibility to find information across all GeoERA projects and all result types, and
- extensive user support facilities and content including an eLearning Platform.

The content and the functionalities have to a very high degree been based on the requirements from the other GeoERA projects. An organisational structure was implemented to facilitate the day-to-day exchange of information and views between the GIP-P and geoscientific projects and three rounds of bilateral meetings with the other projects have been carried out to ensure that their needs were sufficiently understood and implemented in the EGDI platform.

6.5 Work progress and achievements during the period

Work package 1: Coordination

The WP1 about Coordination has had two Tasks: 1.1) Project Management and 1.2) QA, methods, guidelines, etc.

Task 1.1 has been dealing with the organisation and conduct of the Project Assembly and Project Board meetings as well as the follow-up of those. It has not been possible to conduct physical meetings in the reporting period, but the Project Board has had monthly teleconferences and we have also had a Project Assembly meeting. Task 1.1 has also been responsible for the interaction with the GeoERA Executive Board. WP1 has furthermore been conducting the three rounds of bilateral meetings between the GIP-P and the other GeoERA projects. These have been attended by participants from WPs 2, 3, 4, 6, 7 and 8. Finally, WP 1 has carried out several rounds of consultations with the GIP-P partners in order to ensure an optimal usage of the funds. Some partners realised during the project that they were not able to contribute to the project at the expected level while other partners have taken on more work than planned. Funds have been reallocated between these partners accordingly.

In the reporting period the focus under Task 1.2 has been to follow up on the decisions and modes of operations in the other WPs by participating in many of the WP meetings and discussing the progress and results of their work.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
1.1	Project guidelines including procedures for QA, reporting and risk management	GEUS	Report	Confidential	M5	Completed	Review completed with Midterm report.
1.2	Internal progress report (1)	GEUS	Report	Confidential	M7	Completed	Review completed with Midterm report.
1.2	Internal progess report (2)	GEUS	Report	Confidential	M13	Completed	
1.2	Internal progess report (3)	GEUS	Report	Confidential	M19	Completed	
1.2	Internal progess report (4)	GEUS	Report	Confidential	M25	Completed	Covering period until M29
1.2	Internal progess report (5)	GEUS	Report	Confidential	M33	Completed	
1.2	Internal progess report (6)	GEUS	Report	Confidential	M40	Completed	Review completed with Midterm report.

1.3	Project progress meeting minutes (1)	GEUS	Report	Confidential	M2	Completed	Review completed with Midterm report.
1.3	Project progress meeting minutes (2)	GEUS	Report	Confidential	M8	Completed	Review completed with Midterm report.
1.3	Project progress meeting minutes (3)	GEUS	Report	Confidential	M14	Completed	Review completed with Midterm report.
1.3	Project progress meeting minutes (4)	GEUS	Report	Confidential	M20	Completed	
1.3	Project progress meeting minutes (5)	GEUS	Report	Confidential	M26	Completed	Covering period until M29
1.3	Project progress meeting minutes (6)	GEUS	Report	Confidential	M36	Completed	
1.3	Project progress meeting minutes (7)	GEUS	Report	Confidential	M40	Completed	
1.4	Final conference report	GEUS	Report	Public	M41	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
4	End of project	Month 40	Completed	

Work package 2: User Requirements

WP2 has been coordinating the interactions between the GeoERA geoscientific projects (GSPs) and the GIP-P. WP2 had 3 tasks: 2.1) liaison with other projects; 2.2) extract and homogenize requirements from the GSPs; and 2.3) describe extensions to EGDI.
Task 2.1 appointed liaison officers for each GeoERA research theme to assure the flow of information between the GSPs and the GIP-P. This working group continuously assessed and shared the specific information the different GIP-P WPs needed from the GSPs to carry out their tasks and vice versa. During the reporting period, the Deliverables D2.1.2 Data delivery plan and D2.1.3 Wrapping-up synergies and overlaps, highlighted between the projects in terms of geoinformation were realized. D2.1.2's objective was to facilitate the communication between the GSPs and the GIP-P, and to follow up of the data production (harmonisation, standardization, etc.) and data delivery. D2.1.3's objective was to provides an overview of the synergies in terms of geoinformation that have been established among the various GSPs. The Liaison officers continued there facilitating work between the projects and the GIP-P. Task 2.2 systematically identified and compiled the specific requirements the GSPs had in terms of data archiving, delivery and visualization. This work package identified the main formats into which each GSP would deliver their products, as well as the functionalities EGDI should have to properly archive, visualize and share their data. We also worked closely with GIP-P WP3, WP4 and WP8, making sure that the various GSPs got all the support they needed to describe, harmonize and standardize their data and metadata. Task 2.3 provided information to GIP-P WP6 and WP7 on the specific requirements the GSPs had in terms of data archiving and visualization, following up (and reporting back to the GSPs) the extension of EGDI these work packages were undertaking based on the specific needs of the GeoERA projects. During the

reporting period, the Deliverable D2.3.2 was produced. This report describes the extensions to the European Geological Data Infrastructure (EGDI) that the GeoERA Information Platform Project (GIP-P) was implementing in order to meet the user requirements of the different geoscientific projects.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
2.1.1	Highlights of the potential synergies and overlaps between the projects in terms of geoinformation	RBINS-GSB	Report	Public	M12	Completed	Review completed with Midterm report.
2.1.2	Data delivery plan	RBINS-GSB	Report	Public	M27	Completed	
2.1.3	Wrapping-up the synergies and overlaps highlighted between the projects in terms of geoinformation.	RBINS-GSB	Report	Public	M35	Completed	
2.2.1	Description of the requirements to the Information Platform by the GeoEnergy, Groundwater and Raw Materials themes	RBINS-GSB	Report	Public	M6	Completed	Review completed with Midterm report.
2.2.2.	Refinements of the requirements after feedback exchanges related to the prototypes of the EGDI database and the display interface	RBINS-GSB	Report	Public	M18	Completed	Review completed with Midterm report.
2.3.1	Mapping and description of the needed extensions to EGDI.	GEUS	Report	Public	M9	Completed	Review completed with Midterm report.
2.3.2	Fill-out of the gap between the first extensions to EGDI and the actual geoinformation produce by the projects.	GEUS	Report	Public	M21	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1	Preparatory activities finished	Month 6	Completed	Review completed with Midterm report.
2	Prototyping finalised	Month 18	Completed	Review completed with Midterm report.
3	Developments finalised	Month 35	Completed	
4	End of project	Month 40	Completed	

Work package 3: Standards and interoperability issues

The WP3 has had the scope to analyse the data products and services described by the GSPs in order to define guidelines and recommendations on the data model to be used for harmonizing the database and identifying the gaps to be covered to be able to provide all the information required. It had three tasks: 3.1 Standardization and interoperability analysis, 3.2 Data model gap analysis and technical requirements and 3.3 Standards validation procedures.
Task 3.1 analysed the data products defined by other GeoERA projects and that were reported as user requirement in D. 2.2.1 and D.2.2.2. Based on the information provided by the project a first version of data models was prepared to be shared with the GSPS and after that an update has been done when other information was provided.
Task 3.2 started from D3.1, that has designed the data model useful for other GSPs, and has defined in more detail the attributes usable in the GSPs. The task has also produced a first analysis of gaps or overlapping between data products and target data models. Finally, technical requirements to be taken into account in WP5 and implemented in WPs 6 and 7 were defined.
Task 3.3 has identified the methodology and procedure to validate data harmonization and services deployment against the standard schema validation. A set of APIs for validating the network services has been designed and some general schematron rules have been identified for the data models identified by Task 3.1. In order to monitor the recommendations on the standards and the application of the models proposed, WP3 has carried out a monitoring and supervision action in order to identify the level of implementation of the same . Furthermore, WP3 gave important inputs to contribute to the definition and evaluation of the FAIR principles regarding the data and metadata produced in GeoERA with a specific focus on geospatial data and on the aspects of interoperability and access to data.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
3.1	Data models, Standard Guidelines and Toolkits	NERC	Report	Public	M11	Completed	Review completed with Midterm report.
3.2.1	Gap Analysis and Path Extension	BRGM	Report	Public	M14	Completed	Review completed with Midterm report.
3.2.2	Technical requirements	BRGM	Report	Public	M18	Completed	
3.3	Validation service specification and requirements	ISPRA	Report	Public	M18	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1	Preparatory activities finished	Month 6	Completed	Review completed with Midterm report.
2	Prototyping finalised	Month 18	Completed	Review completed with Midterm report.

Work package 4: Semantic harmonisation issues

Two reports were delivered in the last reporting period, mainly to prepare and explain the basics and theory of Linked Data and Thesaurus to the GSPs. A final report was delivered in September 2021 to summarize the "Semantic Harmonization Issues" and describe individual semantic web implementations related to the requirements of other GSPs. The GeoERA Keyword Thesaurus (2596 subject headings) was released in Aug. 2021 as a final version 2.1 and is now used by metadata tagging and EGDI search applications. Project Vocabularies were finalized in creating, modeling, updating by authors and validation against RDF/SKOS standard in September 2021. All vocabulary data (8386 scientific concepts including 1286 bibliographic references) were designed at GBA and published at EuroGeoSurveys' "European Geoscience Registry", see data.geoscience.earth/ncl/. The 15 Project Vocabularies created for 6 different projects (GeoConnect3D, HIKE, HotLime, MUSE, HOVER and EuroLithos) took different approaches in modeling semantics. Those which are designed for elaboration of new codelists or extension of existing codelists are modeled on a generic approach. Other Project Vocabularies describing named features e.g. Fault Systems/Units by HIKE, HotLime or GeoConnect3D have taken a partitive modeling approach.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
4.1	Keyword Thesaurus (RDF file)	GBA	Other	Public	M14	Completed	Review completed with Midterm report.
4.2	Keyword Thesaurus	GBA	Report	Public	M16	Completed	Review completed with Midterm report.
4.3	GeoERA project vocabulary	GBA	Report	Public	M16	Completed	Review completed with Midterm report.
4.4	Final Report on semantic harmonisation	GBA	Report	Public	M38	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1	Preparatory activities finished	Month 6	Completed	Review completed with Midterm report.
2	Prototyping finalised	Month 18	Completed	Review completed with Midterm report.
3	Developments finalised	Month 35	Completed	
4	End of project	Month 40	Completed	

Work package 5: Architecture

The WP5 about Architecture aims at defining the IT guidelines to be applied for the GeoERA Information Platform. It has two Tasks: 5.1) Overall system and 5.2) Central system.
In the second half of the project WP5 produced 3 prototypes for data services:
- a mocked up semantic mapper, to ease the harmonization of data,
- an OGC WFS service based on: Geoserver and an ETL (Pentaho) to illustrate the power of harmonization and dissemination using standard data model accessible through APIs, and
- a SOST API service based on: FROST and an ETL (python script) to illustrate a second possibility for harmonization and dissemination using standard data model accessible through APIs.
WP5 has also conducted the FAIR group assessment which led to a consensus on FAIR principles amongst the GIP project partners.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
5.1	GIP-Blueprint (1)	BRGM	Report	Public	M16	Completed	Review completed with Midterm report.
5.1	GIP-Blueprint (2)	BRGM	Report	Public	M33	Completed	This report and report 5.2, version 2 have been merged into a report 5.3, EGDI Platform - Architecture assessment and perspectives
5.2	GeoERA Central System specification (1)	BRGM	Report	Public	M18	Completed	Review completed with Midterm report.
5.2	GeoERA Central System specification (2)	BRGM	Report	Public	M33	Completed	This report and report 5.1, version 2 have been merged into a report 5.3, EGDI Platform - Architecture assessment and perspectives

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1	Preparatory activities finished	Month 6	Completed	Review completed with Midterm report.
2	Prototyping finalised	Month 18	Completed	Review completed with Midterm report.
3	Developments finalised	Month 35	Completed	
4	End of project	Month 40	Completed	

Work package 6: Developments (user oriented)

During the reporting period WP6 has worked on enhancing the Administration module and making more functionality in the web GIS. The work has been made in close cooperation with WP7 Central development as there is on the daily basis no clear border between the central and user-oriented development. During the last part of the project the EGDI platform has been extended with:
• An advanced search functionality that allows end users to search through metadata, the uploaded datasets, and pdf-files uploaded to the document repository.
• Timeseries showing water levels from national online groundwater monitoring boreholes.
• Support of grid data with multiple values in each cell delivered on the NetCDF format.
• Support for project vocabularies (in close cooperation with WP4).
• Download of the data sets delivered to the platform on GeoPackage, GeoTIFF and NetCDF format.
• The possibility to group layers on the map into sub-groups and sub-sub-groups.
A central part of the EGDI system is the Administration Module. This module allows authorized users to deliver data to EGDI, define their own maps, and to set up their data sets / layers. Much effort has been put into making the data delivery easy and into documentation of the system. The Administration Module has in the last part of the project been made much more user friendly and has been extended with:
• Upload of documents, images and csv files to the document repository.
• Register or non-open access articles through their DOI.
• Extended to handle new functionality on the web GIS.
As a consequence of the developments of the web GIS it has been possible to set up a map (https://data.geus.dk/egdi/?mapname=geoera) including all the datasets and services produces in the 14 GSPs thereby giving a single access point to results of GeoERA and enable end users to combine all results across projects and geoscientific themes.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
6.1	Portal version 1	GEUS	DEC	Public	M3	Completed	Review completed with Midterm report.
6.2	Portal version 1.1	GEUS	DEC	Public	M7	Completed	Review completed with Midterm report.
6.3	Demonstrator portals, Version 1	GEUS	DEC	Public	M16	Completed	Review completed with Midterm report.
6.4	Portal version 2	GEUS	DEC	Public	M24	Completed	
6.5	Demonstrator portals, version 2	GEUS	DEC	Public	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1	Preparatory activities finished	Month 6	Completed	Review completed with Midterm report.

2	Prototyping finalised	Month 18	Completed	Review completed with Midterm report.
3	Developments finalised	Month 35	Completed	
4	End of project	Month 40	Completed	

Work package 7: Developments (central)

At WP7 backend components (databases, services) for various operational data management systems for the GSPs including harvesting systems, central databases, digital archive/repository, metadata system, system management tools, validation services, search system, etc. were developed (upgraded / improved / optimized). The developments have been based on the work in the other WPs, primarily WP2, 5 and 6. The results are programming code and the work carried out has primarily been done through:
• Prototype and agile development. To evaluate how the development meets the requirements and use cases.
• Repeating small and quick development cycles (develop, compile, deploy, test).
• Usage of GitLab platform (https://geusgitlab.geus.dk/egdi) as the main platform for our collaboration and where our work (documentation and code) is stored and available for developers.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
7.1	Working version Metadatabase	CGS	DEM	Public	M18	Completed	Review completed with Midterm report.
7.2	Report on testing	BRGM	Report	Public	M24	Completed	Review completed with Midterm report.
7.3	Final version of Central database / harvesting	GeoZS	Other	Public	M33	Completed	
7.4	Final version of system management tools	IGME	Other	Public	M39	Completed	
7.5	Final version of metadata catalogue and populated metadatabase	CGS	DEM	Public	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1	Preparatory activities finished	Month 6	Completed	Review completed with Midterm report.
2	Prototyping finalised	Month 18	Completed	Review completed with Midterm report.
3	Developments finalised	Month 35	Completed	
4	End of project	Month 40	Completed	

Work package 8: Data provider support

Building on the work described in the mid-term report, WP8 (Data Provider Support) has continued to operate a functioning support network (D8.3.1), triaging questions relating to data provision to the Information Platform, ensuring the questions were directed to those best placed to answer them and documenting the answers to the questions in the public GitHub forum so that they can be referenced by other users experiencing similar issues. The centralised GeoERA data provider support hub is available at https://geoera-gip.github.io/support/. In addition to the support hub, the support network also includes a buddying system where WP8 partners assist science projects in managing and preparing their spatial datasets and in providing spatial data services for inclusion in the information platform. The cookbooks (D8.1) are available from this location. They cover EGDI Data Delivery Guidance providing information describing how to deliver data to the EGDI platform. They provide information on delivering data to EGDI where you can read about the types of data that can be delivered to the EGDI platform and about the pros and cons of delivering data by upload or by data services. Information is provided on creating spatial data sets and you can find help on how to create your data sets in a way that make them most usable for the users at the EGDI platform. Instructions are provided on how to upload data sets or register data services in EGDI. Another set of cookbooks cover metadata. Data providers must have added metadata describing their data sets in the EGDI Metadata Catalogue before they can upload data sets or register data services within the EGDI. Details of how to enter metadata in conformance with the EGDI metadata profile are provided in these cookbooks. A series of e-Learning resources (D8.2) are available. The GIP-P e-Learning platform is available at http://elearning.europe-geology.eu/. The eLearning platform is based on the well-known Open Source LMS Moodle and consists of an eLearning environment designed to host all the training modules created, adapted or expanded as part of the GIP-P and, in the future, by EGDI. The training modules provided on the GIP-P eLearning platform are dynamic and will be enriched over time. The initial content focuses on examples of data standardization based on the work done by the GSPs such as HOVER (data mapping to the Observations & Measurements standard and to the OGC SensorThings API) and HIKE (which provides an example of simple feature mapping functionality). Additional content includes the use of HALE software as a tool to map source data to target data models. A series of training webinars (D8.3.2) have been held. During the course of the project, it became apparent that informal webinars and help videos would be a more effective way of supporting GSPs than holding formal online training workshops. Such content was more focussed and could be made easily available online to revisit in the future or for those who couldn't make the scheduled webinar to refer to in their own time. Such webinars and videos were also better suited to dealing with the practicalities of home working during the COVID-19 pandemic. They better supported asynchronous working and the variable schedules individuals had to adopt in order to balance the demands of their working life, home schooling and caring responsibilities. Training webinars covered the following topics: delivering data to EGDI; using the GitHub issue tracker; a series of five videos to help GSPs and other EGDI data providers better understand how to use the EGDI Metadata Catalogue and create metadata. An investigation into the use of containers (D8.4) to aid the delivery of data services was undertaken. It looked at how common enabling technologies for data service provision (MapServer, GeoServer, Degree) could be containerised to ease the process of setting up and hosting such services on operational infrastructure.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
8.1	A series of cookbooks	NERC	Report	Public	M32	Completed	
8.2	A series of e-Learning resources	ISPRA	DEC	Public	M32	Completed	

8.3.1	A functioning support network (1)	NERC	Other	Public	M12	Completed	Review completed with Midterm report.
8.3.1	A functioning support network (2)	NERC	Other	Public	M35	Completed	
8.3.2	Webinar training workshops (1)	NERC	Other	Public	M28	Completed	This report and the second planned version has been combined into one report with the title"A series of webinars and help videos for GIP data delivery"
8.3.2	Webinar training workshops (2)	NERC	Other	Public	M35	Completed	See above
8.4	A series of example Docker containers	NERC	Other	Public	M35	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
3	Developments finalised	Month 35	Completed	
4	End of project	Month 40	Completed	

Work package 9: Sustainability issues

The work in this Work Package has been centred around the formulation of a proposal for a Horizon Europe Coordination and Support Action (CSA) for the establishment of a Geological Service for Europe (GSE). There is a call for such a CSA with a submission deadline of 5 January 2022. Partners of the GIP-P are currently very active in the proposal writing and it has been decided that a specific WP will be dedicated to further develop EGDI with the purpose of supporting the scientific work in the CSA and in the longer term the GSE. The operations and basic maintenance of EGDI will be funded by the CSA during its lifetime (5 years) and another WP under the CSA will be dealing with the future governance and funding of EGDI under the GSE.
The WP has also continued the investigations regarding funding of EGDI from other sources including from the JRC and EPOS. The connection to EPOS is providing some funding for establishing services that are also useful in other contexts. The long-term governance of EGDI will be a topic in the above-mentioned CSA, but it has already been put on the agenda for more general considerations.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
9.1	Report on the analysis of possible funding sources	GEUS	Report	Public	M18	Completed	
9.2	Report on financial models	GEUS	Report	Public	M39	Completed	

9.3	Report on governance models	GEUS	Report	Public	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
4	End of project	Month 40	Completed	

Work package 10: IPR and data policy issues

Following on from the report in the mid-term report, WP10 has held several meetings with science groups and answered many questions relating to use of the Questionnaire and legal issues. Of course, the law in Europe relating to data access and use has slowly developed: the law of copyright is fairly entrenched and all countries in Europe have signed up to the various conventions such as TRIPs and the Berne Convention. All these have meant the issue of copyright is handled roughly the same in each country in Europe, although there are one or two small differences relating to use of copyright data for academic/publishing purposes. WP10 looked at the issue of data archiving and provided a comprehensive report on the matter. A number of papers were written covering the type of data-release licences best suited for use by GeoERA scientists – one such paper being "GeoERA – Licensing Models and Datasets". It was decided in the GIP-P to use the Creative Commons licences, which we well known in Europe (and throughout the world) and have the advantage of being translated into most global languages, making ease of use a real advantage. Creative Commons licences are now up to Version 4 and many of the early errors and problems have been resolved. GIP-P decided to recommend the "CC:BY" licence as the standard licence for releasing data and data products. The only constraint on this was where the original supplier of data required more commercial security for data release, potentially a CC:BY:NC licence could be used. Hence there is a degree of discretion. Open release of software would be by standard GNU licences, which are regularly used in research fields throughout the world. A webinar for the GSPs was held in November 2020 explaining about the license models.
The final deliverable (D4) emphasised the importance of all GeoERA scientists starting any new data development process by using the GeoERA Questionnaire, which also looked at the issues of personal data and the GDPR, which is now legally entrenched in all EU states. The deliverable also handled some basic assumptions about data – such as so-called raw, processed and analysed data. Derived data, which is a key consideration for GeoERA scientists, was covered and the "grey areas" of law looked at in detail. Clearly deriving materials is what a lot of scientists do (and is covered off in the Questionnaire) so it is really important for a scientist to understand where they stand legally: the worry or fear that there might be later come-back from an original data owner in many years' time is always a worry. Plus, each subsequent use the data where there is a copyright breach, mean there is a continuing breach by everyone using that data in the future. D4 also looked at the FAIR guiding principles and also the increasing take-up by countries and institutions of the FAIRification process. The paper looked finally at GDPR and the latest developments, with data protection regulators in all countries now creating more and more case law with large fines for major breaches, some being Government bodies.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
10.1	Report on questionnaire and interviews (1)	NERC	Report	Public	M7	Completed	Review completed with Midterm report.

10.1	Report on questionnaire and interviews (2)	NERC	Report	Public	M11	Completed	Review completed with Midterm report.
10.2	A report covering limitations on free movement of geodata	NERC	Report	Public	M17	Completed	
10.3	Report on new legislation covering access/open access, etc	NERC	Report	Public	M24	Completed	
10.4	A study of the risks associated with geodata delivery in Europe	GSI	Report	Public	M39	Completed	
10.5	Data Management Plan	GSI	Report	Public	M9	Completed	Review completed with Midterm report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
4	End of project	Month 40	Completed	

Work package 11: Communication and dissemination

Until the end of 2019, the communication strategy in the Communication Manual was elaborated, and the content of the website was also established. Information materials were generated (leaflets, posters) and a first video about the GIP Project was made.
From the beginning of 2020, news on the progress of the project (search system, project semantics, administration module, uploading images to the platform, etc.) and the training webinars held were generated and mainly disseminated on the project's website, blog and Twitter. Contributions were made to the GeoERA Newsletter with news on GIP-P and two more videos were produced, one on the objectives and importance of the information platform and the other on the possible applications and users of the project's results. Other videos produced by GIP-P partner institutions about the work carried out in different WPs were disseminated, including videos of the training webinars. All videos are available on the project's YouTube channel.
In the COVID context it has not been possible to participate in events, but a webinar has been organised to show the GIP-P project to ASGMI (Association of Iberoamerican Geological and Mining Surveys) with the aim of demonstrating an information platform that could be replicated in a similar way in Latin America in the future. The project was also presented at the VIII Congress on Social Communication of Science and at a press conference at IGME.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
11.1	Communication manual	IGME	Report	Public	M6	Completed	Review completed with Midterm report.
11.2	Report on website content determination	IGME	Report	Public	M7	Completed	Review completed with Midterm report.

11.3	Information content material	ISPRA	DEC	Public	M39	Completed	
11.4	Report on Performance Audit	IGME	Report	Public	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
4	End of project	Month 40	Completed	

6.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occurred)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	No
A number of times during the project we have adjusted the budget because some partners could not be engaged as foreseen in the work and others had to have their budget increased to fulfill their tasks. Overall LfU, NGU, LNEG, IGR, SGU, GSI, and GeoInform have had their budgets reduced and RBINS, IGME, GeoZS, ISPRA, and CGS have had their budgets raised.	These changes have been adopted in order to be able to deliver the described results. It became clear during the course of the project that this was best achieved through the changed described	No	No

It turned out to be difficult at an early stage of the project to come up with useful recommendations for changes to the architecture (WP5) of the platform as the requirements from the GSPs were not known at that time.	If was planned to have two version of each of the two reports D5.1 and D5.2 about the architecture of the platform. It was decided to merge the 2nd version of these into one containing recommendations for the future about the architecture into one report (D5.3).	No	No
It was decided early in the project to add a free text searching system based on a system previously developed by the partner IGME to allow users to find information across all the different types of products the GSPs have delivered. This was not foreseen in the proposal.	IGME developed an EGDI-version of the system together with other partners.	Yes	No
It was decided to include a 3D model viewer developed at GBA to work together with the 3D database delivered to the project by GEUS.	GBA developed this viewer as a modification of one developed earlier.	Yes	No
Because we wanted all GSPs to assign license models to their data we put more focus on explaining the Create Commons (CC) models and gave recommendations about these.	BGS wrote an extra report explaining the general concepts of C, the difference between the individual models and gave recommendations on which to use. A webinar was also conducted about this topic.	Yes	No
Because of the COVID related restrictions on travel we did not have a final project conference.	Instead of reporting from such a conference which was planned for a D1.4 GEUS has included in D1.4 a condensed descriptions of major goals of the project and compared those to the results.	No	No

6.7 Communication and dissemination activities

	BLOG	CONGRESS	FACEBOOK	INTERNAL PROJECT MEETING	LEAFLET	LINKEDIN	MEETING	MEETING WITH OTHER GEOERA PROJECTS	NEWSLETTER	OTHER	PINTEREST	PITCH EVENT	POSTER	SCIENTIFIC PUBLICATION	SEMINAR	TECHNICAL REPORT	TWITER	WEBINAR	WEBSITE	WORKSHOP	YOUTUBE	Total
EVENTS		2								3		3			2			7		8		25
MEDIA										2												2
MEETINGS				44			11	58		3												116
ONLINE_MEDIA	12		1			2				2	1						13		1		14	46
PUBLICATIONS					2				6				2	1		2						13
Total	**12**	**2**	**1**	**44**	**2**	**2**	**11**	**58**	**6**	**10**	**1**	**3**	**2**	**1**	**2**	**2**	**13**	**7**	**1**	**8**	**14**	**202**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	260	449		375	80		20			40	1224
MEDIA	15	100									115
MEETINGS	774			263	472					217	1726
ONLINE_MEDIA	1065	117660								193	118918
PUBLICATIONS	950	1860	5	5							2820
Total	**3064**	**120069**	**5**	**643**	**552**		**20**			**450**	**124803**

6.8 Project management

The Project Board (PB) of the GIP-P has had regular teleconference meetings approximately once per month. These have been attended by the WP leaders as well as a number of other Partners. At each PB meeting the work has been evaluated by going through the latest work and written status delivered by each WP prior to the meeting. Corrective actions have been initiated when needed.
The Project Assembly (PA) has first of all been engaged in amendments to the project plan regarding deliverables and the budget reallocations between partners.
The coordination with the GSPs has been very comprehensive. WP1 has been conducting the three rounds of bilateral meetings between the GIP-P and the GSPs. These have been attended by participants from WPs 2, 3, 4, 6, 7 and 8. Furthermore a questionnaire was sent to the GSPs in January 2021 to get their feedback on the collaboration. The results from this was used to optimise our support in the last months of the project.

6.9 General description of the cooperation over the duration of the project

The GIP-P consortium has consisted of partners with very much experience with analysis, design and implementation of information systems aimed at geoscience. The major contributors to the these tasks (primary focus in parentheses) have been GEUS (user oriented developments) , GeoZS (backend developments), IGME (search system), GBA (semantic web), CGS (metadata), BRGM (architecture), ISPRA (standardisation), TNO (backend developments) and MBFSZ (FAIR data). Requirements analysis has primarily been carried out by RBINS and IGME, user support by BGS, CGS, GEUS and GeoZS, and communication has been the responsibility of IGME. It has been a very big advantage that GEUS, GeoZS, IGME, CGS, BRGM, and BGS are also heavily involved in the operations, maintenance and development of EGDI and others (GBA, ISPRA, TNO, and MBFSZ) have brought in experience with technologies and products that has substantially contributed to the overall results. Having a consortium with this background has been absolutely fundamental to the success of it. No single partner could have done it alone.
The partners with smaller contributions have mainly been involved in testing documentations and functionalities.

6.10 Impact statement

According to the GeoERA Programme Specific Research Topic “IP1 - DEVELOPMENT OF AN INFORMATION PLATFORM TO SUPPORT MANAGEMENT AND PROVISION OF DATA FOR THE THREE OTHER THEMES” the GIP-P should “first of all add value by supporting the GSPs in structuring and disseminating their results in an up-to-date, user-friendly and harmonised form thereby strengthening the scientific and societal impact of those”. This has had the highest priority during the GIP-project through the strong focus on mapping and harmonising the requirements of the GSPs and by the selection and extension of the EGDI for the user access and we are confident that our work has had that effect.

In the longer perspective it is a requirement that the GIP-P shall “pave the way for the establishment of a single access point to the combined European geological knowledge base that links the harmonised national information systems at Europe’s GSOs”. The strong focus in the GIP-P on standards and the fact that all GeoERA results are accessible through the EGDI platform ensures this. A dedicated GeoERA instance of an EGDI map (https://data.geus.dk/egdi/?mapname=geoera) has been developed on which approx. 600 layers documenting the GSPs geospatial results is available for easy inspection, download and combination with other data. Comprehensive metadata (http://www.europe-geology.eu/metadata/) document the datasets so that the users are well-informed about the background, quality, etc. of the data of their interest and the free text system at https://geusegdi01.geus.dk/searchsystem/en/GeoERA and the document repository systems at https://search.europe-geology.eu/ makes it easy for the different user categories to find relevant results in the whole complex of data types produced by GeoERA.

The extension of the EGDI “is in itself expected to have huge scientific and societal impacts in that it must enable scientists, public and private decision makers as well as industries to get a vastly improved access to the geological information to better solve their needs regarding geological issues but also in combining the geology with information from other domains like land use, physical infrastructure, transportation, environment, biology, etc.” This again has been ensured by the emphasis on standard, FAIR data principles and the easy and user-friendly access via the EGDI.

Finally, it was required that the GIP-P “must contribute to the general Spatial Data Infrastructure of Europe by establishing or extending standards for data exchange of 3D/4D geology, etc. This is expected to enable stakeholders, like SMEs or consultants, to be able to develop services based on the GeoERA data and information results to thereby creating economic growth for Europe”. The GIP-P has not only been promoting and using the established standards it has also worked on extending those primarily through the implementation of Project Vocabularies where the GSPs’ needs have required that.

6.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontractiong	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. GEUS	344.561,40	283,75	0,00	86.211,29	431.056,44	29,70%	128.023,76	303.032,68
2. BGR	74.932,44	0,00	0,00	18.733,11	93.665,55	29,70%	27.818,67	65.846,88
3. TNO	46.510,97	8.395,87	0,00	13.726,71	68.633,55	29,70%	20.384,16	48.249,39
4. SGU	77.477,85	0,00	0,00	19.369,46	96.847,31	29,70%	28.763,65	68.083,66
5. GeoZS	234.766,18	4.479,34	0,00	59.811,38	299.056,90	29,70%	88.819,90	210.237,00
6. CGS	88.259,15	233,79	0,00	22.123,24	110.616,18	29,70%	32.853,00	77.763,17
7. BRGM	179.379,52	1.506,06	0,00	45.221,40	226.106,98	29,70%	67.153,77	158.953,20
8. NERC	125.144,35	557,20	0,00	31.425,39	157.126,94	29,70%	46.666,70	110.460,24
9. ISPRA	104.017,54	1.927,87	0,00	26.486,35	132.431,76	29,70%	39.332,23	93.099,53
10. GTK	29.378,04	196,89	0,00	7.393,73	36.968,66	29,70%	10.979,69	25.988,97
11. NGU	9.027,74	10,52	0,00	2.259,56	11.297,82	29,70%	3.355,45	7.942,37
12. RBINS	61.990,64	0,00	0,00	15.497,66	77.488,30	29,70%	23.014,03	54.474,28
13. GSI	38.312,23	0,00	0,00	9.578,06	47.890,29	29,70%	14.223,42	33.666,87
14. IGME-Sp	127.657,34	6.073,58	0,00	33.432,73	167.163,65	29,70%	49.647,60	117.516,05
15. GEOINFORM	14.218,64	0,00	0,00	3.554,66	17.773,30	29,70%	5.278,67	12.494,63
16. GIR	7.115,00	785,00	0,00	1.975,00	9.875,00	29,70%	2.932,88	6.942,13
17. GBA	15.642,00	0,00	0,00	3.910,50	19.552,50	29,70%	5.807,09	13.745,41
18. SGSS	16.473,08	0,00	0,00	4.118,27	20.591,35	29,70%	6.115,63	14.475,72
19. MBFSZ	8.984,91	0,00	0,00	2.246,23	11.231,14	29,70%	3.335,65	7.895,49
20. LfU	8.450,08	0,00	0,00	2.112,52	10.562,60	29,70%	3.137,09	7.425,51

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontractiong	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
21. LNEG	5.012,77	0,00	0,00	1.253,19	6.265,96	29,70%	1.860,99	4.404,97
22. PGI	9.490,29	0,00	0,00	2.372,57	11.862,86	29,70%	3.523,27	8.339,59
23. HGI-CGS	6.350,00	0,00	0,00	1.587,50	7.937,50	29,70%	2.357,44	5.580,06
24. ISOR	41.314,34	0,00	0,00	10.328,59	51.642,93	29,70%	15.337,95	36.304,98
					2.123.645,47		**630.722,70**	**1.492.922,76**

Date:	30.11.2021
Person responsible:	Jørgen Tulstrup

7 PROJECT HIKE

7.1 Identification of the project

Project full title:	Hazard and Impact Knowledge for Europe
Project acronym:	HIKE
Project reference number:	GeoE.171.011
Project topic:	Geo-energy
Project specific recearch topic:	GE4 – INDUCED IMPACTS AND HAZARDS
Project website address:	http://geoera.eu/projects/hike/
Period covered from:	01.01.2020 to: 31.10.2021
Report submission date:	15.11.2021
Project coordinator:	TNO
Contact person for the project:	Hans Doornenbal
Tel:	31612749686
E-mail:	hans.doornenbal@tno.nl

7.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek TNO	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Lead
2	Albanian Geological Survey	Albanian Geological Survey	AGS	Albania	951811337	Project Partner
3	Geologische Bundesanstalt	Geological Survey of Austria	GBA	Austria	998164145	Project Partner
4	Royal Belgian Institute of Natural Sciences – Geological Survey of Belgium	Geological Survey of Belgium – Royal Belgian Institute of Natural Sciences	RBINS-GSB	Belgium	998437006	Project Partner
5	Geological Survey of Denmark and Greenland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Partner
6	Bureau de Recherches Géologiques et Minières	The French Geological Survey	BRGM	France	999993662	Project Partner
7	Bundesanstalt für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Partner
8	Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg	State Office for Mining, Geology and Raw Materials Brandenburg	LBGR BRB	Germany	923483942	Project Partner
9	Landesamt für Geologie und Bergwesen Sachsen-Anhalt	State Office for Geology and Mining Saxony-Anhalt	LAGB	Germany	921579444	Project Partner
10	Bayerisches Landesamt für Umwelt	Bavarian Environment Agency - Geological	LfU	Germany	923455230	Project Partner

		Survey (Associated partner)				
11	Islenskar orkurannsoknir - Iceland GeoSurvey	Iceland GeoSurvey	ISOR	Iceland	993296006	Project Partner
12	Istituto Superiore per la Protezione e la Ricerca Ambientale	Italian Institute for Environmental Protection and Research	ISPRA	Italy	997905349	Project Partner
13	Servizio Geologico, Sismico e dei Suoli della Regione Emilia-Romagna	Geological, seismic and soil survey, Emilia Romagna Region	SGSS	Italy	999482375	Project Partner
14	Agenzia Regionale per la Protezione Ambientale del Piemonte	Regional Agency for the Protection of the Environment	ARPAP	Italy	999468892	Project Partner
15	Lietuvos Geologijos Tarnyba prie Aplinkos Ministerijos	Lithuanian Geological Survey	LGT	Lithuania	991988058	Project Partner
16	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	Polish Geological Insitute	PIG-PIB	Poland	999492463	Project Partner
17	Laboratório Nacional de Energia e Geologia	The National Laboratory of Energy and Geology	LNEG	Portugal	994187921	Project Partner
18	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
19	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner

7.3 Publishable summary

Access to clean and secure energy, mineral resources and groundwater is an intrinsic aspect of the United Nations Sustainable Development Goals. These commodities are inevitably connected with subsurface activities, yet these activities may also pose a risk to the environment and human health. Through the drilling of wells or the extraction and injection of substances, the state of the subsurface will be altered. This includes the thermochemical and geomechanical characteristics, in-situ stress state and the composition of formations and fluids which can ultimately lead to impacts at surface (e.g. ground motions, surface deformation) and to other vulnerable resources (e.g. pollution of ground- and surface waters). In order to abide to the SDG's and national regulations on safe and responsible exploitation these hazards and impacts must be minimized. HIKE supports this challenge with demonstration of methodologies and transparent information and knowledge developed by Geological Survey Organizations.

HIKE has contributed three main results to support research and investigation of hazards and impacts: i) a novel information system for faults and other tectonic features, ii) four real case studies in which advanced assessment methodologies are demonstrated, and iii) a knowledge share point for reports, tools and datasets on induced subsurface hazards and impacts. The results are a stepping stone towards integrating, harmonizing and implementing knowledge and information for responsible subsurface exploitation throughout Europe.

European Fault Database (https://geoera.eu/projects/hike10/faultdatabase/)
Faults are common geological features in the subsurface which define the characteristics and distribution of rock formations as well as the geo-mechanical response of the subsurface to natural and anthropogenic influences. Young and active (seismogenic) faults are often associated with the occurrence of natural earthquakes. Such faults are typically present in regions where the earth crust is moving due to plate-tectonic processes and stresses build up. Due to the risk posed on society, many of these faults are

registered and monitored in databases such as the European SHARE database and various national registers. The vast majority of faults in the subsurface however is inactive. These tectonic structures are either visible in surface outcrops or they appear as distinct linear/planar features and discontinuities in subsurface horizons and intervals. Many are hidden under a thick overburden. Until now there was no European online platform with a comprehensive and harmonized overview of passive and buried faults. Few online national databases exist (e.g. Italy and Austria), yet most information is dispersed and presented in varying and heterogeneous formats. In many countries the geological programmes have only limited focus on the development of a consistent national and regional overview of faults and many aspects and attributes are still underexplored. Some exceptions exist such as the GeoMOL project which focused on the 3D modelling and representation of faults in subregions of Southern Germany, Austria and Northern Italy. Detailed fault assessments are typically conducted in location-specific studies yet often these results are company-confidential or hidden in project archives. With the lack of a general fault classification framework, it is generally difficult to place these results in a regional context.
With the development of the European Fault Database, the HIKE project has taken a major step in the assessment, publication and application of national and European fault data. Besides the collection and publication of fault data and information , HIKE has also resulted in a new incentive and approach to establish and improve fault information at national and transnational level according to common pan-European workflows and standards. The development and implementation of semantic principles assists geological surveys and other knowledge institutes with the interpretation, analysis, classification and cross-border correlation of faults consistent with regional and pan-European tectonic boundary concepts. These concepts also enabling the linkage of national fault data with scientific publications and other online published datasets. Cross-border correlations can be established without the need to make these faults also geometrically consistent, thus providing a solution for the fact that datasets and status of mapping and modelling can strongly differ between regions and countries. With the integration in the European Geological Data and Information platform, the HIKE fault database is intended to provide a sustainable foundation for future fault modelling, characterization and dissemination at the European Geological Surveys.

Methods and Case studies (https://geoera.eu/projects/hike10/casestudies/)
HIKE has developed and tested novel methodologies building on top of results from previous projects and research. The work has advanced current state-of-the-art knowledge across different energy exploitation scenarios and various geological settings. The ultimate goal is to improve hazard and impact assessments and provide the basis for better standardization of these evaluations across Europe. With the joint development of methods, workflows and datasets an intensified research collaboration and improved transfer of knowledge has been established.
Different types of energy exploitation of the subsurface give rise to different challenges. These include, but are not limited to: induced seismicity, induced subsidence, as well as reservoir sealing and leakage. The processes are to a varying degree relevant for both energy extraction and subsurface storage. A common theme for these hazards is the importance of faults. Faults can guide subsurface motion as well as provide pathways for leakage. Furthermore, faults can be activated due to changes in external conditions such as pressure changes and lubrication by liquids.
Based on the participating partners' expertise four case studies have been formulated to cover as broad range of methodologies as possible. In all case studies the relevance of the fault database being established in WP2 has been explored. Furthermore, cross-cutting relations between individual case studies has been identified. The outcome of the case studies are made publicly available through the share point in WP4, publications and conference presentations and proceedings.
The following studies have been carries out:

- Advanced localization of seismic events (Denmark, Netherlands and Iceland)
Knowing the precise location of earthquakes is important for multiple reasons: 1) The registration of anthropogenic (induced) earthquakes can be a first warning sign of problems in energy exploitation and subsurface storage, 2) Careful monitoring of microseismicity in combination with precise locations can in

some cases reveal sleeping or unknown faults waking up before major triggered events occur, 3) In many cases it is important to discern causal relationships between registered earthquakes and natural or anthropogenic events in order to take appropriate preventive or mitigative safety measures.
Report D3.2 (HIKE_Improved_Seismic_Events_Localization) presents three case studies focusing on advanced localization of seismic events. The case studies cover three different aspects of subsurface utilization: a geothermal field in Iceland, a decommissioned gas field in the Netherlands and active HC producing fields in Denmark.

The case study area in Iceland is on land and equipped with a denser network of seismometers than the offshore case study areas in the Netherlands and Denmark. The selected site contains the Hverahlid Field used for geothermal energy production at the Hellesheidi power plant. For The Netherlands, we have chosen two decommissioned gas fields as case studies where seismicity occurred after the end of production: the Roswinkel and Castricum gas fields. With new initiatives to re-use old, decommissioned gas fields to energy or CO2 storage together with the fact that seismicity is still occurring at one of the decommissioned gas fields, the exact location and spatial uncertainty of the seismic events is of high importance. Similarly, in Denmark structures in the North Sea are under consideration as future storage sites for CO2. This includes both the Nini West depleted reservoir as well as the Hanstholm formation, which is unrelated to hydrocarbon production. Nini West is located far off-shore posing a challenge for land-based earthquake detection. The Hanstholm formation is close to the cost of Jutland, but also close to a known active seismic zone. Improving the quality of hypocentre solutions will add significant value to the process of maturing these reservoirs for future storage. Due to the sparsity of the seismic network and the relatively small number of earthquakes, all of Denmark is included in the analysis, not only the oil and gas producing fields in the North Sea. To make up for the scarcity of seismographs, the use of Ocean Bottom Seismometers (OBS) has been explored.

- Evaluation of methodologies for the assessment of induced surface displacements (Po Basin in Italy)
In the last years, the advanced synthetic aperture radar (SAR) interferometry (InSAR) has proven its effectiveness in the assessment of ground motion with millimetric accuracy. Its integrated use with traditional (in-situ) topographic height determination techniques, such as geometric leveling and Global Navigation Satellite System (GNSS), is consolidated in underground fluids extraction areas for detecting and monitoring land subsidence. Nevertheless, the lack of a specific standardized methodology does not allow for evaluating different results obtained from different types of analysis. Moreover, PS-InSAR (Permanent Scatterers Interferometric Synthetic Aperture Radar) interferometry data has been used in order to analyse the present crustal mobility with the aim to shed lights on the relation between fault systems and seismic activity at regional scale.
Report D3.3 (HIKE_Subsidence_Assessment_Techniques) presents two case studies: Po Plain 1, localized in Emilia-Romagna region, and Po Plain 2 in Piemonte region. The first Both case studies study show methodologies relevant for the assessment of induced hazards and impacts that are related to the exploitation of subsurface resources. Case study 2 is focused on the analysis of the relation between crustal mobility and fault systems.

- Development and application of novel methods for reservoir sealing assessment (Poland)
Together with growing industrial development and the need to halt climate change, there is an increasing interest in the potential of subsurface storage. Recently, the main focus of the underground space capacity analysis is associated with the possibility of carbon dioxide sequestration. However, the geological structures may also be used for storage of natural gas, hydrogen, or final disposal of acid gases. Bearing in mind that the stored substances are potentially dangerous for the environment, the underground rock structures have to be well-sealed to prevent any leakage from the target formation. To this end geological storage options are assessed in depleted oil and gas reservoirs, deep saline aquifers, deep-seated coal beds, salt caverns, and mines. The most important factor controlling the potential storage level is a tight caprock surrounding the confined reservoir structure. The best lithologies constituting a sealing level are evaporates and shales with high clay content. Laterally, the confinement

of the storage is often created by a convex structure such as an anticline or by a fault plane with sealing properties.
Within the presented study in D3.4 HIKE_Improved_Reservoir_Seals_Assessment, a storage option for liquids such as methane or CO2 in the Wysoka Kamieńska Graben (WKG) located in the north-western Poland is considered. Within the geological context of the study, the fundamental question was the sealing capacity of graben bounding faults to check the existence of potential pathways for fluid migration. Studies presented in the literature indicated the fault planes might act as the seal or as the conduit units, depending on geological condition. The evaluation of the fault sealing potential requires considering numerous factors: possible diagenesis, a level of compaction coupled with the overpressure, tectonic load, or recent tectonic stress field. All of these factors may significantly influence the potential risk of safe sequestration or exploitation increasing the possibility of leakage through the fault plane. Therefore, evaluation of fault sealing potential should be integrated within the basin modelling studies.

- Assessment of seismicity and safety in storage, case studies in Lacq Rousse, France
The use of underground space, and even more, its reuse always pose questions of safety of the activities. Proper assessment of structures' behaviour during and after any human activity is crucial both for safety of further activities development as well as for social approval/licence to operate. The Lacq-Rousse (Southwestern France) area is a depleted gas field, which commercial exploitations ended in 2013. A CO2 injection and storage experiment was carried out in 2010-2013 (51 kton in total) (Thibault et al., 2014). Although the CO2 injection did not induce any significant earthquakes in the area, a few felt earthquakes of magnitude up to 4.5 has been observed since 2014 (Aochi & Burnol, 2018). It is an important task to distinguish if the earthquakes are induced, triggered or cause by natural processes. And, if not natural, which activity in fact is responsible for them.
The case study D3.5 HIKE_Subsurface_Injection_Safety_Seismicity focuses on the seismicity related to underground storage in Lacq-Rousse. The seismicity in the area is monitored by public observational networks. The publicly accessible catalogue is provided by Bureau Central Sismologique Français (BCSF) and Réseau National de Surveillance Sismique (Rénass) (http://www.franceseisme.fr/sismicite.html, last accessed as of the 31st may 2021). A few earthquakes of magnitude 3.5-4.0 are known in the area. We observe that the seismicity is detected down to magnitude 1.5 in the area. Although the precise mapping of the seismicity (many earthquakes) generally allows identifying the activated fault structures, errors in the order of kilometres remain due to the sparse station distributions and the fact that the earthquakes occurred isolated with no obvious aftershocks. A single earthquake can provide useful information with moment tensor solutions to verify the coherency of the mechanism with the known fault structure and tectonic settings. The objectives of the case study were (1) archiving the available catalogues and (2) performing the moment tensor inversions of moderate earthquakes to complete our knowledge in the area.

Knowledge Share point
The knowledge share point represents a central repository and online access point for data sources, state-of-art method reports and case study outcomes relevant to an improved hazard and impact assessment. The share point has been be developed on the basis of meta-databases that incorporate links to locally hosted information sources. Thereby it provides end-user oriented search and download functionalities. The definition of a semantic framework (keywords) and implementation in a LinkedData concept, assists in linking the various contents within the share point. The knowledge share point is intended to further evolve and grow as new information is added after the project lifetime.

7.4 Project contribution to GeoERA project

European Fault Database

The HIKE Fault Database has resulted in a first-of-its-kind platform providing access to information on geological faults covering the majority of European countries including additional non-participating countries liaised with other GeoERA projects (e.g. the Pannonian Basin Area in the GeoConnect3d project). The data has been gathered from national and regional mapping programmes, repositories and new interpretations using standardized and common agreed methods and specifications (GE4-1). These methods and specifications provide a foundation for future extensions and information improvements. The implemented Tectonic Boundary Classification is intended and expected to become a major driver for better harmonized models based on similar concepts supporting stratigraphic interpretations and correlations (GE4-2).

The database provides a large extension of the current European information on seismogenic faults. With the inclusion of passive and buried faults the HIKE database provides a source for other types of fault-related research domains in a wider variety of geological settings and underground uses. So far this information was difficult to access as it only existed in local and non-harmonized archives. Both nationally and at European level this effort has resolved a major gap that became more and more apparent due to the diversification of subsurface uses, the increased attention for environmental and societal impacts and the ongoing digitalization in geosciences (GE-4). Through the implementation of HIKE Fault Database in the EGDI, the information remains available after the end of the project and the GeoERA programme while providing the opportunity to continue its development in future collaborative research activities and policy support (GE-5).

The collaboration among partner geological surveys and the developed practices in HIKE have significantly increased the knowledge base which has stimulated many countries to improve their fault models and information (GE4-2). Leading surveys with advanced fault data platforms have had an important contribution to this development. The development and implementation of the Linked Data principles and Tectonic Boundary Classification for faults is perhaps the most prominent example. This development went parallel with many other GeoERA projects which also used these principles. For this reason it has been relatively easy to exchange information and to jointly work on mutual applications (GE4-1 and GE4-5). In this context the type of information and knowledge in the database has been used as a basis for the Hazard and Impact Case Studies (GE4-3). Other foreseen applications are:

1) Investigation of natural seismic hazards (including possibilities to embed links with existing national and European information platforms)
2) Assessment of induced seismic hazards
3) Assessment of the impact of faults on potential future subsurface uses and resources (e.g.: geothermal energy, underground storage, minerals exploration, hydrocarbons and methane emissions)
4) Reconstruction of the historical geological development at large

Methods and Case studies

All case studies conducted within the HIKE project contribute to the Strategic Research Topics GE4-1, GE-2, GE-3 focusing on improvements and add-ons to the broad range of methodologies employed both in reservoirs characterisation for subsurface use planning as well as direct geo-hazard assessment and cross-cutting evaluation for more precise and reliable results. They have concentrated on seismic hazards and leakage related to human underground activities but directly connected with tectonics and faults network, being able to contribute to the FDB input on one hand and presenting opportunities how to use the data gathered in it in the future on the other. They also indicate directions of future work for further filling-in critical knowledge and information gaps in the area of geo-hazard identification, prediction and mitigation (GE4-4).

Evaluation and prediction of hazards and impacts on natural environment in Europe caused by/derived from geo-energy application is of a paramount importance both for energy security in general and for ensuring fair and even distribution of costs and benefits under the wide term of energy justice. High-quality hazard assessments in concert with state-of-the-art monitoring methods are also critical for public

acceptance of future energy exploitation and climate solutions. Case studies conducted within the HIKE project show that there is a vast catalogue of methods of such assessment, implementing wide range of technologies starting from geophysical logs interpretations, on-land permanent signals monitoring and satellite measurements of various parameters combined with advanced 3D and 4D modelling. However, credibility of their results might be questioned, especially in cases of not sufficient availability or resolution of data, a lack of good reference values and a lack of possibility of cross-checking with other existing results in some way related to problems in question. In big scale activities it might be not enough to estimate an uncertainty of performed assessment, as they might appear not sufficient for proper subsurface use planning and management. An instant development and international cooperation in the field of natural and induced hazards assessment and mitigation is a clue for further safe and efficient progress of geo-energy contribution to climate neutral Europe.

The in-depth work on hazard related methodologies in relation to geo-energy has highlighted the need to assess the long-term stability and behaviour of the subsurface with higher precision than ever before. In addition to the demand for greater precision, also quantitative knowledge of the related uncertainties is required to link individual hazards to distinct locations. The determination of geo-hazards is site specific, but the methodologies involved as well as the need for common standards is an overarching matter for all of Europe.

Hazard assessments for natural seismicity are typically not linked to the seismicity of a specific fault. Instead, the analysis is carried out for a broader area. While the classical seismic hazard methodology based on a long timeline of natural seismicity is still a necessary component, it is far from sufficient for mitigation purposes. Changing the stresses on a fault by injecting or extracting fluids for e.g. harvesting geothermal energy or storing CO2 can lead to unintended seismic activity. Being able to track the microseismicity more precisely - ideally linking it to specific faults or zones in the subsurface - can serve as a first warning of fault reactivation, allowing for action to protect public safety and infrastructure. Furthermore, precise tracking of microseismicity may allow for quick intervention if there is increased risk of CO2 or other gas escape from a deep reservoir. Improving the methodology for locating earthquakes contains several components, all of which have been explored in the HIKE project:

a) more precise hypocentres which can be achieved through denser data collection, better subsurface velocity models and more advanced analysis methods

b) a deeper understanding of the uncertainties on the hypocentres which can be achieved through various statistical methods and stochastically analysis. This aids to discern if an earthquake is related to a specific fault or not

c) full waveform inversion to obtain the earthquake source mechanism can reveal if the earthquake is related to the natural seismicity in the area or to induced stresses

The long term seismological monitoring of an already utilised reservoir (e.g. for HC production) is important to assure the security in general and for potential future usage. In case of depleted HC reservoirs it is inferred that the residual stress due to the compaction can play an important role for the continued seismicity for many years after the end of exploitation. It is crucial to estimate how long it takes to relax the residual stress for the regional seismic hazard assessment. It is also important to follow up on the seismicity and reservoir state, not only for the current security but also for the potential (re)use of the reservoir such as underground gas storage or CO2 storage as required by the EU Storage Directive (2009).

Ground motion observations can vastly contribute to geo-hazards assessment not only in case of surficial landslides but also in deep subsurface applications security assessment. In general, ground motion is correlated to several natural and anthropogenic phenomena such as tectonic activity, subsidence, underground fluid exploitation or storage. All these phenomena and activities have significant implications from an economic, environmental, and social point of view. Topographical variations can have negative impacts on the hydrodynamic setting, the hydraulic and road infrastructure, the coastline setting, the biological ecosystems, and the salinization of aquifers. Therefore, an efficient monitoring of ground movements and the best possible understanding of the causes that determine them are more than ever necessary for the relevant, countless and of various kinds implications that they have on our society.

Satellite based methodologies are explored and improved to study the present-day crustal mobility and the differential uplift mostly driven by the activity of major faults. In particular, the relative ground movements suggested by the Iso Kinematic Maps constructed from satellite measurements could give new perspectives for interpretation of present day kinematic trends. InSAR satellite-based methodology combined with geological and seismology knowledge can be useful to provide constraints on modelling earthquake source mechanisms to guide the land use and subsurface use planning, industrial layouts, urban and major infrastructure development as well as public health hazard assessment. Many challenges are related to analysing subsidence in a region naturally affected by land subsidence because of its geographical and geological features to which the effects of anthropogenic activities are added. Distinguishing the natural subsidence from the anthropogenic component requires careful analysis and measurements over extensive areas as well as detailed ground (in-situ) observations in order to validate and calibrate satellite-based data.

A sufficient sealing of subsurface reservoirs is very important with regard to resources protection (e.g. preservation of hydrocarbons plays) as well as for safety of storage utilities. Since a fault may act as a barrier for fluid flow or a migration path, appropriate recognition of its properties is extremely important for prospection of hydrocarbons and proper development planning. Sealing faults may constitute a trap forming a hydrocarbon reservoir or transform large reservoirs into smaller compartments with different reservoir pressure and fluid characteristics, hindering efficient exploitation. On the other hand, open and permeable faults may cause a loss of mud circulation leading to serious technical problems during the drilling operation (Cerveny et al., 2004; Knott, 1993) as well as environmental hazards. The fault sealing analysis is also crucial in terms of underground storage planning. To assess if a reservoir is appropriate for storage, an evaluation of its long-term confinement stability is a key point. Thus, the sealing or non-sealing properties of faults need to be evaluated considering the significant increase of fluid pressure during the CO2 or other substances injection. Proper evaluation of faults sealing potential based on shale gouge ratio is highly dependent on spatial data which allow for proper identification of fault geometry as well as geochemical data providing reliable quantitative information on clay minerals occurrence in fault-hosting rocks. Detailed information of this kind is not very common and even if exists, not easily accessible. Gathering step by step this information from existing records and further research to acquire new results especially in areas with high underground use potential or prone to seismic hazards to store them in standardised and public data base would certainly help in broader use of presented fault sealing assessment method as well as further improvement in fighting of shortages in this kind of assessment.

Each methodology tested within the HIKE project has been studied by local experts within their own country, while having regular cross-country cross-disciplinary meetings to improve the common perception of geo-hazards. The meetings have also served as a way to communicate the capabilities as well as the limitations of the individual approaches. While progress has been made within all of the fields of study, HIKE is just one important step towards better hazard assessments. Further research is needed within each methodology, and more work is needed to ensure the impact beyond the partner institutions.

7.5 Work progress and achievements during the period

Work package 1: Project Management and Coordination

Coordination of meetings and minutes (D1.2)
Established the Final Project Progress report (D1.3b)
Established the Cumulative expenditures reports (D1.4c)
Incorporated project plan amendments
Review and finalisation of all deliverables

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Project Implementation Plan	TNO	R	CO	M4	Completed	Review completed with Midterm report.
D1.2	Minutes of Meetings	TNO	R	CO	M1-40	Completed	
D1.3a	Midterm Project Progress Report	TNO	R	CO	M18	Completed	Review completed with Midterm report.
D1.3b	Final Project Progress Report	TNO	R	CO	M42	Completed	
D1.4a	Cumulative Expenditure Report 2018	TNO	R	CO	M7	Completed	Review completed with Midterm report.
D1.4b	Cumulative Expenditure Report 2019	TNO	R	CO	M18	Completed	Review completed with Midterm report.
D1.4c	Cumulative Expenditure Report 2020	TNO	R	CO	M30	Completed	
D1.5	Project Data Management Plan	TNO	R	CO	M7	Completed	Review completed with Midterm report.
D1.6	Project Communication, Dissemination and Exploitation Plan	TNO	R	CO	M7	Completed	Review completed with Midterm report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS-1	Kick-Off Seminar (obligatory GeoERA event)	M1	Completed	Brussels event
MS-2	Mid-Term Project Review (obligatory GeoERA event)	M21	Completed	
MS-3	Final Project Review (obligatory GeoERA event)	M40	Completed	online on Nov 22
MS-4	Technical workshop 1, planned together with other GeoERA projects	(Indicative M9/M10)	Completed	Vienna workshop convened March2019
MS-5	Technical workshop 2, planned together with other GeoERA projects	(Indicative M27/M28)		Not done due to Covid, in stead bi-lateral meetings with other projects > see sheet Deviations

Work package 2: Fault Database Development

The following work activities for WP2 have been executed:
- Created datamodel for the European Fault Database (FDB)
- Created structure for project vocabularies
- Created templates for data delivery
- Combined delivered data
- Connected combined data to project vocabularies
- Created data presentation
- Uploaded data to EGDI
- Configured EGDI presentation
- Created documentation

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1a	Draft Fault Data Characterization Catalogue	TNO	R	CO	M19	Completed	
D2.1b	Final Fault Data Characterization Catalogue	GBA/TNO	R	PU	M36	Completed	
D2.2a	Mid-term fault data collection report	TNO	R	CO	M19	Completed	
D2.2b	Final fault data collection report and database	TNO	R/data	PU	M39	Completed	
D2.3	Final report on fault characterization and data	TNO	R	PU	M39	Completed	
D2.4	Final report on FDB application and evaluation	TNO/GBA	R	PU	M39	Completed	
D2.5	Fault data collected by partners embedded in the European Fault database developed in cooperation with the GeoERA Information Platform	TNO/GBA	R/data	PU	M33	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS-9	End of fault data collection, start for final processing and reporting	M31	Completed	

Work package 3: Hazard and Impacts Method Development

Hazard assessment methodologies have been developed and explored in relation to:
- Advanced localization of seismicity (3 case study areas in Denmark, Iceland and The Netherlands
- Methodologies for induced surface displacement (2 case study areas in Italy)
- Reservoir sealing assessments (1 case study area in Poland)
- Seismicity and safety in storage (1 case study area in France)

Four reports (D3.2, D3.3, D3.4, and D3.5) elaborating on the details of the methodologies as well as applications thereof have been produced. Parts of the results have been published in two scientific papers. The importance of the HIKE European Fault Database to the different methodologies has been established. Furthermore, the use of the methodologies in other scenarios supporting the future societal needs for clean energy and CO2 sequestering has been discussed. Finally, a strong working relationship has been built among the participating partners across the individual case studies.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	Intermediate report specifying the concrete interaction scenarios to be investigated between WP-3 case studies and the Fault Database contents	GEUS	R	CO	M17	Completed	Review completed with Midterm report.
D3.2	Final case study report on improved localization of seismic events, Denmark, Netherlands, Iceland	GEUS	R	PU	M39	Completed	
D3.3	Final case study report on surface deformation assessment techniques, Po Basin area, Italy	ISPRA	R	PU	M39	Completed	
D3.4	Final case study report on improved assessment of reservoir seals, Poland	PIG-PIB	R	PU	M39	Completed	
D3.5	Final case study report on geological hazards and safety of subsurface injection, Rousse, France	BRGM	R	PU	M39	Completed	

Work package 4: Hazards and Impacts Knowledge

The basic specifications and functionalities for the knowledge share point were established and reported (D5.1b). The semantic framework, the specification and the core concepts (D4.2) were established from a synthesis (D4.1) of case studies (including WP3), sources and methods (including WP2), and various European studies and research projects. The document repository was developped by the GIP-Project within the EGDI framework. The knowledge base is intended to further evolve and grow as new information is added after the project lifetime. A report (D4.3) supports the implementation and dissemination of the Knowledge Share Point developed in HIKE, as a guideline. HIKE report D4.2 (HIKE_KSP_Specifications_Background) includes the relationship with the EPOS Thematic Core Services on Anthropogenic Hazards.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Final project synthesis, recommendations and best practices report	PIG-PIB	R	PU	M39	Completed	
D4.2a	Draft scientific specifications and requirements for the hazards and impacts data share point and definitions for the Semantics Web service.	BRGM	R	CO	M19	Completed	
D4.2b	Final scientific specifications and requirements for the hazards and impacts data share point and definitions for the Semantics Web service " delivery date 30.11.2019 (M36)	BRGM	R	PU	M40	Completed	
D4.3	Final data and knowledge share point implementation and report	BRGM	R/data	PU	M39	Completed	

Work package 5: Information Platform Interface

Meetings with partners to support data delivery and vocabulary delivery for fault data base were held (03/2020 - 08/2021). Meeting with other GeoERA projects (Hotlime, Geoconnect3d) for coordination of compatibility of data structures between projects were held during 2020. Support provided for HIKE keywords structure used in KSP (2020). Meeting with GIP-IP for evaluation of HIKE data structure was held (organised by GIP-IP, June 2020). Information for Metadata was collected from partners and metadata records for all partner data sets were created (04-10/2021). Implementation of functionalities in the HIKE project vocabulary were discussed with GIP-IP WP4 - Semantics (2020-2021). User Manuals for Fault Database and Knowlegde Sharepoint were written (D5.2b; 06-10/2021). Final Project Data Management Implementation report was written (D5.3; 09/2021).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1a	Technical IP requirements for the Fault Database (in EGDI)	GBA/ TNO	R	CO	M6	Completed	Review completed with Midterm report.
D5.1b	Technical IP requirements of the knowledge share point (in EGDI)	GBA/ BRGM	R	CO	M12	Completed	Review completed with Midterm report.
D5.2a	Draft user manual for the Fault Database and	GBA/ TNO	R	CO	M24	Completed	

	the knowledge share point						
D5.2b	Final user manual for the Fault Database and the knowledge share point	TNO/ GBA	R	PU	M39	Completed	
D5.3	Final Project Data Management Implementation report	GBA/ TNO	R	PU	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS-6	Start of the Fault Database architecture development in the GeoERA Information Platform (by the GeoERA IP project team)	M7	Completed	Review completed with Midterm report.
MS-7	Start of the Knowledge/data share point architecture development in the GeoERA Information Platform (by the GeoERA IP project team)	M13	Completed	Review completed with Midterm report.
MS-8	Functional implementation of the final FDB and Knowledge Share Point data architecture in the GeoERA Information Platform	M25	Completed	

7.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			YES
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	
Milestone 5 (technical workshop with other GeoERA projects) has not been done due to Covid restrictions.	Instead we have had frequent online meetings with other projects (3DGEO-EU, HOTLIME, Geoconnected3d) to incorporate their data in the database, explain and communicate guidelines and perform Quality Checks. Various projects have contributed to the overview of Fault Databasre applications (reported in D2.4)	No	

7.7 Communication and dissemination activities

	BLOG	CONGRESS	INTERNAL PROJECT MEETING	MEETING	MEETING WITH OTHER GEOERA PROJECTS	OTHER	PITCH EVENT	SCIENTIFIC PUBLICATION	SEMINAR	WEBSITE	WORKSHOP	Total
EVENTS		3					4		1		6	14
MEETINGS			2	3	3							8
ONLINE_MEDIA	1									3		4
PUBLICATIONS						1		3				4
Total	**1**	**3**	**2**	**3**	**3**	**1**	**4**	**3**	**1**	**3**	**6**	**30**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	40835		60	120	65					0	41080
MEETINGS	133				10						143
ONLINE_MEDIA		3508									3508
PUBLICATIONS	1540						2			20	1562
Total	**42508**	**3508**	**60**	**120**	**75**		**2**			**20**	**46293**

7.8 Project management

Deliverable 1.2 provides a long list of Project meeting and interactions with partners.
• Project board Meetings
• Technical workshops, instruction meetings, guidelines, templates
• WP2 Intensive FDB Meetings: data collection and country data reports
• WP3/WP4 Meetings: progress of activities, joint development of methods, integration of results
• Intensive interactions with GIP-P and other projects (e.g. 3DGEO-EU, GeoConnect3d, Hotlime)
• Joint development of concepts/keywords

Amendments to the workplan/project plan have been decided with the project team and have been approved by partners

7.9 General description of the cooperation over the duration of the project

Fault Database:
- Specifications: TNO, GBA, LFU, GeoConnect3d, Hotlime…
- Data and Country reports (all partners + 3DGeoEU, Hotlime, Geoconnect3d)
- Applications: TNO, GBA, LNEG, GEUS, BRGM, ISOR, ARPAP, ISPRA, PGI-PIB, VOGERA, GARAH, HOTLIME, GeoConnect3d, 3DGEO-EU
- FDB development and deployment: TNO, GBA, GIP-P

Methods and case studies:
- TNO, LNEG, GEUS, BRGM, ISOR, ARPAP, ISPRA, PGI-PIB

Sharepoint:
- Definition vocabs + content: BRGM, TNO, GBA, PGI-PIB, LNEG, GEUS, ...
- Development of tool: TNO, GBA, + GIP-P (repository, hosting)

7.10 Impact statement

Below is a summary of the expected impacts as reported in the proposal:

Overall GeoERA Grand Challenges

1) Economy and strategic value: Hazards and impacts may significantly raise the cost of economic activities. These costs must be evaluated in the total cost and benefit equation when assessing the net economic value of resource exploitation.
• All activities in HIKE are aimed at improving the assessment of hazards and disclosure of essential information and knowledge to such assessments.
- Fault Database: assess potential seismic hazards or failing integrity of sealing formations in storage activities
- Methods and use cases: evaluate/develop methods, improve quality of hazard assessments (seismicity, seal integrity, ground motion). Exchange knowledge, methods and experiences among surveys
- Knowledge Share Point: disclose information, knowledge , data and tools on hazard assessment to stakeholders and other surveys.

2) Welfare and health: Subsurface resources (energy, groundwater, minerals) provide benefits to society. These benefits should be in balance with the potential hazards and impacts resulting from their exploitation (see "economy and strategic value).
• The results in HIKE (Fault database, Methodology development, Knowledge Share Point) deliver information and tools to better assess these hazards and support preventive measures. (see above)

3) Climate: Escape of greenhouse gases (e.g. methane emissions) and safety of CO2 storage are typical topics in hazard research.
• Two out of the four case studies in WP3 specifically address the safety of subsurface storage, taking into account the influence of faults (WP2: Fault Dababase)

4) Safety and environment:
• This is the main scope of HIKE. The results in HIKE (Fault database, Methodology development, Knowledge Share Point) deliver information and tools to better assess these hazards and support preventive measures (see above).

Specific HIKE impacts

1) Foundation and platform for the (future) alignment of national research on geo-energy related (induced) impact and hazard assessments across Europe.
• Activities and deliverables in WP2, WP3 and WP4 have led to concrete collaboration and knowledge-sharing among partners and partner projects. With the available developed concepts the HIKE project needs to engage external stakeholders (applicability for use cases, align with relevant projects and science platforms). We are currently linking with national case studies, regulators as well as the EU research infrastructure EPOS.
• The HIKE project has created a first-of-its-kind European Fault Database that has collated and harmonized relevant information and knowledge on all types of geological faults.This unique product enables current and future dissemination on faults which was not available before. The Fault Database is interlinked with other (external) databases on seimsic hazards (e.g. SHARE, ITHACA) and have resulted in a better integration and correlation of EU faultdata.

2) Means and support to develop and improve methods to predict, prevent and mitigate hazardous and polluting effects induced by subsurface exploitation
• This is concretely done in WP3 in actual use cases. WP4 works on making these results available to the broader science community. We engage EPOS to enhance the integration outside GeoERA

3) Contribution to the reduction of economic and societal costs resulting from such effects by minimizing the risks.
• The information collected in the Fault database is resulting from billions of euro's worth in data acquisition (e.g. O/G data, decades of data acquisition and mapping in national geological survey programmes). These data are now prepared and disseminated and will reduced costs that would otherwise be spent in subsurface assessments (e.g. mapping of faults)
• The Fault database is connected to clear hazard cases. In partner countries the application of the fault databse is evaluated in the context of national induced seismic hazard asessements. With a succesfull implementation we can better avoid such seismic risks (reduce societal costs) and make assessment more efficicient (reduce assessment costs).
• In relation to the HOTLIME project: the faults in the fault database can be used to better assess geothermal resources and reduce risks of failing projects (e.g. expensive drilling)

4) Translate the achievements and results to the policy and societal domains.
• With the specification of the Knowledge Share Point HIKE identifies specific user groups. The semantics concept framework is developed to assist non-technical end-users to information that is relevant for them (assisted search).
• The knowledge generated in WP3, in particular in relation to improved methodologies for locating earthquakes will be built upon in the ACT3 project SHARP starting 1. November 2021.
• Moreover, the need for a standardized methodology for calibrating InSAR data has been considered in the implementation of the European Ground Motion Service that will be released by the European Environment Agency in the first quarter of 2022.

5) Help countries to improve their own assessment and determination of induced hazards and impacts.
• These impacts are reached with the collaboration in WP3 (methods/use cases), the knowledge sharepoint (joint framework and definition of vocabulary terms, sharing documents/tools) and the common specifications and structures of the fault database and knowledge share point. These products are aligned with other external platforms (interfaces). The knowledge on fault characterization is shared between countries in various workshops (including links to other projects)

6) Allow stakeholders and end-users to benefit from the established results and thereby avoid unnecessary data acquisition and research costs.
• HIKE has delivered the technical and scientific specifications. The joint development of the platform infrastructure is programmed between the projects and will be realized towards end of 2020 (prototyping, elaborating the final platform). Inrelation to EPOS it is possible to align repositories and reduce costs of double work.
• The information collected in the Fault database is resulting from billions of euro's worth in data acquisition (e.g. O/G data, decades of data acquisition and mapping in national geological survey programmes). These data are now prepared and disseminated and will reduced costs that would otherwise be spent in subsurface assessments (e.g. mapping of faults)

7) The transparency and open access to information are considered first principles and requisites for public awareness creation.
• One of the main goals for HIKE is to bring the results and achievements under the attention of external stakeholders and the public. Surveys have their own interactions with local/regional/national stakeholders and end-users. All results are open and publicly accessible through EGDI (following FAIR data principles).

7.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual		(0,25*A+B)				
1. TNO	133.067,45	49,57	33.279,26	166.396,28	29,70%	49.419,69	116.976,58
2. AGS	14.836,00	1.500,00	4.084,00	20.420,00	29,70%	6.064,74	14.355,26
3. GBA	98.020,02	0,00	24.505,01	122.525,03	29,70%	36.389,93	86.135,09
4. RBINS-GSB	14.416,74	0,00	3.604,18	18.020,92	29,70%	5.352,21	12.668,71
5. GEUS	73.230,96	0,00	18.307,74	91.538,70	29,70%	27.186,99	64.351,71
6. BRGM	50.336,91	238,16	12.643,77	63.218,84	29,70%	18.775,99	44.442,84
7. BGR	18.066,48	0,00	4.516,62	22.583,10	29,70%	6.707,18	15.875,92
8. LBGR BRB	6.225,03	0,00	1.556,26	7.781,29	29,70%	2.311,04	5.470,25
9. LAGB	15.792,50	3.561,10	4.838,40	24.192,00	29,70%	7.185,02	17.006,98
10. LfU	56.403,10	0,00	14.100,78	70.503,88	29,70%	20.939,65	49.564,22
11. ISOR	78.322,00	0,00	19.580,50	97.902,50	29,70%	29.077,04	68.825,46
12. ISPRA	56.865,71	624,80	14.372,63	71.863,14	29,70%	21.343,35	50.519,79
13. SGSS	7.940,77	0,00	1.985,19	9.925,96	29,70%	2.948,01	6.977,95
14. ARPAP	14.014,00	0,00	3.503,50	17.517,50	29,70%	5.202,70	12.314,80
15. LGT	13.202,03	632,40	3.458,61	17.293,04	29,70%	5.136,03	12.157,01
16. PIG-PIB	68.738,24	0,00	17.184,56	85.922,80	29,70%	25.519,07	60.403,73
17. LNEG	33.260,70	2.270,32	8.882,76	44.413,78	29,70%	13.190,89	31.222,88
18. GeoZS	21.020,40	0,00	5.255,10	26.275,50	29,70%	7.803,82	18.471,68
19. GEOINFORM	9.459,69	0,00	2.364,92	11.824,62	29,70%	3.511,91	8.312,70
	783.218,73	8.876,35		990.118,85		294.065,30	696.053,55

Date:	15.11.2021
Person responsible:	Hans Doornenbal

8 PROJECT HOTLIME

8.1 Identification of the project

Project full title:	Mapping and Assessment of Geothermal Plays in Deep Carbonate Rocks – Cross-domain Implications and Impacts
Project acromyn:	HotLime
Project reference number:	GeoE.171.007
Project topic:	Geo-energy
Project specific recearch topic:	GE2 - Geothermal Energy
Project website address:	http://geoera.eu/projects/hotlime6/
Period covered from:	01.01.2020 to: 30.06.2021
Report submission date:	00.08.2021
Project coordinator:	Dr. Gerold Diepolder
Contact person for the project:	Dr. Timo Spörlein
Tel:	+49 9281 18004741
E-mail:	hotlime.geoera@lfu.bayern.de

8.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Bayerisches Landesamt für Umwelt	Bavarian Environment Agency	LfU	Germany	923455230	Project Lead
2	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner
3	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for Applied Scientific Research	TNO	Netherlands	999988909	Project Partner
4	Vlaams Gewest (Planbureau voor Omgeving) [represented by third party VITO]	Flemish region (Bureau for Environment and Spatial Development)	VLO	Belgium	999575107	Non-funded partner
5	Geologische Bundesanstalt	Geological Survey of Austria	GBA	Austria	998164145	Project Partner
6	Regierungspräsidium Freiburg	Regional Council Freiburg	LGRB	Germany	942768124	Project Partner

7	Istituto Superiore per la Protezione e la Ricerca Ambientale	Italian Institute for Environmental Protection and Research	ISPRA	Italy	997905349	Project Partner
8	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
9	Servizio Geologico, Sismico e dei Suoli della Regione Emilia Romagna	Geological, seismic and soil survey of Emilia Romagna Region	SGSS	Italy	999482375	Project Partner
10	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
11	Office of Prime Minister [formerly: Ministry for Transport and Infrastructure]	Office of Prime Minister Ministry for Finance and Employment OPM MFE	OPM	Malta	953280111	Project Partner
12	Agenzia Regionale per la Protezione Ambientale del Piemonte	Regional Agency for the Protection of the Environment	ARPAP	Italy	999468892	Project Partner
13	State Informational Geological Fund of Ukraine *)	State Informational Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner
14	Česka geologická služba	Czech Geological Survey	CGS	Czech Republic	999546783	Project Partner
15	Regione Umbria - Sevizio geologico	Umbria Region - Geological Survey	RU	Italy	997980233	Project Partner
16	Institut Cartogràfic i Geològic de Catalunya	Institut Cartogràfic i Geològic de Catalunya	ICGC	Spain	935977542	Project Partner
4a	Vlaamse Instelling voor Technologisch Onderzoek [third party to VLO]	Flemish Institute for Technological Research	VITO	Belgium	999645238	Third Party

8.3 Publishable summary

Hydrothermal systems in deep carbonate bedrock are among the most promising low-enthalpy geothermal plays across Europe. Apart from a few areas where viability of hydrothermal heat and power generation has been proved, most deep carbonate bedrock has received relatively little attention, because, particularly in low-enthalpy systems, where tapping suitable temperatures for geothermal energy commonly requires drilling to depths of more than 3 km, exploration and development of the deep subsurface is an acknowledged high-risk investment and baseline data for focusing, thus de-risking, E&P have not been available or harmonized. Beyond HotLime's basic objective, the cross-fertilising collaboration among the project partners – contributing knowledge, experience and skills thereby bringing the partners to a common, higher level –, HotLime was geared towards the mapping, characterization, estimation, comparison and prospect ranking of hydrothermal plays in deep carbonate rocks from different target areas across Europe. During the first half of the project mapping and characterization was implemented and reported in detail in HotLime Midterm Summary Report. In the second half, estimation, comparison, geothermal base assessment and map production was accomplished, with all results summarized in HotLime's Knowledebase, the Atlas of Carbonate Rock Geothermal Reservoirs Across Europe. This comprehensive overarching product of HotLime, retrievable via HotLime's EGDI web site, includes map sets of all 11 case study areas under investigation, hyperlinked

with cross-sections of the geological setup, factsheets with underpinning information, the comprehensive HotLime reports, as well as HotLime's Linked Open Data Semantic Web vocabularies on features represented in the maps and cross-sections. All spatial products prepared are also exploitable as georeferenced, downloadable map series in the EGDI map viewer attached to HotLime's EGDI web site and are supplemented by the topical reports of HotLime, elucidating applied methods and their constraints, publicly available via the EGDI docs repository: the Report on play and prospect evaluation (D3.1), the Report on carbonate play development strategies and impact (D4.1) and the HotLime partners' legislation synopsis (5.1.1).

8.4 Project contribution to GeoERA project

HotLime substantially contributes to GeoERA's objective to integrate the GSO's information and knowledge on clean (low-carbon) and efficient subsurface energy, at the heart of the H2020's Societal Challenge 3, and with this more specifically underpins the aim of Geo-Energy theme to develop transparent, harmonized and science-based pan-European information and knowledge on the subsurface potential to deliver energy resources. The joint approach of HotLime's partners in characterizing and assessing the geothermal potential in deep carbonate reservoirs, based on state-of art methodologies for harmonized mapping and common assessment methods, results in pan-European data and information services on the distribution of geo-energy hyperlinked to various explanatory reports and factsheets. Such Information in understandable form will enable policy decisions to support a safe and responsible exploitation of subsurface resources and capacities. Implementing scientific intelligence and information into the policy domain considering relevant cross-thematic links to groundwater and mineral resources will help to evaluate competition, interference and synergies between different uses of subsurface space.

8.5 Work progress and achievements during the period

Work package 1: Project Coordination

WP1 was/is responsible to perform daily management of the project (monitoring of progress, communication between partners/work packages and with the TC and GeoERA Executive Board, financial management, reporting, decision making, contingency and conflict management). In the COVID impacted M19-36 period this has been implemented exclusively by web conferences and intensifying e-mail exchange.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1.1	Project Implementation Plan	LfU	Report	GeoERA internal	M3	Completed	Review completed with Midterm report.
D1.1.2	Minutes of Meetings	LfU	Minutes	GeoERA internal	M1-36	Completed	submitted as bundle 2021-08-12
D1.1.3	Project Progress and Monitoring Report	LfU	Report	GeoERA internal	M18	Completed	Review completed with Midterm report.

D1.1.4	Final Project Progress Report	LfU	Report	public via GeoERA	M36	Completed	this document
D1.1.5	Annual Expenditure Reports	LfU	Report	GeoERA internal	M12	Completed	Review completed with Midterm report.
D1.1.5	Annual Expenditure Reports	LfU	Report	GeoERA internal	M24	Completed	Review completed with Midterm report.
D1.1.5	Annual Expenditure Reports	LfU	Report	GeoERA internal	M36	Completed	Re-scheduled to M 30 (Cumulative Expenditures 2020)
D1.2	Project Communication and Exploration Plan	LfU	Report	public via GeoERA	M6	Completed	Review completed with Midterm report.
D1.3	Project Data Management Plan	LfU	Report	GeoERA internal	M6	Completed	Review completed with Midterm report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS7	Final reports finalized, all data in EGDI	M36	Completed	Reports available

Work package 2: Characterization & Mapping

Operationally finalized in M 18, in M19-36 period the Report D2.0 was delivered and a publishable summary "HotLime Mid-term Summary Report" was published via HotLime's website. D2.0, originally classified "internal", was published in M36 as part of HotLime's all-embracing knowledge base.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.0	Summary report of resources mapping and characterization, catalogue of methods and required parameters, best practice and guidelines	LGRB	Report	public via IP	M18	Completed	Review completed with Midterm report.
D2.1-D2.10	Geology of prospective geothermal	LGRB	10 Map series	public via IP	M18	Completed	Review completed with

	reservoirs parameterized / categorized		3D models				Midterm report.
D2.1	3D geological model of the central Molasse Basin (DE, AT)	LfU	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.2	3D geological model of the Jurassic limestone reservoir of the Molasse Basin Carpathian - Foredeep transition zone	GBA	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.3	3D geological models of the Lough Allen Basin and Dublin Basin	GSI	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.4	Base & top maps of Dinantian carbonates of the London-Brabant Massif franls (NL, BE)	TNO	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.5	An improved 3D model of Po Basin from Piemonte region to the Adriatic coastline	ISPRA	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.6	3D structural and geological model of geothermal reservoir of Krško-Brežice sub-basin	GeoZS	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.7	Constructed model of the Zagreb geothermal field	HGI-CGS	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.8	A2D structural and geological model of the geothermal reservoir close to the Pantelleria-Linosa Malta rift	OPM	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.9	2D maps and 3D geological model of the Empordà Basin	ICGC	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.
D2.10	2D structural and geological model of the geothermal reservoir in the Tuscan-Umbria-Marche units	RU	Map series / 3D model	public via IP	M18	Completed	Review completed with Midterm report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS1	Concepts of 3D-modelling are coordinated	M6	Completed	Review completed with Midterm report.
MS2	3D-models and map series available	M18	Completed	Review completed with Midterm report.

Work package 3: Play/Prospect Evaluation

WP3, due to COVID extended to M30, was pooled into one task as it builds upon the mapping results of HotLime WP2, feeding into a iterative process for generic and representative evaluation, classification and ranking. Readily available fast models were selected based on public domain, in-house and/or commercial reservoir simulators. This task should have been lined up with activities of GE2-Geo4Sure for methodology and classification (WP6, Task 6.2), however this had to be cancelled as Geo4Sure was not funded, thus implemented. For HotLime's case study areas it turned out that so much uncertainty exists about the level of confidence of the estimate (resources and reserves) that application of the UNFC classification is not useful. This especially holds for the lack of data regarding developing projects, and reservoir quality data required to estimate producible resources. Therefore, emphasis was put on the calculation of the heat-in-place (HIP) using a set of common reservoir parameters. The results of HIP geothermal base assessment and the considered baseline data are represented in the HotLime Geothermal Atlas Knowledgebase and downloadable from the EGDI platform. D3.1.4, a stochastic HIP calculation tool, was achieved by PP16 ICGC, in collaboration with University of Barcelona.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1.1	Best practice manual for resource assessment	TNO	Report	public via IP	M33	Completed	Bundeled in one all-embracing D3.1 Report
D3.1.2	Spatial resource assessment in areas in focus	TNO	Map series 3D models	public via IP	M33	Completed	publicly available via EGDI Doc Repository:
D3.1.3	Classification system for plays and prospects	TNO	Webbased tool	public via IP	M33	Completed	https://repository.europe-geology.eu/egdidocs/hotlime/hotlime_deliverable_31.pdf
D3.1.4	Quantitative assessment tool for carbonate rocks	TNO	Webbased tool	public via IP	M33	Completed	Chapter 3 in D3.1 Report

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS3	Report and classification system are set	M24	Completed	Review completed with Midterm report.

Work package 4: Deep Carbonate Play Development

The objective of WP4 is to compare knowledge and experience of exploration for geothermal energy in carbonate basins and to seek those common geological factors that can inform exploration, reduce uncertainty (risk) and enhance the chance of success of a project. It examined the development of several deep geothermal projects from HotLime partner countries in order to compare and contrast application strategies and approaches to developments of carbonate geothermal projects. The results of WP4 provide learnings from these case studies to: 1) improve future development strategies; 2) identify and mitigate risks pertinent to carbonate targets; and 3) support policy-making. The learnings are compared to the resource risk mitigation recommendations of https://www.georisk-project.eu to specify these for carbonate geothermal reservoirs. As the technical geothermal planning issues queried in the WP5 questionnaire completely overlap the WP4 topics, D5.1.2 "Geothermal planning recommendations" tacitly is an integral part of the D4.1 report.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Report on deep carbonate play development strategies and impacts	GSI	Report	public via IP	M36	Completed	LINK

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS6	Play development report finished	36	Completed	LINK

Work package 5: Knowledge transfer

In the first half of HotLime project implementation the project team have identified the main stakeholders (around 100), the list of which was continuously updated and it was finalised at 192 identified stakeholders. This will probably be consulted and updated and expanded through collaboration in follow-up projects and initiatives. The list encompasses regulatory bodies, water and energy authorities, national/regional/local governing bodies, users and potential users, scholars and academics, NGOs nad LAGs, as well as the general public. This transnational database of cross-sectoral stakeholders is included in the final project report with more details. -- In the second half of the project partners were asked to summarise the regulatory framework concerning research and utilisation of geothermal waters and to provide input on the problems concerning such regulation and its implementation in their respective countries via a standardised questionnaire. Based on that, the "Licensing and regulation report" and "Geothermal planning recommendations" were devised (D5.1.1 and D5.1.2, the latter as integral part of D4.1)

Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1.1	Licensing regulations report	HGI-CGS	Report	public via IP	M36	Completed	LINK

D5.1.2	Geothermal planning recommendations	HGI-CGS	Report	public via IP	M36	Completed	Integral part of D4.1 Report on deep carbonate play development strategies and impacts
D5.1.3	Joint information event	HGI-CGS	Report	public	M30		Cancelled due to Covid restrictions - replaced by 2020-11-12 GeoEnergy webinar with presentations of all GE projects
D5.2.1	Specifications/technical requirements for data repository/semantic web	LfU	Report	IP	M18	Completed	Review completed with Midterm report.
D5.2.2	Glossary of technical terms (feature data code lists)	LfU	dbase	public via IP	M33	Completed	D5.2.2. and D5.2.3 as fact sheets integrated into the all-embracing HotLime Knowledgebase:
D5.2.3	Knowledge database	LfU	dbase	public via IP	M36	Completed	LINK

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS4	Knowledge base prepared for upload	30	Completed	LINK

Work package 6: Project-Project Interface

WP6 coordinated the cross-topic intersections with HIKE and GeoConnect3d to exploit the synergies with these projects and to add value either-way and to the GE theme in general. It governed the knowledge transfer for preparing the takeover and uptake of data and to information from/to other projects and to ensure a harmonized rendering. The semantic Web vocabularies on tectonic boundaries of HotLime's case study areas featuring a comprehensive inventory of the fault network have been shared / interlinked with the HIKE vocab. Likewise, the fault traces have been integrated into the European Fault Database of HIKE. The GeoConnect3d methodology has been tested in two HotLime pilot areas of contrasting geological setting.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D6.1.1	Fault property requirements and exchange logbook	LfU	Report	GE4-HIKE	M18	Completed	Review completed with Midterm report.
D6.1.2	Implementation of fault network in FaultDB	LfU	dbase population	public	M36	Completed	LINK LINK
D6.3	Geomanifestation methodology evaluation log	LfU	Report	GE6-GeoConn	M33	Completed	GeoConn D5.2a and D5.2b

Work package 7: IP Interface

WP7 governed HotLime's interactions with the GIP-P in order to safeguard the standardized representation of geoscience information and to ensure that the requirements addressed in D7.1 and 7.2 are properly implemented. To this end the systematic organization and joint representation of maps and the HotLime Knowledgebase was stipulated in several bilateral telcos and the intense email exchange specifically with GIP-P WP4 in charge for the Semantic Web vocabularies. However, with all HotLime products ready for upload by mid of June, the upload of the spatial products turned out a real challenge. As the first SRP to end, thus spearheading trial & error in uploading products to the EGDI publication and dissemination tools and interlinking HotLime's Knowledge Base also with information of other projects, required a lot of advice and support by the GIP-P team, willingly granted but limited due to the holiday season. Thus by the time of drafting this FPPR the upload of raster maps is not completed for all HotLime case study areas.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D7.1	Specifications/technical requirements for EGDI spatial data repository	LfU/LGRB	Report	IP	M6	Completed	Review completed with Midterm report.
D7.1	Specifications/technical requirements for EGDI spatial data repository	LfU/LGRB	Report	IP	M12	Completed	Review completed with Midterm report.
D7.2	Requirements catalogue for the common knowledge base	LfU	Report	IP	M18	Completed	Review completed with Midterm report.

D7.3	Final data/project results implementation report	LfU	dbase population	public	M36	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS5	Data and product transfer to IP finalized	30	Completed	IP approval

8.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities. Due to the unpostponable retirement of the PL, effective 0202-09-01, specifically this project was not extended. Minor internal delays of project activities (thereby keeping the overall runtime of HotLime and the finalization of all deliverables and spatial products as well as meeting the milestones) have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	Not yet clear how to deal with the considerable underspending of some partners (see 9. Financial statements)
At the very end of HotLime, with all products prepared by July 2012, it turned out that beyond the minor internal adjustments mentioned, the collaboration with other, extended GeoERA Projects was toilsome and generated unexpected delays. Specifically spearheading the upload of spatial data to EGDI and linking HotLime's Knowledge Base with the data.geoscience.earth GeoERA vocabularies faced major embarrassments, as the projects in charge of deployment have not been as far as expected.		No	

8.7 Communication and dissemination activities

	ABSTRACTS	CONGRESS	FACEBOOK	INTERNAL PROJECT MEETING	LEAFLET	MEETING	MEETING WITH OTHER GEOERA PROJECTS	NON SCIENTIFIC PUBLICATION	OTHER	SCIENTIFIC PUBLICATION	TRAINING	WEBSITE	WORKSHOP	Total
EVENTS		8									1		1	10
MEDIA									2					2
MEETINGS				10		4	1							15
ONLINE_MEDIA			2									1		3
PUBLICATIONS	6				1			3		7				17
Total	**6**	**8**	**2**	**10**	**1**	**4**	**1**	**3**	**2**	**7**	**1**	**1**	**1**	**47**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	10774	400									11174
MEDIA	20										20
MEETINGS	180			15	16		40				251
ONLINE_MEDIA		30000			50	100	20		30	50	30250
PUBLICATIONS	61352	500		1		100				50	62003
Total	**72326**	**30900**		**16**	**66**	**200**	**60**		**30**	**100**	**103698**

8.8 Project management

In the M19-36 reporting period, LfU as Project Coordinator and the WP leads (GSI, TNO, LGRB, HGI-CGS) continued as a steering group with responsibilities to monitor the project progress in line with all relevant regulations and proceedings. However, this coordination and steering was strongly impaired with the impact of COVID, means, the successful face2face project meetings, hands-on seminars and ad-hoc bi-/multilateral status meetings of the M1-18 period had to be surrogated by web conferences and intensifying e-mail exchange. With this caesura, the loss of interest of some partners couldn't be expressed clearer, two of them attending none of the overall 6 plenary telcos which were held as project status control and for dissemination of information provided in web seminars and email communication by the Secretariat, MT and TC/GEEG. However, thanks to the engagement of the core team, an efficient coordination and cooperation could be maintained also in challenging times. -- Likewise, the cooperation with other projects, namely GeoConnect3d, HIKE and GIP-P, executed by the project coordinator (also WP6 Project-Project Interface and WP7 IP interface lead) could be fairly well maintained from remote. The exchange with HIKE, GIP-P liaison, and GIP-P WP4 had been particularly intense, in order to integrate HotLime's results into a larger framework and to set up the Semantic Web and Knowledge Base. However, finalizing HotLime in August, the first holiday high season with loosened Corona restrictions, and well ahead of all other GeoERA SRPs, definitely was not a good idea. Even though unavoidable due to the unpostponable retirement of the HotLime coordinator, spearheading trial & error in uploading products to the EGDI publication and dissemination tools, with many advisors on leave, and interlinking HotLime's Knowledge Base with information of other projects, with no final URI's available yet, truly was a challenge.

8.9 General description of the cooperation over the duration of the project

For HotLime the cross-fertilising collaboration among the project partners – contributing knowledge, experience and skills thereby bringing the partners to a common, higher level – has been a basic objective of the project. Accordingly, during the first half of the project's run time, personal contacts, joint workshops and the onsite observation have been particularly valuable to achieve this goal for mutual benefit. However, this face-to-face knowledge exchange performed on the object, highly appreciated by the HotLime partners, came to an abrupt end with the impact of COVID. -- It is certainly not the role of a coordinator and project lead, by virtue of his function in charge of the sound and proper implementation of a project, to judge this implementation and the project coordination at the end of the project. In order to obtain a more impartial view if the 'aims and objectives', 'ambition' and 'expected impact' have been accomplished, all HotLime Partners have been asked for a short appreciation of and lessons learnt from the project. All returns from the partners delivered until end of July 2021 have been collated in the 14 pages "HotLime Partners' letters of appreciation and Lessons Learnt" report sent to MT on 2021-08-06.

8.10 Impact statement

The development of a common procedure for assessing the viability of geothermal reservoirs and its application to different pilot areas yields a common high level of understanding of hydrothermal systems in carbonate rocks. This transnational focus substantially contributes to an improved and better harmonized European overview of prospective and identified geothermal energy resources and leaves behind an established expert network safeguarding the sustained dialog over the upcoming challenges of boosting geothermal energy. The easy to compare depiction of the results as part of a comprehensive knowledgebase allows policy makers to focus future investigations on the most promising “hot spots”. Specifically HotLime’s geothermal base assessment using a common applicable methodology which is less data demanding, allows for the transfer of the assessment to other deep carbonate rocks, much more widespread in Europe than the project’s scope. The access to the pooled information via EGDI ensures an easy and enduring impact spread beyond the project, for science education, civil society’s awareness-raising and policy making alike. Thereby, the modular design of the “HotLime Geothermal Atlas” also allows for future extension by further areas.

8.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontractiong	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. LfU	122.475,79	0,00	0,00	30.618,95	153.094,73	29,70%	45.469,14	107.625,60
2. GSI	91.739,76	0,00	0,00	22.934,94	114.674,70	29,70%	34.058,39	80.616,31
3. TNO	60.613,56	0,00	0,00	15.153,39	75.766,95	29,70%	22.502,78	53.264,17
4. VLO	0,00	0,00	0,00	0,00	0,00	0,00%	0,00	0,00
5. GBA	27.855,60	0,00	0,00	6.963,90	34.819,50	29,70%	10.341,39	24.478,11
6. LGRB	58.271,20	0,00	0,00	14.567,80	72.839,00	29,70%	21.633,18	51.205,82
7. ISPRA	20.867,40	0,00	0,00	5.216,85	26.084,25	29,70%	7.747,02	18.337,23
8. GeoZS	14.269,84	0,00	0,00	3.567,46	17.837,31	29,70%	5.297,68	12.539,63
9. SGSS	21.844,45	0,00	0,00	5.461,11	27.305,56	29,70%	8.109,75	19.195,81
10. HGI-CGS	11.880,00	0,00	0,00	2.970,00	14.850,00	29,70%	4.410,45	10.439,55
11. OPM	5.033,65	0,00	0,00	1.258,41	6.292,06	29,70%	1.868,74	4.423,32
12. ARPAP	9.435,00	0,00	0,00	2.358,75	11.793,75	29,70%	3.502,74	8.291,01
13. GEOINFORM	0,00	0,00	0,00	0,00	0,00	29,70%	0,00	0,00
14. CGS	2.956,50	0,00	0,00	739,13	3.695,63	29,70%	1.097,60	2.598,02
15. RU	0,00	0,00	0,00	0,00	0,00	29,70%	0,00	0,00
16. ICGC	40.506,72	0,00	0,00	10.126,68	50.633,40	29,70%	15.038,12	35.595,28
					609.686,84		**181.076,99**	**428.609,85**

Date:	30.11.2021
Person responsible:	Dr. Gerold Diepolder

9 PROJECT HOVER

9.1 Identification of the project

Project full title:	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
Project acronym:	HOVER
Project reference number:	731.166
Project topic:	Groundwater
Project specific recearch topic:	GW4 - CONTRIBUTE TO GROUNDWATER MANAGEMENT WHEN INTERACTING WITH ENERGY AND MINING
Project website address:	https://geoera.eu/projects/hover8/

Period covered from: 01.01.2020 to: 31.10.2021

Report submission date:	30.11.2021
Project coordinator:	BRGM

Contact person for the project:	Laurence Gourcy
Tel:	33238644859
E-mail:	L.Goury@brgm.fr

9.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	Role in the project
1	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO	NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK TNO	TNO	Netherlands	Project Partner
1a	STICHTING DELTARES	DELTARES	DLT	Netherlands	Third Party
2	GEOLOGISCHE BUNDESANSTALT	GEOLOGISCHE BUNDESANSTALT	GBA	Austria	Project Partner
3	VLAAMSE MILIEUMAATSCHAPPIJ	Flanders Environment Agency (VMM)	VMM	Belgium	Project Partner
4	FEDERALNI ZAVOD ZA GEOLOGIJU SARAJEVO	Geological Survey of Federation of Bosnia and Herzegovina	FZZG	Bosnia-Herzegovina	Project Partner
5	HRVATSKI GEOLOSKI INSTITUT	Hrvatski Geološki Institut (HGI-CGS)	HGI-CGS	Croatia	Project Partner
6	MINISTRY OF AGRICULTURE, NATURAL RESOURCES AND ENVIRONMENT OF CYPRUS	MINISTRY OF AGRICULTURE, NATURAL RESOURCES AND ENVIRONMENT OF CYPRUS	GSD (GSD Cyprus)	Cyprus	Project Partner
7	CESKA GEOLOGICKA SLUZBA	Czech Geological Survey	CGS	Czech Republic	Project Partner
8	Geological Survey of Denmark and Greenland	Geological Survey of Denmark and Greenland	GEUS	Denmark	Project Partner
9	GEOLOGIAN TUTKIMUSKESKUS	Geologian Tutkimuskeskus	GTK	Finland	Project Partner

10	Bureau de Recherches Géologiques et Minières	Bureau de Recherches Géologiques et Minières	BRGM	France	Project Lead
11	BUNDESANSTALT FUER GEOWISSENSCHAFTEN UND ROHSTOFFE	Bundesanstalt für Geowissenschaften und Rohstoffe (BGR)	BGR	Germany	Project Partner
12	Landesamt für Bergbau, Energie und Geologie Niedersachsen	Landesamt für Bergbau, Energie und Geologie Niedersachsen	LBEG	Germany	Project Partner
13	MAGYAR FOLDTANI ES GEOFIZIKAI INTEZET	Mining and Geological Survey of Hungary	MFGI (MBFSZ)	Hungary	Project Partner
14	ISLENSKAR ORKURANNSOKNIR	Iceland GeoSurvey	ISOR	Iceland	Project Partner
15	Department of Communications, Energy and Natural resources	Department of Communications, Energy and Natural resources	GSI	Ireland	Project Partner
16	Istituto Superiore per la Protezione e la Ricerca Ambientale	Istituto Superiore per la Protezione e la Ricerca Ambientale	ISPRA	Italy	Project Partner
17	LATVIJAS VIDES, GEOLOGIJAS UN METEOROLOGIJAS CENTRS SIA	Latvian Centre of Geology, Environment and Meteorology	LEGMC	Latvia	Project Partner
18	Lietuvos Geologijos Tarnyba prie Aplinkos Ministerijos	Lietuvos Geologijos Tarnyba prie Aplinkos Ministerijos	LGT	Lithuania	Project Partner
19	MINISTRY FOR TRANSPORT AND INFRASTRUCTURE	Ministry for Transport and Infrastructure	MTI	Malta	Project Partner
20	PANSTWOWY INSTYTUT GEOLOGICZNY - PANSTWOWY INSTYTUT BADAWCZY	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	PIG-PIB	Poland	Project Partner
21	Laboratorio Nacional de Energia e Geologia I.P.	Laboratório Nacional de Energia e Geologia (LNEG)	LNEG	Portugal	Project Partner
22	INSTITUTUL GEOLOGIC AL ROMANIEI	Institutul Geologic al României	IGR	Romania	Project Partner
23	Geological Survey of Serbia	Geological Survey of Serbia	GSS	Serbia	Project Partner
24	GEOLOSKI ZAVOD SLOVENIJE	Geološki zavod Slovenije	GeoZS	Slovenia	Project Partner
25	INSTITUTO GEOLÓGICO Y MINERO DE ESPAÑA	Instituto Geológico y Minero de España	IGME-Spain	Spain	Project Partner
26	Institut Cartogràfic i Geològic de Catalunya	Institut Cartogràfic i Geològic de Catalunya	ICGC	Spain	Project Partner
27	SVERIGES GEOLOGISKA UNDERSOKNING	Sveriges Geologiska Undersökning	SGU	Sweden	Project Partner
28	STATE RESEARCH AND DEVELOPMENT ENTERPRISE STATE INFORMATION GEOLOGICAL FUND OF UKRAINE	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	Project Partner
29	NATURAL ENVIRONMENT RESEARCH COUNCIL	Natural Environment Research Council	NERC	United Kingdom	Project Partner
30	Eesti Geoloogiakeskus OÜ	Eesti Geoloogiateenistus	EGK (EGT)	Estonia	Non-funded partner
31	INSTITUT ROYAL DES SCIENCES NATURELLES DE Belgique	Institut Royal des Sciences Naturelles de Belgique	RBINS-GSB	Belgium	Non-funded partner
32	Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg (LBGR)	Landesamt für Bergbau, Geologie und Rohstoffe Brandenburg	LBGR	Germany	Non-funded partner
33	INSTITOUTO GEOLOGIKON KAI METALLEFTIKON EREVNON	Hellenic Survey of Geology & Mineral Exploration	HSGME	Greece	Non-funded partner

9.3 Publishable summary

The challenge of HOVER was to gain understanding of the controls on both natural and polluted groundwater quality across Europe using the combined expertise and data held by member states. The project was built around 6 technical axes related to i) geogenic elements naturally present in high concentration in groundwater, ii) links between aquifer microbial ecology and diversity to contaminant transforming processes at European groundwater-surface water transition zones, iii) diffuse pollution of nitrate and pesticides from agriculture activities, iv) Groundwater age and travel time distributions in European aquifers v) vulnerability assessment of pollution risk from the surface and iv) organic contaminants of emerging concern.
Beyond the fruitful technical and scientific exchange between European GSOs, the project reached producing various guidelines, thematic maps, web service tools at pan-European and pilot study scale and databases available through the Information Platform / the European Geological Data Infrastructure (EGDI)
The elaboration of a web service on thermal and mineral water, allowing an overview of main physico-chemical and trace element composition of these social waters. Also three maps of valuable interest for the diffuse pollution (nitrate and pesticide) impact assessment were made available on EGDI, together with the dataset and the method elaborated : Redox potential map, transfer time of nitrate through the unsaturated zone and the nitrate stored in the unsaturated zone from 1900 up to 2000. More than 20 pilot studies on the application of more than 10 environmental tracers and supporting parameters for assessment of groundwater age distributions across Europe. The assessment of the vulnerability of the upper aquifer to pollution using the well established DRASTIC method and COP for specific karstic areas covers a large part of EU and is made available for further studies. The various case studies, guidelines and technical document describing the groundwater age distribution gives an good overview on the availability and use of such information in Europe and the need for further development and improvement such as as a global standard for a structured database for environmental tracers and derived groundwater age distributions and vulnerability of water supply wells towards pollution from the surface. Organic contaminants of emerging concerns were compiled from published and unpublished litterature giving a good overview of the monitoring status over Europe.

9.4 Project contribution to GeoERA project

HOVER is one of the four groundwater projects. The main goals were therefore towards improvement of groundwater knowledge and preparing tools for water stakeholders. The project focus on mainly on relationships between geology/lithology, unsaturated zone characteristics and groundwater quality to ensure that the risk associated with high concentrations of natural origin and agriculture activities are properly characterized to enable protection of groundwater used for drinking water or for supporting surface water aquatic and terrestrial ecosystems. Various web tools and maps were proposed in pilot sites in a variety of hydrogeological settings over Europe and translated into useful information for decision makers and the public. This work was made in close relation with the Water Framework Directive and the Groundwater Directive. The project reached the use of harmonized methodologies and data on hydrostratigraph/lithology, groundwater quality and age in a number of pilot sites and one pan-EU map as a first step towards harmonization of information at European scale. Progress beyond the current state-of-the-art in demonstrating the merits of uniform approach in lithological, transfer time, vulnerability and chemical characterization enabled a European vision of some main groundwater quality problems links to nitrate, pesticides or elements of natural origins such as As or F. HOVER developed various maps and web services in close collaboration with GIP-P in order to integrate European GSOs' information and knowledge on water to contribute to sustainable use and management of the subsurface. Specially the following products: Web Services with multi-lingual legend concerning special ground water in Europe and visualization of data on natural mineral and thermal waters was prepared. The Web services include data on physico and chemical parameters of thermal and natural mineral waters

from 13 countries. Two other maps were built in relation to arsenic and fluoride of natural origin in groundwater. The maps of groundwater-N travel time is based on a series of common, evidence-based conceptual models for nitrate transport in the shallow subsurface. Progress was also made in the evaluation of the state-of-the art in organic emerging compounds monitoring and need to improve sampling, analyses and data interpretation. Data and modelling collected over case studies allowed proposing a web service on the nitrate stored in the unsaturated zone from 1900 up to 2000. Based on data available and methods applied in participating countries a simple common approach was proposed to define the oxic and anoxic environment or mix condition at each sampling point and to prepare a redox potential map. A collection of more than 20 use cases of the environmental tracers for groundwater age distribution allowed preparing a good practice guidance, age indicator sampling guide and the database structure. Finally, HOVER project enabled the vulnerability assessment of the upper aquifer to pollution at pilot areas scale using DRASTIC and COP methods.

9.5 Work progress and achievements during the period

Work package 1: BRGM-Project management and scientific coordination

Project management consisted in regular WP meetings (11 meeting in total), preparation and animation of the project meetings (1 in Brussels in 2018, 1 in Madrid/virtual in 2020) and 1 in Brussels in 2021), participation to geoera and geoera Groundwater coordination meetings, assisting the WP leaders in some activities (DMP for WP2, orientation,...) and promoting the project and outputs at international scales. The WP leader also managed all deliverables registration to the Geoera Secretariat, the HOVER cloud and EGDI. The cumulative expenditure reports are revised and submitted to the secretariat. The progress report and the final report were prepared under the supervision of the WP1 leader. A newsletter published 2/3 times per year has also be prepared by the WP1 leader in order to keep the project partners informed and got short abstracts on main HOVER outputs easy to distribute outside the HOVER community.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.2a	Project progress report	BRGM	Report	Internal	M20	Completed	
D1.2b	Final project report	BRGM	Report	Internal	M42	Completed	
D1.3a	Cumulative expenditure report 2018	BRGM	Report	Internal	M7	Completed	Review completed with Midterm report.
D1.3b	Cumulative expenditure report 2019	BRGM	Report	Internal	M19	Completed	
D1.3c	Cumulative expenditure report 2020	BRGM	Report	Internal	M31	Completed	
D1.3d	Cumulative expenditure report 2021	BRGM	Report	Internal	M42	Completed	

Milestones (for all WP)				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
MS1	Kick off meeting	M1	Completed	Review completed with Midterm report.
MS2	WP and PB meeting	M8	Completed	Review completed with Midterm report.
MS3	Seminar with IP	M18	Completed	Review completed with Midterm report.
MS4	Mid-term meeting	M20	Completed	Minutes available
MS5	Project Board meeting	M26	Completed	Minutes available
MS6	Final meeting	M38	Completed	Minutes available

Work package 2: IP & CT coordination, data management and dissemination

Objectives of WP2 are: 1.) To define and coordinate data and information handling from all HOVER WPs and develop a Data Management Plan (DMP) in collaboration with the GIP team in order to make HOVER data findable, accessible, interoperable and reusable according to GeoERA D1.3 and the "FAIR" principles of H2020. and 2.) To develop a project communication, dissemination and exploitation plan including social media, the project web site and scientific journals. Where required in collaboration with the other themes and the GeoERA secretariat and following the dissemination and exploitation plan (D5.1) of GeoERA. The interaction between HOVER and GIP-P project aims to define HOVER products in terms of information systems and the necessary functionalities to make these products accessible to a wide range of end users through EGDI platform.
The collaboration started in October 2018 with a first meeting attended by all the project "liasons" . As a result of this meeting, a series of functionalities requested by GeoERA projects as a whole were extracted. With the idea of outlining the products and functionalities required by HOVER, the GIP-P attended the project board meeting held in Paris in March 2019. At this meeting, a template for D2.2 and a delivery schedule were established. Since then, this document has been refined as the WPs have outlined the desired products and requirements. The latest version was produced in December 2019 and is a key source of information for GIP-P project.
Exchanges with GIP-P on D 2.3.2 permitted solving poblemens due ti NetCDF format or other complex products HOVER pmlanned to produce. All products wree delivered, placed on depository (for reports) and HOVER EGDI. The main products (considered as with more interest for external persons or more ready-tu-use can be accessed through EGDI external platform. The DMP was regularly updated directly as a shared document so HOVER and GIP-P could access it. WP2 ensured also coordination between groundwater projects and dissemination of results (see communication, dissemination).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D.2.1.	Data management plan	GEUS	Report	internal	M9	Completed	Review completed with Midterm report.
D.2.2.a	Definition of data requirements for GIP based on GIP recommendations	GEUS	Technical note	internal	M8	Completed	Review completed with Midterm report.
D.2.2.a	Definition of data requirements for GIP based on GIP recommendations	GEUS	Technical note - update	internal	M16	Completed	Review completed with Midterm report.

D.2.2.b	Provision of data for upload and testing of GIP second version	GEUS	Technical note	internal	M30	Completed	continuous work
D.2.3.a	Communication, dissemination and exploitation plan	GEUS	Report	internal	M8	Completed	Review completed with Midterm report.
D.2.3.b	Article(s) submitted to international peer reviewed journal(s)	GEUS	Articles	Scientific community	M36	Completed	see spreadsheet 6

Work package 3: GBA-Hydrogeochemistry and health

On the element of natural origin in high concentrations in groundwater: The thermal and mineral water database contains various physico and chemical parameters including metallic trace elements. The Web service attached to the database permits to locate the areas of these waters and presents some common characteristics such as high temperature or high concentration in some Potentially Toxic Geogenic Trace Elements (PTGTE). Further focus was given to arsenic and fluoride and an overview of groundwater points with concentrations higher than the recommended drinking water values (e.g. by using indicators like the HydroGeoToxicity index, HGT) from participating countries. It is important to know the primary concentrated sources to be able to diagnose the distribution of PTGTE in groundwater, understand its distribution pattern and improve management policies. The project also contributed to the development of NBL determination: In detail, the BRIDGE method was revised in order to improve the links between dissolved elements and main lithologies and a HOVER appoach suggested and implemented with data from case studies. The findings comprise the application of statistical tests to distinguish the influence of prevailing pressure on trace contamination helps to evaluate the dataset confidence for Natural Background Levels (NBL) calculation by discarding data when necessary. The method, applied for 8 elements (SO4, As, Cd, Cr, Cu, Ni, Zn and F) constitutes an important contribution to the definition of NBLs which should be further consolidated by regional studies and at national levels for the Water Framework Directive.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D.3.1.	Database for concentrations of dissolved elements and associated parameters and harmonized terminology to define thermal and mineral water	GBA	Database report	internal	M12	Completed	Review completed with Midterm report.
D.3.2.	A litho-geological classification system based on the capacities of rocks to release elements to GW including development of the methods in some EU countries	GEUS	Report	internal	M12	Completed	Review completed with Midterm report.
D.3.3.	Data set of the results of the statistical data treatment allowing the preparation of the raw elements for the tasks 4	BRGM	Database report	internal	M32	Completed	

	and 5 i.e. concentrations of elements of natural origin per typologies						
D.3.4.	Compilation of indicators, analyses of possible use at pan-European scale and test application in countries of contrasted main litho/geology	IGME	Report	Scientific community Policy Makers Internal	M32	Completed	
D.3.5.a	Data model and the legend of the planned web service	GBA	Report	internal	M29	Completed	
D.3.5.b	Development of European exposure maps of selected elements (and indicators) based on GIS interpolation of measurements	GBA	Maps Articles Flyers	Scientific community Policy Makers Internal General Public Medias	M38	Completed	
D.3.5.c	Support to GIP for the development of a Web Services with multi-lingual legend concerning special ground water in Europe	GBA	Web service	Policy Makers Internal General Public Medias Industry	M38	Completed	

Work package 4: GEUS-Groundwater-surface water transition zones

Linking aquifer microbial ecology and diversity to contaminant transforming processes at European groundwater-surface water transition zones concerned 3 case studies within two countries due to COVID restrictions. WP4 focuses on linking aquifer microbial ecology to contaminant transformation processes in the hyporheic zone within the HOVER project. The main aim has been to determine the potential for degradation of organic pollutants in the hyporheic zone and link this to the microbial community composition. Where D4.2 focuses on degradation results, D4.3 focuses on the microbial community composition. The main research interest within WP4 was focused on the influence of flow direction and sorption processes on the biodegradation potential of pesticides and sulfonamides in the hyporheic zone. Based on the three sites included in thi study, it is not possible to make a solid conclusion on the influence of upwelling and downwelling conditions. However, our data reveal that the largest number of degraded organic pollutants occurs at the River Crieu, which coidence with the downwelling conditions. The influence of bacterial abundance and diversity is a known factor influencing the degradation potential. This is discussed in D4.3.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D.4.1.	Characterization of field sites based on existing and measured data as input to task 4.3	GEUS	Report	internal	M16	Completed	Review completed with Midterm report.
D.4.2.	Degradation and mineralisation of selected contaminants in European GW-SW	GEUS	Report	Internal Scientific community	M40		

	transition zones as input to task 4.3						
D.4.3.	The use of microbial diversity measures for monitoring contaminant transforming processes at GW-SW transition zones	BRGM	Report	Policy Makers	M40		

Work package 5: NERC-Nitrate and PST transport from soil to groundwater receptors

Denitrification process is important as it allow a decrease of N concentration in water. These natural processes can be used in order to maintain or obtain high quality water for example building wetlands or keeping the geochemical conditions allowing this process. In the pressure-impact studies it is necessary to know where denitrification occurs in order to correctly evaluate the location of the main pressure and to differentiate dilution to denitrification. This is important as denitrification is not a permanent processes and anthropogenic activities may lead to the decrease of the denitrification process and subsequently a drastic increase of NO3 concentration in groundwater. The Redox potential map established within HOVER is therefore an important tool for stakeholder in order to analyse the apparent discrepancy between pressure and concentration of nitrate in groundwater. In some cases, knowing the extent and potential of denitrification may be a parameter taken into account in the N fertilizer management plans. Evaluating transfer time of nitrate in the unsaturated zone is needed to explain time lag between actions and chemical quality recovery. Travel times have significant implications for management of nitrate pollution and the pilots show that there are significant time lags between nitrate losses at the base of the soil zone and receptors. Applied at EU scale this information would help decision makers and the EU to evaluate the efforts, in time, before a global decrease of nitrate in groundwater. Nitrate stored in the unsaturated zone established at EU scale can be used as a screening to evaluate whether further regional to basin scale investigations into nitrate transport in the unsaturated zone are likely to be required. Trend (rather than threshold)-based, multidecadal scale monitoring and evaluation of the impacts of measures to reduce nitrate concentrations at receptors are required. Evaluations of measures put in place to reduce nitrate concentrations should take into consideration the diversity of hydrogeological settings.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D.5.1.	Atlas of geological/hydrogeological settings found across Europe with selected type sites	NERC	Report and map	internal	M12	Completed	Review completed with Midterm report.
D.5.2.	Datasets with characterization of these settings relevant for agrochemical transport	TNO	Report	internal	M18	Completed	
D.5.3.	Assessments of N travel times for a number of relevant European settings	NERC	Report	Internal Scientific community	M29	Completed	
D.5.4.	Assessments of attenuation patterns for a number of relevant European settings	BRGM	Report	Internal Scientific community	M29	Completed	

D.5.5	Maps of groundwater-N travel time – pan-European if there are sufficient partners	NERC	Map	Policy Makers Scientific community	M39	Completed	
D.5.5b	Redox potential maps	BRGM	Map	Policy Makers Scientific community	M33	Completed	

Work package 6: GEUS-Groundwater Age Distributions and residence times in Europe

The work performed on « groundwater age distribution » included a great diversity of actions with the aim to better use this information for groundwater management through more than 20 case studies, synthetic documents and specific studies carried out in Denmark and The Netherlands. The presented case studies presented here serve to reinforce the general principle that multiple sampling points with multiple environmental tracers (stable and radioactive isotopes including 39Ar, noble gases, groundwater temperature, and water chemistry) are needed to provide the information necessary for an adequate characterization of mean groundwater ages along flow paths together with available resources or vulnerability of aquifers. One important conclusion of the guidance document on trend estimation and age dating would be the paradox linking the concept of mean residence time and the measurable effects of any pressure change on the aquifer. As it is may appear to be urgent to see the effect of a mitigation measure, it should be kept in mind that aquifers with long residence time will have a long and delay answer to this change. In some extent, it could be think that it is more urgent to act on 'old' groundwater, as effects will be longer to be seen, and pollution would stay longer in the USZ/aquifer. Appreciation of this memory effect of the aquifer is exactly the goal of the environmental tracers, and a certainly good motivation to use them. A database structure for groundwater age tracers was proposed and made available in the EGDI for further development.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D6.1.b	A classification system based on groundwater age distributions defining shallow and deep aquifer vulnerability classes indicating the risk of pollution and elevated concentrations of geogenic elements	GEUS	Report	Internal Policy Makers Scientific community	M15	Completed	Review completed with Midterm report.
D.6.1.a	Database for concentrations of groundwater age indicators, estimated mean ages and age distributions, vulnerability classes and associated guidance	GEUS	Database Report	Policy Makers Scientific community	M40	Completed	

D.6.2.	Collection of use cases including good practice guidance and age indicator sampling guide	MBFSZ	Report	Scientific community	M29	Completed	
D.6.1.c	Maps and cross sections on the information platform / EGDI showing spatial distribution of groundwater age and vulnerability classes in selected European aquifers	GEUS	Web service	Policy Makers General public	M34	Completed	
D.6.3	Recommendations for estimating groundwater age distributions and the application of these in groundwater monitoring and quality estimation (including trend assessment)	BRGM	Report	Policy Makers	M40	Completed	
D.6.4	Investigation of age distributions in water supply wells with long screens and recommendations for application of tracers and models mainly for estimating groundwater ages between 10 and 1000 years	TNO	Report	Scientific community	M40	Completed	

Work package 7: BGR-Harmonized vulnerability to pollution mapping

DRASTIC and COP (for karst aquifers) method was applied at the pan-EU and pilot scale for the assessment of the vulnerability of upper aquifer to pollution. The vulnerability maps obtained are important tools for groundwater management, through which specific high vulnerability areas can be identified and preventive or corrective actions can be taken at different scales for their protection. HOVER provided the map and related data sets through EGDI that can be reusable for further studies.The construction of the vulnerability maps needed a preliminary task consisting in the comparison of the internationally commonly applied index methodologies for assessing the vulnerability of the upper aquifer to pollution. The report portrays existing methods assessing the groundwater vulnerability to pollution and proposes a methodology to enable vulnerability maps at the pan-European and regional transboundary scale. The Sensitivity analysis jointly with the Pairwise correlation matrix gives a general idea of which are the most significant parameters in each pilot depending on the hydrogeological settings and the available input data. Within this WP, an other objective was to develop a method based on indices and variables to summarise vulnerability at aquifer scale. Information on the potentially “affected” volumes (where the vulnerability is over a certain threshold) is generated at different spatial scales, moving from areal maps to representative conceptual cross section and lumped indices. It needs information about the spatial

distribution of the groundwater resources and the vulnerability values/classes obtained by applying different vulnerability methods (Eg. DRASTIC, COP, etc). Due to a urge work need to implement this approach only one EGS could contribute.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D.7.1.	Comparison of international commonly applied index methodologies for assessing the vulnerability of the upper aquifer to pollution	BGR	Report	Scientific community	M6	Completed	Review completed with Midterm report.
D.7.2.	Compilation of the examination results of the data sets of input data for the respective methodologies assessing vulnerability of the upper aquifer to pollution.	BGR	Report and dataset	Internal	M29	Completed	
D.7.3.	Provision of scale and data-dependent products on the vulnerability of the upper aquifer to pollution using GIS.	ICGC	Maps and dataset	Scientific community Internal	M34	Completed	
D.7.4.	Delivering of cross sections and maps of extend of selected aquifers in specific national pilot areas	IGME	Maps and report	Internal Scientific community	M34	Completed	

Work package 8: BRGM-Effective monitoring of emerging contaminants

Groundwater occurrence data on emerging organic compound, part of the contaminant of emerging concern (CEC) in groundwater in the peer reviewed and grey (not published data) literature for Europe has been formally reviewed. A total of 39 published studies and questionnaires completed by 30 European institutes allowed the comprehensive compilation of data in Europe. The aims of this review was to; understand the current state of groundwater sampling of EOC's in Europe and the developments in recent years, understand the different methods for sampling and analysing CEC's in Europe, and highlight ongoing research and further areas for research necessary to develop a picture of CEC's in Europe.

An inventory of approaches that help to assess and predict concentration of CECs in groundwater, to estimate the limits for their application and evaluate and review relationships between the occurrence of emerging organic contaminants in groundwater and environmental settings. As there is not enought labs involved for an intercmarison exercice, the action has been reoriented on a comparison on different sampling stations, with different qualities of groundwater, different concentration levels on emerging

cotaminants, to have a first assessment of the difficulties associated with these substances. Recommendations for monitoring emerging pollutants in EU groundwater weer alos proposed within this WP. Beyond the questions which are specifically linked to the emerging nature of these new compounds, it turns out that the establishment of monitoring of these emerging compounds brings to light more traditional monitoring questions such as, for example, the concepts of the definition of limit of quantification and its meaning, estimation of uncertainty or difficulties with interpretation of the data and more generally the need of harmonized rules for method validation.
As there is not enough labs involved in this action, the action has been reoriented on a comparison on different sampling stations, with different qualities of groundwater, different concentrations levels on emerging contaminants contamination, to have a first assessment of the difficulties associated with these substances.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D.8.1.a	Critical review report of European monitoring results for organic emerging contaminants	NERC	Report	Scientific community	M17	Completed	Review completed with Midterm report.
D.8.1.b	Critical review report of non-published European-monitoring results for organic emerging contaminants	NERC	Report	Internal	M29	Completed	
D.8.2	Report with recommendations for monitoring of key parameters with reference to environmental context, geological setting and risk assessment	IGME	Report	Policy Makers Scientific community	M40		
D.8.3	Report describing new sampling analyses and interlaboratory tests directed towards potential hotspots for emerging contaminants transport	TNO	Report	Internal	M40		
D.8.4	GIS-layers published by a GeoERA (EGDI) web service on the selected ECs	BRGM	Dataset	Policy Makers Scientific community General public	M38	Completed	
D.8.5	Concrete proposal and design for an EU wide monitoring program	BRGM	Report	Policy Makers	M40		

	customized to emerging pollutants of high concern						

9.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	no

9.7 Communication and dissemination activities

	ABSTRACTS	BLOG	CONGRESS	FACEBOOK	INTERNAL PROJECT MEETING	LINKEDIN	MEETING	OTHER	RESEARCHGATE	SCIENTIFIC PUBLICATION	TWITER	WEBINAR	WEBSITE	WORKSHOP	Total
EVENTS			16									3		1	20
MEETINGS					34		1	1							36
ONLINE_MEDIA		1		1		1			1		1		1		6
PUBLICATIONS	4									7					11
Total	**4**	**1**	**16**	**1**	**34**	**1**	**1**	**1**	**1**	**7**	**1**	**3**	**1**	**1**	**73**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	8255	50	147	8		10	11				8481
MEETINGS	550		10		1						561
ONLINE_MEDIA	32000	22000	2000	20	50	50	100	50	100	50	56420
PUBLICATIONS	9000						10				9010
Total	**49805**	**22050**	**2157**	**28**	**51**	**60**	**121**	**50**	**100**	**50**	**74472**

9.8 Project management

The coordination activities consisted in quarterly meetings by videoconf with all wP leaders and three physical meeting held in Brusels in July 2018, Paris in June 2019 with a special session with GIP coordinatorand Brusels in Septembre 2021 . The project coordination consisted also in preparing and sending to all participants a Newsletter. Six Newsletters were sent to HOVER, GEOERA partners and other scientist. In each work packages various meetings were also proposed by videoconf or in various countries before COVID crises for WP7 (Germany, Spain, Ireland), WP5/WP6 (Viena), WP3 (Paris, Aarhus), WP4 (Brussels) and WP8 (France) - Regular meeting (every two months about) were also proposed by the GEOERA Groundwater coordinator in order to exchange information between HOVER, RESOURCE, TACTIC and VOGERA - In September 2019 the project coordinator participated to a seminar organised in parrelel to the Groundwater Quality Conference in Liege (Belgium). The seminar on the Alliance on, Water Quality brought together the IAH, UNEP, IGRAC and was an opportunity to initiate links with HOVER activities - We are starting discussions with the IAEA for a possible international database on groundwater age dating - The project was also presented to the CIS GWWG meeting held in 2018 in Vienna. Most of the deliverables were constructed based on fruitfull discussions held between partners, sharing data and methods in order to agree on common and pan-European approaches.

9.9 General description of the cooperation over the duration of the project

HOVER could reached very good results thanks to a core team of 9 EGS composed of BRGM, BGR, TNO, GEUS, GEO-ZS, IGME, ICGC, GBA, MBFSZ. These institutes were WP or task leaders and involved in various activities from methodological development to application at regional or national scale. Other EGS dedicated most of their time in only one WP but with implication from methods to application such as HGI-CGS, GSI, LEGMC, PIG-PIB, SGU, GSS, EGT, HSGME. The other institutes (VMM, FZZG, ISPRA, GSD, CGS, GTK, LBEG, ISOR, LGT, MTI, IGR) mainly delivered data or applied a proposed method to a pilot site. These participations were very important in the objectives of covering the greatest possible part of Europe and at least all typologies. The implication of many countries helped in understanding the great variabilities in geology, lithology, groundwater management and data collection/storage. At the beginning of the project it has therefore be necessary to revise some scientific conviction on which the initial methods were based in order to take into account the local conditions and knowledge. This process allowed interesting exchange and innovative methods based on quite simple concept were proposed. These methods have the great advantage to be fast to implement and would permit in the future to easily propose pan-Eu maps and webs services. The collaboration also give also opportunities to some EGS not so familiar to international publication to present their work that cannot be easily accessible due to language limitations.

9.10 Impact statement

On the element of natural origin in high concentrations in groundwater: The thermal and mineral water database contains various physico and chemical parameters including most of the metallic trace elements. The Web service attached to the database permit to locate the areas of “special water” presenting some common characteristics such as high temperature or high concentration in some Potentially Toxic Geogenic Trace Elements (PTGTE). Focus was given to arsenic and selenium and an overview of groundwater points with concentration higher than the recommended drinking water values (HydroGeoToxicity index, HGT) was obtained for 17 European countries. It is important to know the primary concentrated sources to be able to diagnose the distribution of PTGTE in groundwater, understand its distribution pattern and improve management policies. Also, the BRIDGE method was

revised in order to improve the links between dissolved elements and main lithologies. The application of statistical tests to distinguish the influence of prevailing pressure on trace contamination helps to evaluate the dataset confidence for Natural Background Levels (NBL) calculation by discarding data when necessary. The method, applied for 8 elements (SO4, As, Cd, Cr, Cu, Ni, Zn and F) constitutes an important contribution to the definition of NBLs which should be further consolidated by regional studies and at national levels for the Water Framework Directive.

Linking aquifer microbial ecology and diversity to contaminant transforming processes at European groundwater-surface water transition zones concerned 3 case studies within two countries due to COVID restrictions.

Nitrate and pesticides transfer: Denitrification process is important as it allow a decrease of N concentration in water. This natural processes can be used in order to maintain or obtain high quality water for example building wetlands or keeping the geochemical conditions allowing this process. In the pressure-impact studies it is necessary to know where denitrification occurs in order to correctly evaluate the location of the main pressure and to differentiate dilution to denitrification. This is important as denitrification is not a permanent processes and anthropogenic activities may lead to the decrease of the denitrification process and subsequently a drastic increase of NO3 concentration in groundwater. The Redox potential map established within HOVER and published in the EGDI is therefore an important tool for stakeholder in order to analyse the apparent discrepancy between pressure and concentration of nitrate in groundwater. In some cases, knowing the extent and potential of denitrification may be a parameter taken into account in the N fertilizer management plans.

Evaluating transfer time of nitrate in the unsaturated zone is needed to explain time lag between actions and chemical quality recovery. Travel times have significant implications for management of nitrate pollution and the pilots show that there are significant time lags between nitrate losses at the base of the soil zone and receptors. Harmonised travel time maps produce in HOVER and published in EGDI will support decision makers and the EU to evaluate the efforts, in time, before a global decrease of nitrate in groundwater. Furthermore, maps of nitrate stored in the unsaturated zone established at EU scale derived in HOVER can be used as a screening to evaluate whether further regional to basin scale investigations into nitrate transport in the unsaturated zone are likely to be required. Trend (rather than threshold)-based, multidecadal scale monitoring and evaluation of the impacts of measures to reduce nitrate concentrations at receptors are required. Evaluations of measures put in place to reduce nitrate concentrations should take into consideration the diversity of hydrogeological settings.

The work performed on « groundwater age distribution » included a great diversity of actions with the aim to better use this information for groundwater management through more than 20 case studies, synthetic documents and specific studies carried out in Denmark and The Netherlands. The presented case studies presented here serve to reinforce the general principle that multiple sampling points with multiple environmental tracers (stable and radioactive isotopes including 39Ar, noble gases, groundwater temperature, and water chemistry) are needed to provide the information necessary for an adequate characterization of mean groundwater ages along flow paths together with available resources or vulnerability of aquifers. One important conclusion of the guidance document on trend estimation and age dating would be the paradox linking the concept of mean residence time and the measurable effects of any pressure change on the aquifer. As it is may appear to be urgent to see the effect of a mitigation measure, it should be kept in mind that aquifers with long residence time will have a long and delay answer to this change. In some extent, it could be think that it is more urgent to act on ‘old’ groundwater, as effects will be longer to be seen, and pollution would stay longer in the USZ/aquifer. Appreciation of this memory effect of the aquifer is exactly the goal of the environmental tracers, and a certainly good motivation to use them. A database structure for groundwater age tracers was proposed and made available in the EGDI for further development.

The well recognized DRASTIC and COP (for karst aquifers) methods were applied at the pan-EU and pilot scale for the assessment of the vulnerability of upper aquifer to pollution. The vulnerability maps obtained are important tools for groundwater management, through which specific high vulnerability areas can be identified and preventive or corrective actions can be taken at different scales for their protection. This also represents a first step to satisfy the urgent need of comparable vulnerability assessments across

Europe, providing foundation for common policy and regulation implementation. This was made possible through the agreement reached regarding the DRASTIC rating scheme which is valid for all pilots and pan-EU application, ensuring comparability between pilots (and in-between them) and the PAN-EU map (and hence specific national vulnerability methods). Supplementary, the application of a method to summarize the affected aquifer volumes per DRASTIC vulnerability class using 2D representative conceptual cross sections allows users to quantify the potentially vulnerable aquifer volumes to pollution. HOVER provided the map and related data sets through EGDI that can be reusable for further studies.

For contaminant of emerging concern it seems essential to prioritise monitoring locations in order to minimise uncertainties caused by limited sampling. As a means of achieving effectiveness of groundwater monitoring programmes, comprehensive knowledge of physical processes jointly with the purpose and objectives of monitoring are required. The first and most critical step to improve their efficiency is the elaboration of a sound hydrogeological conceptual model. In HOVER it was considered primary factors, additional drivers, features of prevalent contaminant and source area processes. Among the primary factors, Soil properties (Organic carbon content, pH and clay content), the properties of the Physical Structure (Lithology), Aquifer and Groundwater properties (Groundwater parameters, Unsaturated zone thickness, Hydraulic conductivity, Age, pH, Redox conditions, DO), Hydrological processes (Relationship river-aquifer, Climate, Flow condition and Seasonal variation) have proved to be useful for the posterior interpretation of data, so they must be considered and recorded whenever possible. Guidelines for the establishment of quality standards (threshold values or maximum contaminant levels) were also proposed. Recommendation for monitoring the contaminant of organic concern (CEC) highlighted some important points sur as i) sampling has been recognized as a key point in the measurement chain and for its quality, ii), the delay between sampling and analysis is also an important parameter. On the analytical level, new methods using high-resolution mass spectrometry and allowing the acquisition of a complete "fingerprint" of a sample are methods of the future, particularly for the monitoring of emerging pollutants. the chemical expertise of laboratory staff is necessary for a good definition of the parameters to be analyzed. Finally, the validation of analytical methods remain, for emerging pollutants as for other pollutants, important elements of the quality of the results.

9.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontractiong	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1 TNO	89.689,62	22.063,35	0,00	27.938,24	139.691,21	29,70%	41.488,29	98.202,92
1a Deltares	25.797,43	0,00	0,00	6.449,36	32.246,79	29,70%	9.577,30	22.669,49
2 GBA	56.986,47	1.048,82	0,00	14.508,82	72.544,11	29,70%	21.545,60	50.998,51
3 VMM	6.896,55	0,00	0,00	1.724,14	8.620,69	29,70%	2.560,34	6.060,34
4 FZZG	7.278,00	0,00	0,00	1.819,50	9.097,50	29,70%	2.701,96	6.395,54
5 HGI-CGS	19.456,56	175,00	0,00	4.907,89	24.539,45	29,70%	7.288,22	17.251,23
6 GSD	7.301,89	0,00	0,00	1.825,47	9.127,36	29,70%	2.710,83	6.416,53
7 CGS	1.013,00	0,00	0,00	253,25	1.266,25	29,70%	376,08	890,17
8 GEUS	284.202,61	23.560,35	0,00	76.940,74	384.703,70	29,70%	114.257,00	270.446,70
9 GTK	5.899,56	0,00	0,00	1.474,89	7.374,45	29,70%	2.190,21	5.184,24
10 BRGM	188.154,70	13.413,78	0,00	50.392,12	251.960,60	29,70%	74.832,30	177.128,30
11 BGR	113.218,61	1.656,04	0,00	28.718,66	143.593,31	29,70%	42.647,21	100.946,10
12 LBEG	17.467,09	0,00	0,00	4.366,77	21.833,86	29,70%	6.484,66	15.349,21
13 MBFSZ	17.264,29	381,91	0,00	4.411,55	22.057,75	29,70%	6.551,15	15.506,60
14 ISOR	9.148,23	0,00	0,00	2.287,06	11.435,29	29,70%	3.396,28	8.039,01
15 GSI	52.401,70	0,00	0,00	13.100,43	65.502,13	29,70%	19.454,13	46.047,99
16 ISPRA	11.020,00	6.976,40	0,00	4.499,10	22.495,50	29,70%	6.681,16	15.814,34
17 LEGMC	5.790,00	1.657,89	0,00	1.861,97	9.309,86	29,70%	2.765,03	6.544,83
18 LGT	6.300,00	465,00	0,00	1.691,25	8.456,25	29,70%	2.511,51	5.944,74
19 OPM	14.926,00	0,00	0,00	3.731,50	18.657,50	29,70%	5.541,28	13.116,22
20 PIG-PIB	19.811,89	659,52	9.286,24	5.117,85	34.875,50	29,70%	10.358,02	24.517,48
21 LNEG	15.544,56	0,00	0,00	3.886,14	19.430,70	29,70%	5.770,92	13.659,78

22 IGR	31.331,05	418,44	0,00	7.937,37	39.686,86	29,70%	11.787,00	27.899,86
23 GSS	2.042,40	784,00	0,00	706,60	3.533,00	29,70%	1.049,30	2.483,70
24 GeoZS	74.998,21	4.675,87	0,00	19.918,52	99.592,60	29,70%	29.579,00	70.013,60
25 IGME-Sp	217.921,53	21.036,98	0,00	59.739,63	298.698,14	29,70%	88.713,35	209.984,79
26 ICGC	23.476,97	0,00	0,00	5.869,24	29.346,21	29,70%	8.715,83	20.630,39
27 SGU	22.343,79	0,00	0,00	5.585,95	27.929,74	29,70%	8.295,13	19.634,61
28 GEOINFORM	0,00	0,00	0,00	0,00	0,00	29,70%	0,00	0,00
29 NERC	52.820,13	-449,97	0,00	13.092,54	65.462,69	29,70%	19.442,42	46.020,27
30 HSGME	35.000,00	0,00	0,00	8.750,00	43.750,00	29,70%	12.993,75	30.756,25
31 RBINS	0,00	0,00	0,00	0,00	0,00	29,70%	0,00	0,00
					1.926.819,01		**572.265,25**	**1.354.553,76**

Date:	30.11.2021
Person responsible:	Laurence Gourcy

10 PROJECT MINDESEA

10.1 Identification of the project

Project full title:	Seabed Mineral Deposits in European Seas: Metallogeny and Geological Potential for Strategic and Critical Raw Materials
Project acronym:	MINDeSEA
Project reference number:	GeoE.171.001
Project topic:	Raw materials
Project specific research topic:	RM3 – METALLOGENY – GEOLOGICAL POTENTIAL
Project website address:	http://geoera.eu/projects/mindesea2/

Period covered from: 01.01.2020 to: 31.10.2021

Report submission date:	05.11.2021
Project coordinator:	Francisco Javier González Sanz

Contact person for the project:	Francisco Javier González Sanz
Tel:	34913495864
E-mail:	fj.gonzalez@igme.es

10.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Lead
2	Bundesanstalt für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Partner
3	Elliniki Archi kai Metalleftikon Erevnon	Institute of Geology and Mineral Exploration	IGME-Gr	Greece	925968015	Project Partner
4	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner
5	Norges Geologiske undersokelse	Geological Survey of Norway	NGU	Norway	999466758	Project Partner
6	Laboratorio Nacional de Energia e Geologia I.P.	The National Laboratory of Energy and Geology	LNEG	Portugal	994187921	Project Partner
7	Sveriges Geologiska Undersökning	Geological Survey of Sweden	SGU	Sweden	995575991	Project Partner
8	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	Geoinform	Ukraine	947331392	Project Partner
9	Instituto Português do Mar e da Atmosfera	Sea and Atmosphere Portuguese Institute	IPMA	Portugal		Non-funded partner
10	Instituto de Geociencias	Geosciences Institute	IGEO	Spain		Non-funded partner

11	United States Geological Survey	United States Geological Survey	USGS	United States of America	994374064	Non-funded partner
12	Russian Ministry of Natural Resources	Institute for Geology and Mineral Resources of the Ocean	VNIIOkeangeologia	Russia		Non-funded partner

10.3 Publishable summary

Covering more than 70% of the planet, seas and oceans represent a potentially promising new frontier for the exploration of mineral resources. Security of mineral supply has been identified by the European Commission as a priority challenge facing the raw materials sector. The 2020 list of Critical Raw Materials (CRM) reflected societies growing demand for an ever-increasing number and quantity of elements and minerals required to address global climate change and the high- and green-technologies required for a transition from a carbon-based to green-energy-based world. Sustainable access to resources is a strategic security question for Europe's ambition to deliver the "Green Deal", and the global ocean is at the core of these issues. The global demand for cobalt, tellurium, nickel, lithium, rare earth elements, copper, and other strategic and critical metals, concurrent with the rapidly diminishing quality and quantity of land-based mined deposits, has highlighted the seafloor as a promising new frontier for the exploration of mineral resources. Spanning a large diversity of environments and resource types, including high and low temperature hydrothermal deposits (SMS, SEDEX), phosphorites, cobalt-rich ferromanganese crusts, and manganese nodules, deep-sea deposits are particularly attractive for their polymetallic nature with high contents of rare and critical metals. Moreover, shallow-water resources, like marine placer deposits, represent another source for many industrial materials, critical metals, and gems. The seabed mineral resources host the largest reserves on Earth for some critical metals like cobalt, tellurium, manganese, and the rare earth elements, critical for Industry. The EC's Blue Growth strategy estimated that "By 2030, 10% of the world's minerals, including cobalt, copper and zinc could come from the ocean floors. Global annual turnover of marine mineral mining can be expected to grow from virtually nothing to €10 billion by 2030". The materials coming from recycling, including seabed mining related wastes, will contribute to the circular economy.

Extracting minerals from the deep sea represents an enormous scientific and technological challenge for humankind. The global ocean can play a key role in mitigation of climate change, but also in improving the sustainable use of mineral resources. These issues include judicious consideration among the fisheries and minerals industries, offshore wind production, and the preservation of aquatic environments and ecosystems, among other uses of the marine areas included in the maritime spatial plannings. Considerable improvement in our knowledge of the oceans and seas is necessary to develop a sustainable "Blue Economy", and in obtaining social license. But seabed geology and ecosystems are widely unexplored, and new geological and environmental studies are required to address the impacts of potential mining activities. New developments focusing on applying new technologies for deep-sea exploration and mining will be required. In addition, a regulatory framework for minerals extraction and marine spatial planning are necessary for seabed mining sector development. The International Seabed Authority (ISA), made up of 167 Member States, and the European Union, is finishing the normative regulations that will permit the states, organizations or companies to extract minerals in areas beyond national jurisdictions. Thirty one contractors have entered into 15-year contracts with ISA for exploration for manganese nodules, polymetallic sulphides, and cobalt-rich ferromanganese crusts in and on the seabed of the deep Atlantic, Pacific, and Indian oceans. Several projects have been promoted by the European Union, with the Raw Materials Initiative, in order to find and evaluate the sustainable production of strategic and critical minerals, which Europe is strongly dependent on imports. Recently, the EU research programmes are funding projects to increase knowledge about seabed minerals, marine minerals exploration, extraction technologies, and environmental issues. The European, National, and International programs related to the research, exploration, and exploitation of marine minerals, and

environmental impact studies of marine mining activities, will play pivotal roles in the emerging “Blue Economy” and sustainable industrial growth.

The project GeoERA-MINDeSEA aims to map and to establish the metallogenic context for different seabed mineral deposits with economic potential in the pan-European setting. It is a joint contribution of 12 national Geological Survey Organisations and Marine Institutes from 8 European countries, USA, and Russia. The project is part of GeoERA, an ERA-NET action under Horizon 2020 “Establishing the European Geological Surveys Research Area to deliver a Geological Service for Europe (GeoERA)”. This project addresses an integrative metallogenetic study of principal types of seabed mineral resources (hydrothermal sulphides, ferromanganese crusts, phosphorites, marine placers and polymetallic nodules) in the European Seas. This study will publish marine resource information, cases studies and maps; identify areas for responsible resource exploration and extraction; inform management and Marine Spatial Planning.

The MINDeSEA project is compiling data and genetic models for all these deposit types based on extensive studies carried out previously, which include geophysical surveys, dredging stations, underwater photography and ROV surveys, and mineralogical, geochemical, and isotopic studies. The project is built on previously and currently developed pan-European and national databases, and expand the strategic and CRM knowledge trough a compilation of mineral potential and metallogenic studies of critical raw materials resources in pan-European seas. The project is providing recommendations for future target areas, studies and standards to be used across Europe as part of this project.

The objectives include:
1) Characterise deposit types in European seas including volcanogenic massive sulphides and hydrothermal mineralisation; ferromanganese crusts, phosphorites; marine placer deposits and polymetallic nodules.

2) Characterise the trace element content of the deposit types including strategic and CRM, for which the EU is highly dependent. The project aims to emphasise the importance of varied marine deposits and evaluate their potential to provide succeeding generations with a supply of base metals and CRM. The project will identify and define the critical minerals and metals focused on the current list of CRM, but considering also the strategic importance of some of those very enriched in the marine deposits, such as manganese, cobalt, rare earth elements, niobium, phosphate rock, lithium, tellurium, and others such as silver, copper, lead and iron ore.

3) Identify the principal metallogenic provinces, improving the information on the regional geological processes involved in mineral formation and accurate geographical distribution of concentrated mineralisation. Identified strategic and critical metals will be included on the metallogenetic map. Modern metallogenic studies are necessary for developing new exploration methods where off-shore mineral deposits are proven and speculated, and for the development of new genetic models.

4) Develop harmonized mineral maps and datasets of seabed deposits incorporating Geological Survey Organization datasets, along with mineral potential and prospectivity maps. This project will compile and standardise fragmented marine data and data products, then make these available through the GeoERA Information Platform project (GIP-P) and the European Geological Database Infrastructure (EGDI) portal (following INSPIRE guidelines and Open Geospatial Consortium (OGC) standards).

5) Demonstrate how the case-study results can be used in off-shore mineral exploration, using this understanding to predict and develop new mineral deposits or deposit types. An innovation potential of this project will be the proposals of pilot zones with high mineral-potential areas for future exploration.

6) Analyse present-day exploration and exploitation status in terms of regulation, legislation, environmental impacts, exploitation and future directions; promoting the development of robust environmental policy for exploitation of seabed mineral resources in Europe.

7) Demonstrate the efficiency of a pan-European research approach for understanding seabed minerals and modes of exploration, extending state of the art knowledge and information relating to submarine minerals, metallogenic studies, standards and technologies across the European community. The project is producing informative products that will better educate the EC and Society regarding the CRM potential in European Seas.

The pan-European seas cover about 15 millions square kilometres in the Arctic and Atlantic oceans and the Mediterranean, Baltic, and Black seas, from shallow waters up to 6000 m water depth. The MINDeSEA results show the potential of the pan-European seas for critical metals, and the enormous gaps of information covering vast marine sectors. 691 mineral occurrences and more than 1100 analysed samples are reported in the MINDeSEA database including: hydrothermal mineralisation, cobalt-rich ferromanganese crusts, phosphorites, manganese nodules and marine placer deposits. Seamounts, submarine volcanoes and banks in the Macaronesia sector (Portugal and Spain) and the Arctic ridges (Norway, Denmark, Iceland) show a high potential for Fe-Mn crusts, rich in energy-critical elements like cobalt but also tellurium, rare earth elements, titanium and manganese. Fe-Mn crusts are accompanied by phosphorites on the seafloor of continental shelves and slopes along the western continental margins of Portugal and Spain. These marine phosphorites concentrate rare earth elements and yttrium in addition to phosphate and fluoride. Seafloor polymetallic sulphides and metalliferous sediments precipitating from hot hydrothermal solutions and plumes are forming today in the Azores Islands (Portugal), the Arctic (Norway, Denmark) and, the Mediterranean volcanic arcs (Italy and Greece). They are among the most important marine resources for copper, zinc, silver, and gold. In addition, hydrothermal deposits may contain economic grades of cobalt, tin, barium, indium, bismuth, tellurium, gallium, and germanium. Placer deposits of chemically resistant, physically durable minerals have been discovered on shallow-water settings (<50 m water depth on estuaries, deltas, beaches) linked to the weathering of onshore rocks and ore deposits from the Variscan Belt in UK, France, Portugal and Spain, Eastern Mediterranean (Albania, Greece and Cyprus), Black Sea (Ukraine, Rumania, Bulgaria), the Arctic Ocean (Russia, Norway, Denmark) and the Baltic Sea (Poland, Latvia). Accumulations of heavy minerals include monazite, ilmenite, rutile, zircon, garnet, gold, diamonds, cassiterite and magnetite. Finally, shallow-water concretions and nodules from the Arctic (Norway, Russia), Baltic (Sweden, Poland, Finland, Russia, Estonia, Germany), and Black Sea (Ukraine, Romania) represent potential targets for metals exploration and environmental studies.

In December 2018, MINDeSEA produced the first pan-European compilation map of “energy- critical elements” based on ferromanganese deposits. The map reports occurrences and deposits for cobalt and lithium and can be downloaded at: https://geoera.eu/projects/mindesea2/

The project is co-operating with the GeoERA Secretariat in its efforts to disseminate the results to stakeholders including policy makers, industry and academia. Widespread dissemination of the Project activities and products is ensured by: participation and communication in international forums, workshops, seminars, educational activities, knowledge exchange, scientific and promotional publications, reports, newsletters, press release and media news, internships, dissertation of Doctoral Theses (PhD) and Master Theses, and work-training experiences for last year students from national and international Universities; as well as the creation, management and continuous update of the GeoERA-MINDeSEA website (https://geoera.eu/projects/mindesea2/), a dedicated website (https://geoeramindesea.wixsite.com/mindesea) and Social Media (https://twitter.com/MINDeSEA and https://www.facebook.com/mindesea.mindesea.9) are contributing to display all these referred issues.

10.4 Project contribution to GeoERA project

MINDeSEA is the flagship project of GeoERA on seabed mineral deposits in the European Seas, and one of the cornerstones of the GeoERA Raw Materials theme. The Earth provides mineral resources that are vital for human life. As global demand grows, especially for strategic metals and critical raw materials (CRM) crucial for low-carbon energy production and new technologies, there is a proportionate risk of increasing supply shortage for resources that are identified as critical to Europe's economy. In addition, the COVID-19 pandemic has posed significant challenges for supply chains globally. This project handles the Critical Raw Materials in a follow up of the EU Commission's concerns regarding the sustainable sourcing of strategic and critical raw materials to Europe's industry, the contribution to the Blue Growth strategy, the Battery Alliance and the transition from a carbon-based to green-energy-based world.

MINDeSEA aims to assess the quantity and quality of marine CRM's, and a more comprehensive pan-European identification and compilation of mineral potential and classification of metallogenic seafloor mineral deposits, including predictive areas. MINDeSEA also aims to provide guidance for the management of impacts resulting from deep sea resource exploitation, minimising environmental impacts and footprints. Marine spatial planning to ensure conservation of oceans as well as prevent conflict with other ocean users is in its core action.

This overall philosophy of research within MINDeSEA fulfills the main objective of GeoERA, which is to contribute to the sustainable use and responsible management of the subsurface. GeoERA will aim to support: 1) a more integrated and efficient management, maximising its added value and 2) a more responsible and publicly accepted, exploitation and use of the subsurface, minimising environmental impacts and footprints.

10.5 Work progress and achievements during the period

Work package 1: Project Management and Coordination

The coordinator in collaboration with the WP leaders has carried out reporting to the GeoERA during period evaluated. Regular WebEx teleconferences on coordination have been celebrated with all the Raw Materials projects and our RM Coordinator, Antje Wittenberg. The cumulative expenditure documents for each Partner Organization have been delivered by December 2020 and May 2021. Internal Project Progress Reports were delivered as planned by June 2020, December 2020, June 2021 and the present Final Project Progress Report. An Amendment 2 document to the Project Plan was produced changing the deliverable dates due to the negative impact of COVID-19 pandemic and the extension of GeoERA projects until 31 October 2021. The Amendment counts on the agreement for each MINDeSEA Partner Organization, and was delivered by 8 of March 2021, and approved by the GeoERA Assembly on 25 March 2021. MINDeSEA consortium has celebrated three internal face to face meetings in Brussels (3-5 July 2018), at IGME-Sp in Madrid (6-7 May 2019) and at NGU in Trondheim (26-27 November 2019) with the participation of all the project partners and multiple on-line meetings since March 2020. The pan-European compilation map of "energy-critical elements" based on marine mineral deposits has been updated by March 2020, reported to GeoERA and the EC (DG GROW and DG MARE) and published in the EU Blue Economy Report 2020 and 2021 editions. A cooperative action was successfully developed with the participation of EXPLOSEA, EMODnet and MINDeSEA projects members, in the development of research and publications on seabed minerals in pan-European seas. The coordinator of MINDeSEA and partner members (BGR, USGS, VNIIOkeangeologia) have supported with letters different proposals in

competitive calls for the acquisition of new equipment in Research Labs at IGME-Sp and the Complutense University of Madrid. The milestones M1.3 and M1.4 have been reached.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Internal Progress Report	IGME-Sp	Report	Theme Coordinator	M6, M12, M18, M24, M30, M36	Completed	Review completed with Midterm report.
D1.2	Project Progress Report	IGME-Sp	Report	GeoERA Stakeholder Council	M18	Completed	Review completed with Final report.
D1.3	Final Project Progress Report	IGME-Sp	Report	GeoERA Stakeholder Council	M40	Completed	Review completed with Midterm report.
D1.4	Cumulative Expenditure Reports	IGME-Sp	Report	GeoERA	M6, M18	Completed	Review completed with Midterm report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M1.1	Kick-off Meeting	M1	Completed	Review completed with Midterm report.
M1.2	Project Progress Report	M18	Completed	Review completed with Midterm report.
M1.3	Final Project Progress Report	M40	Completed	Review completed with Midterm report.
M1.4	Final Meeting	M40	Completed	Review completed with Midterm report.

Work package 2: Communication, Dissemination and Exploitation

A detailed report on the dissemination and exploitation activities of MINDeSEA have been produced and delivered as Deliverable D2.4 - Dissemination Products.
The MINDeSEA website (**http://geoera.eu/projects/mindesea2/**) was integrated in the GeoERA site (www.geoera.eu) in July 2018 and periodically updated. In July 2018, dedicated Twitter account (**https://twitter.com/MINDeSEA) and Facebook profile (https://www.facebook.com/mindesea.mindesea.9**) were created. These social media active along the project life have been daily updated. A dedicated website: https://geoeramindesea.wixsite.com/mindesea was created in October 2018 and frequently updated with the progresses of MINDeSEA. Website links have been created (from July 2018) in the partners organization websites in order to increase the visibility of MINDeSEA and GeoERA (eg., http://www.igme.es/divulgacion/actualidad/MINDeSEA.htm; http://www.lneg.pt/iedt/projectos/614/; http://geoinf.kiev.ua/mizhnarodne-spivrobitnytstvo-1/projekt-geoera/rm3-proekt-mindesea/; http://srv-v-fm.ngu.no/pls/oradb/!pbs2.vis.prosj_beskr?projnr=380900; https://www.gsi.ie/en-

ie/programmes-and-projects/marine-and-coastal-unit/research/Pages/default.aspx), thus increasing the number of potential visitors. For internal communication between consortium members a FTP site is available (ftp.igme.es) in addition to the GeoERA intranet.
MINDeSEA consortium has created a visual identity including logos, colors, fonts, templates, photos, etc, with the aim to make the project identifiable to its target audiences. Cooperative e-newsletters and have been published with the aim to keep all stakeholders interested in GeoERA Raw Materials and MINDeSEA informed.
MINDeSEA consortium in cooperation with GeoERA Raw materials projects has presented press releases and continuous communication of activities in several Spanish Media (https://geoeramindesea.wixsite.com/mindesea/press-release).
The MINDeSEA Consortium has attended different International Conferences and Meetings on Marine Geology and Mineral Resources presenting oral and poster communications (see spreadsheet 6. Communication, dissemination and deliverable D2.4). Between the project's start in 2018 and its conclusion in 2021, the project partners published 29 papers and 46 abstracts at conferences covering topics on exploration and cartography, mineralogy, geochemistry and processing of submarine mineral deposits (see spreadsheet 6. Communication, dissemination and deliverable D2.4). MINDeSEA consortium has contributed to "The EU Blue Economy Report, editions 2019, 2020 and 2021 attending the petition of the DG MARE for comments and contribution in the section 4.3 Marine Minerals. Educational and outreach activities during period 2020-2021 include: the defence of a Doctoral Thesis on critical metals and ferromanganese crusts (Egidio Marino PhD); one Master Thesis on Geochemistry of metalliferous sediments and iron-rich deposits in active volcanic-hydrothermal systems from the Aeolian Islands (Italy) (Steve Hamilton Escobar); seminars in research and education institutions (eg., Univ. Buenos Aires-Argentina; Univ. Barcelona, Univ. Complutense Madrid); and working-training experiences for last year students from national and international Universities. Different talks on the activities and progresses of MINDeSEA project to the Mineral Resources Expert Group- (MREG) and the Marine Geology Expert Group (MGEG) Eurogeosurveys (see spreadsheet 6. Communication, dissemination and deliverable D2.4).
MINDeSEA consortium has organized three workshops dedicated to the main themes of the work packages and celebrated on-line (see spreadsheet 6. Communication, dissemination and deliverable D2.4).
IGME-Sp (Luis Somoza and Javier González) have coordinated the edition of a Special Issue in Minerals entitled "Marine Geology and Minerals" focused on the investigation, exploration and potential future exploitation of submarine mineral resources, published in 2020 and including 18 scientific papers. For further information see: https://www.mdpi.com/journal/minerals/special_issues/marine_geology_minerals
The milestone M2.2: Report on Communication strategy has been reached.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	WP2 Task guide	IGME-Sp	Task guide	GeoERA and Partners	M3	Completed	Review completed with Midterm report.
D2.2	Disseminatio n products	IGME-Sp	Digital products	Public	M1-40	Completed	Review completed with Midterm report.
D2.3	Workshops	IGME-Sp	Workshop	GeoERA and Public	M11, M17, M21, M30, M40	Completed	Review completed with Midterm report.

D2.4	Report WP2	IGME-Sp	Report	Public	M40	Completed	Review completed with Final report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M2.1	Dissemination on the website and apps	M6-40	Completed	Review completed with Midterm report.
M2.2	Report on Communication strategy	M40	Completed	Delivery of report D2.4

Work package 3: Seafloor Massive Sulphide Deposits

All the WP3 deliverables have been submitted according the project plan. The milestones for the WP3 are completed.
The MINDeSEA consortium has compiled and created new databases of existing data on SMS deposits and hydrothermal mineralisation in European waters. The MINDeSEA consortium has discussed and approved the inclusion in this WP of "Hydrothermal Deposits" as more presentative of this group of mineralization instead of "Seafloor Massive Sulphide Deposits". Many of these mineralizations are represented by other than sulphides like in the case of hydrothermal oxides, silica caps or sulfate/carbonate chinmeys being more indicated the use of the generic term "hydrothermal deposit".
The INSPIRE-compliant harmonised dataset and maps have been delivered to GIP-P and GeoERA, and described in the deliverable D3.2. The dataset and GIS cartography contain 153 occurrences, 173 individual analysed samples, in 6 marine regions (Arctic Ocean, Bay of Biscay and Iberian Coast, Central-NE Atlantic Ocean, Macaronesia, Aegean Sea and Mediterranean Sea) and 8 EU countries (Cyprus, Spain, Greece, Greenland, Iceland, Italy, Norway, Portugal) and contiguous International Waters. 16 critical elements (Sb, Ba, Bi, Co, Ga, Ge, HREE, LREE, In, Nb, Sc, Ta, W, V, Li, Ti) and 4 strategic metals (Ni, Cu, Mo, Zn) are compiled in the database and mapped at a scale 1:250,000.
Metallogenic models and map for hydrothermal mineralization have been detailed presented in the deliverables D3.3 (report + map) and their associated CRM are discussed in the deliverable D3.4. Predictive and mineral exploration potential areas are included in the metallogenic map and described in the deliverable D3.4.
Case studies are based on the first review of compiled and harmonized data. Case studies identified include from high- to low-temperature hydrothermal deposits of sulphides, oxides and sulfates in different geotectonic settings: mid-Atlantic ocean ridge-Moytirra (Somoza et al., 2020; 2021), Canary hot-spot volcano-Tagoro (González et al., 2020) and back-arc volcanoes-Aeolian Islands (Hamilton Escobar, 2021).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	WP3 Task guide	NGU	Task guide	GeoERA and Partners	M3	Completed	Review completed with Midterm report.
D3.2	Database and maps on SMS	NGU	Dataset	Public	M1-40	Completed	Review completed with

							Midterm report.
D3.3	SMS metallogenic models	NGU	Report (modelization)	Public	M34	Completed	Review completed with Final report.
D3.4	SMS potential assessment	NGU	Report	Public (decision makers)	M40	Completed	Review completed with Final report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M3.1	Database and metallogenic map on SMS	M34	Completed	Delivery of report D3.2, database and maps
M3.2	Metallogenic settings and CRM potential on SMS	M34	Completed	Delivery of reports D3.3 and D3.4
M3.3	Predictive and mineral exploration potential map	M40	Completed	Delivery of report D3.4 and metallogenic map

Work package 4: Ferro-manganese Crusts, Phosphorites and Critical Raw Materials

All the WP4 deliverables have been submitted according the project plan. The milestones for the WP4 are completed.
The MINDeSEA consortium has compiled and created new databases of existing data on ferromanganese crusts and phosphorites in European waters. The INSPIRE-compliant harmonised dataset and maps have been delivered to GIP-P and GeoERA, and described in the deliverable D4.2. The dataset and GIS cartography on ferromanganese crusts contain 141 occurrences, 260 individual analysed samples, in 7 marine regions (Arctic Ocean, Norwegian Sea, Bay of Biscay and Iberian Coast, Celtic Sea, Central-NE Atlantic Ocean, Macaronesia and Mediterranean Sea) and 7 EU countries (Denmark, Spain, Portugal, Iceland, Norway, Russia, United Kingdom) and contiguous International Waters. 12 critical elements (Bi, Co, HREE, LREE, Nb, P, Sc, W, V, Li, Ti, PGM) and 5 strategic metals (Mn, Ni, Cu, Mo, Zn) are compiled in the database and mapped at a scale 1:250,000. The database on phosphorites contains 12 occurrences, 45 individual analysed samples, in 2 marine regions (Bay of Biscay and Iberian Coast, Macaronesia) and 2 EU countries (Spain, Portugal). 6 critical elements (F, HREE, LREE, phosphate rock, P, Ti) and 1 strategic metal (Mn) are compiled in the database and mapped at a scale 1:250,000.
Mineral-potential and prospectivity maps for Fe-Mn crusts and phosphorites were submitted in the deliverable D4.3 (2 maps).
Fe-Mn crusts and phosphorites metallogenic models have been detailed presented in the deliverables D4.4 (report + map).
The report D4.5 describes the exploration potential of CRM. New analyses on critical metals like cobalt, lithium, tellurium, and rare earth elements have been developed in specific representative samples (Canary Islands, Norwegian seas and Iberian margins). Innovative technics (FTIR, LA-ICP-MS, Raman) were used for these studies (Marino et al., 2018; 2019; Marino, 2020).
Status of regulation, legislation and exploitation for seabed mineral deposits and specially ferromanganese crusts and phosphorites are detailed in the deliverable D4.6.
Results of the case study for ferromanganese crusts and phosphorites in the Macaronesia area (NE Atlantic Ocean) are proposed in the deliverable D4.7.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	WP4 Task guide	IGME-Sp	Task guide	GeoERA and Partners	M3	Completed	Review completed with Midterm report.
D4.2	Database and maps on Fe-Mn crusts and phosporites	IGME-Sp	Dataset	Public	M1-40	Completed	Review completed with Midterm report.
D4.3	Mineral-potential and prospectivity maps	IGME-Sp	Maps	Public	M40	Completed	Review completed with Final report.
D4.4	Fe-Mn crusts and phosphorites metallogenic models	IGME-Sp	Report (modelization)	Public	M34	Completed	Review completed with Final report.
D4.5	Exploration potential of CRM	IGME-Sp	Report	Public (decision makers)	M36	Completed	Review completed with Final report.
D4.6	Status of regulation, legislation and exploitation	IGME-Sp	Report	Public	M40	Completed	Review completed with Final report.
D4.7	Case study	IGME-Sp	Report (modelization)	Public (decision makers)	M40	Completed	Review completed with Final report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M4.1	Database and metallogenic map on Fe-Mn crusts and phosphorites	M34	Completed	Delivery of report D4.2 database and maps
M4.2	Metallogenic settings and CRM potential on Fe-Mn crusts and phosphorites	M36	Completed	Delivery of reports D4.4, D4.5 and metallogenic map
M4.3	Predictive and mineral exploration potential map	M40	Completed	Delivery of maps (D4.3) and report D4.6
M4.4	Case study	M40	Completed	Delivery of report D4.7 and maps

Work package 5: Marine Placer Deposits

All the WP5 deliverables have been submitted according the project plan. The milestones for the WP5 are completed.
The MINDeSEA consortium has compiled and created new databases of existing data on marine placers in European waters. The INSPIRE-compliant harmonised dataset and maps have been delivered to GIP-P

and GeoERA, and described in the deliverable D5.2. The dataset and GIS cartography on marine placers contain 89 occurrences, in 12 marine regions (Arctic Ocean, Baltic Sea, Great North Sea, Bay of Biscay and Iberian Coast, Celtic Sea, English Channel, Inner Seas of the West Coast of Scotland, Irish Sea and St. George's Channel, Macaronesia, Adriatic Sea, Mediterranean Sea and Black Sea) and 14 EU countries (Albania, Bulgaria, Cyprus, Iceland, Spain, France, United Kingdom, Ireland, Italy, Latvia, Poland, Romania, Russia, Ukraine), and mapped at a scale 1:250,000.
Mineral-potential and prospectivity maps for marine placers were submitted in the deliverable D5.3 (map).
Marine placers metallogenic models have been detailed presented in the deliverables D5.4 (include report and maps contained within).
The report D5.5 describes the status of regulation, legislation and exploitation for seabed mineral deposits and specially for placers.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1	WP5 Task guide	HSGME	Task guide	GeoERA and Partners	M3	Completed	Review completed with Midterm report.
D5.2	Database and maps on marine placers	HSGME	Dataset	Public	M1-40	Completed	Review completed with Midterm report.
D5.3	Mineral-potential and prospectivity maps	HSGME	Maps	Public	M40	Completed	Review completed with Final report.
D5.4	Placers metallogenic models	HSGME	Report (modelization)	Public	M38	Completed	Review completed with Final report.
D5.5	Status of regulation, legislation and exploitation	HSGME	Report	Public (decision makers)	M36	Completed	Review completed with Final report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M5.1	Database and metallogenic map on marine placers	M34	Completed	Delivery of report D5.2, database and maps
M5.2	Metallogenic settings for marine placer deposits	M36	Completed	Delivery of reports D5.4 and D5.5
M5.3	Predictive and mineral exploration potential map	M40	Completed	Delivery of maps (D5.3)

Work package 6: Polymetallic Nodules

All the WP6 deliverables have been submitted according the project plan. The milestones for the WP6 are completed.
The report D6.2 present a review on the polymetallic nodules prospect evaluation parameters. The MINDeSEA consortium has compiled and created new databases of existing data polymetallic nodules in European waters. The INSPIRE-compliant harmonised dataset and maps have been delivered to GIP-P

and GeoERA, and described in the deliverable D6.3. The dataset and GIS cartography on polymetallic nodules contain 296 occurrences, 490 individual analysed samples, in 7marine regions (Arctic Ocean, Baltic Sea, Bay of Biscay and Iberian Coast, Celtic Sea, Central-NE Atlantic Ocean, Macaronesia and Black Sea) and 16 EU countries (Germany, Denmark, Estonia, Spain, Finland, France, United Kingdom, Ireland, Latvia, Norway, Poland, Portugal, Romania, Russia, Sweden, Ukraine). 12 critical elements (Ba, Bi, Co, HREE, LREE, Nb, P, Sc, W, V, Li, Ti) and 5 strategic metals (Mn, Ni, Cu, Mo, Zn) are compiled in the database and mapped at a scale 1:250,000.
Mineral-potential and prospectivity map for polymetallic nodules were submitted in the deliverable D6.4 (map).
Polymetallic nodules prospect evaluation has been detailed presented in the deliverable D6.5 (include report and maps contained within).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D6.1	WP6 Task guide	LNEG	Task guide	GeoERA and Partners	M3	Completed	Review completed with Midterm report.
D6.2	Polymetallic nodules prospect evaluation parameters	LNEG	Report	Public	M32	Completed	Review completed with Final report.
D6.3	Database and maps on polymetallic nodules	LNEG	Dataset	Public	M1-40	Completed	Review completed with Midterm report.
D6.4	Mineral-potential and prospectivity maps	LNEG	Maps	Public	M40	Completed	Review completed with Final report.
D6.5	Polymetallic nodules prospect evaluation	LNEG	Report	Public	M40	Completed	Review completed with Final report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M6.1	Database and metallogenic map on polymetallic nodules	M32	Completed	Delivery of report D6.3, database and maps
M6.2	Metallogenic settings for polymetallic nodules	M32	Completed	Delivery of report D6.2 and metallogenic map
M6.3	Predictive and mineral exploration potential map	M40	Completed	Delivery of maps (D6.4) and report D6.5

Work package 7: Exploration in the Atlantic, Mediterranean, Baltic and Black Sea

All the WP7 deliverables have been submitted according the project plan. The milestones for the WP7 are completed.
The MINDeSEA consortium has compiled and created new databases of existing data on exploration in European waters. The INSPIRE-compliant harmonised dataset and maps have been delivered to GIP-P and GeoERA, and described in the deliverable D7.2. The dataset and GIS cartography on exploration contain 32 cruise surveys, in 5 marine regions (Baltic Sea, Barents Sea, Bay of Biscay and the Iberian Coasts, Macaronesia, Mediterranean Sea) and 6 EU countries (Spain, Portugal, Italy, Sweden, Norway) and contiguous International Waters. Detailed information on the seafloor exploration technics and explored areas is available on Deliverable 7.3 and its specific maps.
Mineral-potential and prospectivity maps for exploration in pan-European seas were submitted in the deliverable D7.3 (general map and zoom areas).
Present-day status of exploration has been detailed presented in the deliverable D7.4 (include report, tables and maps contained within).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D7.1	WP7 Task guide	IGME-Sp	Task guide	GeoERA and Partners	M3	Completed	Review completed with Midterm report.
D7.2	Database and maps on Exploration	IGME-Sp	Dataset and Maps	Public	M1-40	Completed	Review completed with Midterm report.
D7.3	Mineral-potential and prospectivity maps	IGME-Sp	Maps	Public	M40	Completed	Review completed with Final report.
D7.4	Present-day status of exploration	IGME-Sp	Report	Public (decision makers)	M40	Completed	Review completed with Final report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M7.1	Database and maps of marine minerals explored in Europe	M34	Completed	Delivery of report D7.2, database and maps
M7.2	Present-day status of exploration	M40	Completed	Delivery of report D7.4
M7.3	New prospectivity areas	M40	Completed	Delivery of report D7.4 and maps (D7.3)

Work package 8: Link to Information Platform

All the WP8 deliverables have been submitted according the project plan. The milestones for the WP8 are completed. Completion of project databases and fully functional portal was reached. The list of web products, vocabularies, datasets and functionalities has been created.
The continuous dialogue with the GeoERA Information Platform team, learn planned approaches to: website set; principals and guidelines; standards and methodologies; prototyping; testing and implementation of fully functional data services; communication throughout the project lifespan.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D8.1	WP8 Task guide	GSI	Task guide	GeoERA and Partners	M3	Completed	Review completed with Midterm report.
D8.2	Project metrics	GSI	Report	Public	M1-40	Completed	Review completed with Midterm report.
D8.3	Best practice manual with practical guidelines and workflows for data	GSI	Manual	Public	M18	Completed	Review completed with Midterm report.
D8.4	Completion of project databases & fully functional portal	GSI	Dataset	Public	M1-40	Completed	Review completed with Midterm report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M8.1	Data normative and format requirements	M18	Completed	Review completed with Midterm report.
M8.2	Publication and fully functional web layers of products	M24, 40	Completed	Acceptance by IP coordinator
M8.3	Recommendations on resource, research and exploration practices	M40	Completed	Delivery of report

10.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	Yes, workplan (deliver dates changed due to the negative impact of COVID-19 pandemic) Approbed by GeoERA Assembly on 25 March 2021

10.7 Communication and dissemination activities

	CONGRESS	FACEBOOK	INTERNAL PROJECT MEETING	MEETING WITH OTHER GEOERA PROJECTS	MEETING WITH OTHER PROJECTS	NEWSLETTER	OTHER	SCIENTIFIC PUBLICATION	THESIS	TWITER	WEBINAR	WEBSITE	WORKSHOP	YOUTUBE	Total
EVENTS	22						3				7		1		33
MEETINGS			1	4	1										6
ONLINE_MEDIA		1								2		2		4	9
PUBLICATIONS						2	12	15	1						30
Total	**22**	**1**	**1**	**4**	**1**	**2**	**15**	**15**	**1**	**2**	**7**	**2**	**1**	**4**	**78**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	60270		138	119	181	67	148		97		61020
MEETINGS	1960		14	22	12		3				2011
ONLINE_MEDIA	6141	32662	61	79	21		16	11	77		39068
PUBLICATIONS	31770		80	140	116		60		79		32245
Total	**100141**	**32662**	**293**	**360**	**330**	**67**	**227**	**11**	**253**		**134344**

10.8 Project management

• Maintaining an open communication channel between project coordinator, WP leaders and consortium members
• A close quarters, open dialogue stream with the GeoERA Secretariat, the GeoERA Raw Materials Theme coordinator, Antje Wittenberg, and Monitoring Team
• Fomenting the interaction between WP's; essential for the success of MINDeSEA, as well as between MINDeSEA and the other Raw Materials projects namely, FRAME, Eurolithos, Mintell4EU and GIP-IP
• Maintaining an open cooperation framework with other projects and research groups for the study of submarine mineral deposits at national and international scale (EMODnet-Geology, EXPLOSEA, Marine E-tech)
• Opening a communication highway between MINDeSEA and the Marine Geology Group (MGEG) and Mineral Resources Group (MREG) of EuroGeoSurveys (EGS). This has been particularly useful in getting countries that do not belong to the consortium to deliver data or stablishing dialogue for future cooperation. This close interaction with MGEG and MREG and EGS is clearly a benefit and has already been instrumental in achieving a complete map of submarine mineral deposits in Europe, metallogenic and potential-prospectivity maps, and a first version on the map of the Energy-Critical Elements Co and Li in pan-European seas
• This interaction with EGS and MREG has resulted in meetings of the MREG group having a B2B meeting with the GeoERA RM projects. The formula has been applied in face to face meetings in Rome (November 2018), Trondheim (May 2019), Madrid (November 2019) and Lisbon (September 2021), on-line meetings in 2020-2021 due to the COVID-19 restrictions, and has been successful and is seen as essential to discuss project details
• The interaction with EGS and MGEG has resulted in a meeting of the MGEG group having a B2B meeting with the EMODnet-Geology project. The formula has been applied in Albania (October 2018) and on-line meetings in 2020-2021 due to the COVID-19 restrictions.
• Maintaining an open dialogue with the EU Commission and its constituent DG's (DG MARE, DG GROW), contributing to the preparation of the Eu Blue Economy Report, editions 2019, 2020 and 2021.
• Maintaining an active visual presence of MINDeSEA in social media (Twitter and Facebook) and the project website as well as pitching MINDeSEA in congresses, public events, training at the school and Universities and workshops/ seminars.
• Maintaining an up to date Deliverable and Milestone plan.

10.9 General description of the cooperation over the duration of the project

MINDeSEA consortium is forming a network of expertises with a common interest on seabed minerals. All the Partners have actively contributed to the activities of dissemination and exploitation of results along the project time life. The project has provided transnational work. Mineral harmonised resource datasets and maps; genetic/predictive models for resources and analysis of impact assessments for European seabed mineral resources presented here represent a common effort to work together understanding European seabed mineral resources without limitation of frontiers. The identification of data gaps and target areas will facilitate more directed and transnational future projects. IGME (Spain) has led the development of the MINDeSEA project (WP1), providing support to the partners and trans-project cooperation at the GeoERA level (eg., Raw Materials projects, GIP-P). IGME has led the communication and dissemination activitities of MINDeSEA (WP2) and the development of datasets, maps (inventory, metallogeny, prospectivity) and reports for ferromanganese crusts and phosphorites and their associated CRM (WP4), and exploration in pan-European seas (WP7). NGU (Norway) has lead the compilation of dataset, maps and reports on seafloor hydrothermal mineralisation, including massive sulphides (WP3). HSGME (Greece) has led the reports, datasets and maps on marine placers in pan-European seas (WP5). LNEG (Portugal) has led the tasks on reporting and mapping polymetallic nodules

under the MINDeSEA project (WP6). GSI (Ireland) has stablished the link with GIP-P (WP8) providing INSPIRE compliant datasets and cartographies in the GeoERA and EGDI portals. BGR (Germany) has contributed to the development of reports, papers and high-resolution analysis of ferromanganese crusts and polymetallic nodules in different sectors of the European seas. SGU of Sweeden has provided data and expertise on the polymetallic nodules from the Baltic Sea, contributing to the inventory and reports. Geoinform of Ukraine has provided detailed information on the seabed mineral deposits in the Black Sea, contributing to the datasets and maps for polymetallic nodules and marine placers at this area. Non-funded partners (USGS, IPMA, IGEO and VNII Okean) have contributed with expertise to the different WPs, dissemination activities (eg., Seminars) and exploitation products (eg., reports, papers).

10.10 Impact statement

- First compilation maps and reports in Europe for seabed mineral deposits, including their associated strategic and CRM
- DG-GROW and DG-MARE are using the inventory, occurrence maps, metallogenic maps and predictive maps as useful tools for marine spatial planning, to locate future targets for CRM exploration, for environmental protection and so on.
- Obtain a complete overview of the European seabed mineral resources, highlighting areas and resources with high potential for future exploitation; pilot laboratories in the international framework and an expertise network in Europe
- There are clear impacts on: ethics related to the exploitation and preservation of marine areas, including regulations in the national and international level, synergies with science education and research centers in Europe and around the world working together increasing the knowledge in marine minerals and marine geology, interdisciplinary cooperation with expertise in environment, marine biology, policy makers and the civil society showing the complex dimension of human activities in the marine environment and on the seafloor.

10.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontracting	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. IGME-Sp	214.265,59	22.215,94	27.840,90	59.120,38	323.442,80	29,70%	96.062,51	227.380,29
2. BGR	85.586,16	0,00	0,00	21.396,54	106.982,70	29,70%	31.773,86	75.208,84
3. HSGME	18.523,20	23,35	0,00	4.636,64	23.183,19	29,70%	6.885,41	16.297,78
4. GSI	46.274,58	4.578,22	0,00	12.713,20	63.566,00	29,70%	18.879,10	44.686,90
5. NGU	18.306,37	0,00	0,00	4.576,59	22.882,96	29,70%	6.796,24	16.086,72
6. LNEG	31.992,24	1.207,59	9.188,78	8.299,96	50.688,57	29,70%	15.054,51	35.634,06
7. SGU	3.749,62	0,00	0,00	937,41	4.687,03	29,70%	1.392,05	3.294,98
8. Geoinform	0,00	0,00	0,00	0,00	0,00	29,70%	0,00	0,00
	418.697,76	**28.025,10**	**37.029,68**	**111.680,72**	**595.433,25**		**176.843,67**	**418.589,57**

Date:	30.11.2021
Person responsible:	Francisco Javier González Sanz

11 PROJECT MINTELL4EU

11.1 Identification of the project

Project full title:	Mineral Intelligence for Europe
Project acronym:	Mintell4EU
Project reference number:	GeoE.171.016
Project topic:	Raw Materials
Project specific research topic:	RM1 – IMPROVING AND SUSTAINING THE RAW MATERIALS KNOWLEDGE BASE BY PERIODICALLY DELIVERING A MINERALS YEARBOOK AND INVENTORY INFORMATION SYSTEM
Project website address:	https://geoera.eu/projects/mintell4eu7/

Period covered	from:	1 Jan. 2020	to: 31 Oct. 2021

Report submission date:	16 Nov. 2021
Project coordinator:	Lisbeth Flindt Jørgensen, GEUS

Contact person for the project:	Lisbeth Flindt Jørgensen
Tel:	+4591333620
E-mail:	LFJ@GEUS.DK

11.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	De nationale geologiske undersøgelser for Danmark og Grønland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Lead
2	Bundesanstalt Für Geowissenschaften und Rohstoffe	The French Geological Survey	BRGM	France	999993662	Project Partner
3	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
4	Ministry of Agriculture, Natural Resources and Environment of Cyprus	Cyprus Geological Survey Department	GSD	Cyprus	999434845	Project Partner
5	Istituto Superiore per la Protezione e la Ricerca Ambientale	Italian Institute for Environmental Protection and Research	ISPRA	Italy	997905349	Project Partner
6	Norges Geologiske undersokelse	Geological Survey of Norway	NGU	Norway	999466758	Project Partner

7	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
8	Sveriges Geologiska Undersökning	Geological Survey of Sweden	SGU	Sweden	995575991	Project Partner
9	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner
10	Statny Geologicky ustav Dionyza Stura	State Geological Institute of Dionyz Stur	SGUDS	Slovakia	995391982	Project Partner
11	Laboratorio Nacional de Energia e Geologia I.P.	The National Laboratory of Energy and Geology	LNEG	Portugal	994187921	Project Partner
12	Institouto Geologikon kai Metalleftikon Erevnon	Institute of Geology and Mineral Exploration	IGME-Gr	Greece	925968015	Project Partner
13	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
14	Geologian Tutkimuskeskus	Geological Survey of Finland	GTK	Finland	999432614	Project Partner
15	UK Research and Innovation	British Geological Survey	NERC (UKRI)	United Kingdom	906446474	Project Partner
16	Regierungspräsidium Freiburg	Regional Council Freiburg	LGRB	Germany	942768124	Project Partner
17	Bundesanstalt für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Partner
18	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner
19	Institut Royal des Sciences Natueelles de Belgique	Geological Survey of Belgium – Royal Belgian Institute of Natural Sciences	RBINS-GSB	Belgium	998437006	Project Partner
20	Magyar Bányászati és Földtani Szolgálat	Mining and Geological Survey of Hungary	MBFSZ	Hungary	967592364	Project Partner
21	Administration Des Ponts et Chaussees Direction; Service Géologique du Luxembourg	National geological survey	SGL	Luxemburg	983408408	Project Partner
22	Geological Survey of Serbia	Geological Survey of Serbia	GSS	Serbia	919767678	Project Partner

23	Per Sherbimin Gjeologjik Shqiptar	Albanian Geological Survey	AGS	Albania	951811337	Project Partner
24	Ceska Geologicka Sluzba	Czech Geological Survey	CGS	Czech Republic	999546783	Project Partner
25	Federalni Zavod Za Geologiju Sarajevo	Geological Survey of Federation of Bosnia and Herzegovina	FZZG	Bosnia and Herzegovina	947831524	Project Partner
26	Regione Umbria	Servizio Geologico	RU	Italy	997980233	Project Partner
27	Geologische Bundesanstalt	Geological Survey of Austria	GBA	Austria	998164145	Project Partner

11.3 Publishable summary

We tend to forget or ignore the importance of raw materials and minerals in our daily lives. Every time we reach for our cell phone, enter our car, climb our bike or use any means of transport, even in our daily life in our homes, we should recall – but probably very few do – that none of these would exist without raw materials. Humans have exploited these materials since prehistoric times, from rocks in the Stone Age, metals and fuels through the industrial revolution, to Critical Raw Materials essential for the Green Transition. This more recent change in approach has increased the political focus on raw materials. The European Commission now advocates an approach to explore the opportunities to expand extraction of raw materials inside Europe, to reduce the dependency on importation of materials. In the light of this, the work carried out in MINTELL4EU is extremely important, as this project has worked to extend and improve European minerals intelligence, to underpin decision making by governments and industry.

National or regional geological surveys play an important role in mapping raw material resources, and most geological surveys host data on raw materials. However, these data are typically organized in different ways from one country to another based on different geological traditions, legal frameworks etc. The MINTELL4EU project builds on previous and parallel projects such as Minerals4EU, EURare, ProSUM, ORAMA and RESEERVE; projects that all contributed to the establishment of a harmonized European Knowledge Base on raw materials. MINTELL4EU has extended this collection of data and worked to further harmonize and optimise data, as well as automate the data collection to facilitate regular updates of comprehensive and reliable information across borders. MINTELL4EU has provided updated aggregated data at national level on production, trade, resources, reserves and exploration – the electronic Minerals Yearbook – as well as extended the spatial coverage and harmonisation of data on mineral occurrences and mines – the Minerals Inventory. For the latter, data were added from Luxembourg, a German state and six West Balkan countries while already existing data provides updated their input. All data are stored in the central database MIN4EU, and code lists are updated e.g. with UNFC. Data are downloadable under a common license, and user-friendly visualizations are offered in a harmonized way at the European Geological Data Infrastructure (EGDI). A smaller task was the collection of data and the delivery of a map of historic mine sites with touristic features, an invaluable output when it comes to dissemination to the general public. In addition, test cases of the United Nations Framework Classification (UNFC) have been completed, giving recommendations on the way forward to implement UNFC methodology on European raw material resources. Finally, data are shared with other information platforms such as the Raw Materials Information System (RMIS) of JRC.

11.4 Project contribution to GeoERA project

The MINTELL4EU project has supported the overall aim of GeoERA – to integrate European Geological Survey Organisations' information and knowledge on subsurface energy, water and raw material resources to contribute to sustainable use and management of the subsurface. As mentioned above, MINTELL4EU has worked to improve the European Union Raw Materials Knowledge Base by updating the electronic Minerals Yearbook and by extending the spatial coverage, improving harmonization, as well as by refining data quality in the MIN4EU database. Therefore, the scope described for projects under the GeoERA Programme Specific Research Topic "RM1 - IMPROVING AND SUSTAINING THE RAW MATERIALS KNOWLEDGE BASE BY PERIODICALLY DELIVERING A MINERALS YEARBOOK AND INVENTORY INFORMATION SYSTEM" is fulfilled.

Not only is the electronic Minerals Yearbook updated, data have also been further harmonized (in terms of common code lists with the Minerals Inventory) and transferred to the MIN4EU database to allow automation and sustainability. This enables appropriate and streamlined interfaces towards end users through the EGDI where maps illustrate the potential of combining data from the Yearbook with Minerals Inventory data. Moreover, the geographical coverage of raw materials data in the minerals inventory is extended with the addition of Luxembourg and one German state as well as six West Balkan countries through cooperation with the EIT Raw Materials project RESEERVE. The data quality and harmonization have been addressed via training, workshops and the development of quality assurance tools. Automatised collection (harvesting) procedures have been further developed to ensure correct data acquisition. Furthermore, MINTELL4EU has implemented recommendations from the ORAMA project, including testing the use of the UNFC on European mineral resource data. This provided invaluable information on the readiness of the geological surveys to use this classification system and how the system can provide better harmonization of data and eventually help in providing more accurate Pan-European mineral inventories. Finally, besides sharing data through the EGDI, MINTELL4EU makes selected data sets visible at the Raw Materials Information System (RMIS) via embedded viewers.

Together with the other three GeoERA Raw Material projects, MINTELL4EU has been closely connected to the Expert Group on Minerals Resources (MREG) under the auspices of EuroGeoSurvey. Meetings were held at least twice per year discussing cooperation as well as challenges, paving many roads forward. This interaction has indeed enhanced communication and a successful outcome of MINTELL4EU as well as the other raw material projects. Finally, DG GROW has closely followed the work of the GeoERA Raw Materials, partly in dedicated meetings, partly by participating upon invitation in biannual meetings between MREG and the GeoERA Raw Materials projects.

11.5 Work progress and achievements during the period

Work package 1: Management, communication, dissemination, and sustainability

Task 1.1 - Management and reporting (M1-40):

The period from January 2020 until end of October has been characterised by the travel restrictions imposed by the COVID-19 epidemic. The only physical meeting has been a MREG meeting b2b with the GeoERA RM projects in Lisbon in September 2021, where only a few partners were present, while others participated online. No dedicated project meeting was arranged, but a MINTELL4EU presentation was given by the PL.

Since January 2020, two online project assemblies have been conducted. One was 28 October 2020 back-to-back with a workshop on the Minerals Inventory, a project board meeting, and a UNFC test case workshop, all online. All 27 MINTELL4EU partners participated online. The second was a closing project assembly, also held online on the very last official working day of the project, 29 October 2021. 17 partners participated.

20 project board meetings took place since the beginning of 2020, all online. At these meetings, WP leads

presented the latest progress and issues of concern or challenges to be discussed and solved with partners. All partners were invited to participate in these meetings and a few partners often took advantage of this opportunity.
Besides, several bilateral meetings with and between individual partners have taken place, e.g. on preparing data for the harvesting to the Minerals Inventory. Other meetings were organised e.g. with the other GeoERA Raw Material projects to facilitate integration of new data into the Minerals Inventory or helping in adding data to the EGDI system.
As MINTELL4EU and GIP-P PLs are colleagues at GEUS, the cooperation has run smoothly on a number of issues related to data and EGDI.
Two D3.1 reports have been produced, the first (Management report no. 1, M18) gives a brief overview of the project progress in the first 18 months of the project, while the next, (Final project mangement report, M40), gives an overview of the project progress since January 2020.
Task 1.2: Communication Plan (M1-40):
Completed in month 6, nothing to add.
Task 1.3: Dissemination and communication of project results (M1-40):
The project progress and outcome have been communicated and disseminated at a number of events or occasions , large as small. MINTELL4EU has been represented at three Raw Materials Weeks, at two EGU conferences, at GeoUtrecht and GeoKarlsruhe, at PDAC 2021 as well as at several meetings with other projects. Besides, the MINTELL4EU UNFC pilot has been presented and discussed at two UNECE events. MINTELL4EU PL has contributed to a scientific publication 'GeoERA Raw Materials to support Europe's resilience on raw materials', SGA news no. 48, a paper jointly authored by the GeoERA Theme Coordinator and the Raw Materials PLs. Besides, a monograph presenting an overview of the full outcome of the four GeoERA RM projects is under elaboration, lead by Theme Coordinator Antje Wittenberg.
On the initiative of the MINTELL4EU PL, but strongly supported by the Theme Coordinator and the other GeoERA RM PLs, a twitter account 'Did you know…' was issued at the beginning of the COVID-19 lockdown, at that point with the ambition of highlighting the importance of raw materials in the Green Transition and when producing medical equipment necessary during a pandemic. Later, the twitter account has been used to highlight several outputs from the GeoERA RM projects and related events as well as important political initiatives related to (critical) raw material. The tweets are also shared at blogs at the GeoERA web page under the Raw Materials Theme page. In total, 68 tweets/blogs were issued until end of October 2021, and the tweets will continue at least until the final conference in January 2022.
Task 1.4: Sustainability (M1-40):
Previous projects collecting raw materials data did so far not succeed in establishing a sustainable solution to ensure maintenance and further development of harvesting, data and databases. One of the most important goals of MINTELL4EU has been to contribute to the sustainability by building on the results of ORAMA but also by including as much as possible content in the EGDI which will have to be sustained in some form after GeoERA supporting not only MINTELL4EU but all GeoERA projects. The close coordination and cooperation with the GeoERA Information Platform project (GIP-P) and with EGDI ensure that new or updated data are added to the MIN4EU database and related maps displayed at the platform. The maintenance of services and the database will be taken up by the CSA GSE in 2022 (if granted) by the work package dealing with EGDI. Consolidating the network of data providers as well as further work with harmonisation of data is also expected to be continued in the CSA GSE by the work package on raw materials.
D1.5, Roadmap for future actions towards full sustainability, describes this in more details and lists some recommendations for future work.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
1.1	Data Management Plan	GEUS	Report	Public	M6	Completed	Review completed with Midterm report.
1.2	Project Management Plan, Inception Report	GEUS	Report	Public	M6	Completed	Review completed with Midterm report.
1.3	Management reports (1)	GEUS	Report	Public	M18	Completed	
1.3	Management reports (final)	GEUS	Report	Public	M40	Completed	
1.4	Communication and Dissemination Plan	GeoZS	Report	Public	M6	Completed	Review completed with Midterm report.
1.5	Roadmap for future actions towards full sustainability	GEUS	Report	Public	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1.1	Kick-off meeting	M1	Completed	Review completed with Midterm report.
1.2	Midterm management reporting approved	M22	Completed	Review completed with Midterm report.
1.3	Final project reporting approved	M43	Pending	

Work package 2: Update to Electronic European Minerals Yearbook

Task 2.1 - Production data updates for 2014 to 2017 and trade data updates for 2014 to 2016 (M1-12)
Completed, nothing to add
Task 2.2 - Production data updates for 2018 and 2019 together with trade data updates for 2017 and 2018 (M13-40)
During months 13 to 18 production data for 2018 were compiled from the usual wide range of data sources into the BGS World Mineral Statistics database. These were quality checked from month 19 onwards ready for electronic transfer around month 24. Also during months 13 to 18, the trade data for 2017 and 2018 were purchased. The data were assessed and formatted into the structure needed. As part of this process, data gaps were identified and additional data sourced to fill them where possible. The data were transferred electronically transfered month 29.
Production data for 2019 were collected, QA'ed during months 22 to 32. Data were delivered electronically in month 39.
Task 2.3 - Resources, reserves and exploration data updates with a reference year of 2019 (M25-40)
The online survey for mineral resource, reserve and exploration data was designed and tested between months 26 and 31. Partners had the option of providing production data in this survey but it was not the main purpose of the activity. The survey was opened to partners in month 32 and remined open for longer than planned until month 36, to accomodate delays (mostly due to covid) to the partners delivering the data. Data were QC'ed in a collaborative manner with partners during months 37 to 39. Data were

delivered electronically to be integrated into the MIN4EU and for sharing at EGDI in month 39. One partner that initially committed to this task failed to deliver data (SGIDS), while three extra partners (AGS, GTK and NGU), originally not a part of this task, contributed anyway.
D2.1, Electronic Minerals Yearbook (M39), describe the processes developed for updating the European electronic Minerals Yearbook.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
2.1	Report describing the processes developed for updating the electronic European Minerals Yearbook	UKRI/BGS	Report	Public	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
2.1	Updated pages of the electronic European Minerals Yearbook with production data for 2014 to 2017 and trade data for 2014 to 2016	M12	Completed	Review completed with Midterm report.
2.2	Updated pages of the electronic European Minerals Yearbook with production data for 2018 and trade data for 2017 and 2018	M29	Completed	Data was online month 29
2.3	Updated pages of the electronic European Minerals Yearbook with production data for 2019 and resources, reserves and exploration data with a reference year of 2019	M39	Completed	Data was online month 40

Work package 3: Minerals Inventory

Task 3.1 Minerals Inventory Improvements (M1-40)

New or modified data from 36 data providers from 31 countries are available in the Minerals Inventory. The spatial coverage is extended with Luxembourg and a German State (Baden-Württemberg) besides from six West Balkan countries (in cooperation with the RESEERVE project: Albania, Bosnia&Herzegovina Federation, Bosnia&Hercegovina Rep. of Srpska, Montenegro, Serbia, and West Macedonia). Older data, from providers that delivering data in the Minerals4EU project but were not a part of MINTELL4EU, were updated to the new data model so that they are included in the new data dataset. Two partners (BRGM and HSGME) did not succeed in updating their input to the Minerals Inventory as expected. One GeoERA partner, not a partner in MINTELL4EU (PGI) updated the Polish data, partly with resources originally allocated to the GIP-P project.
The subsequent task on data control and harmonization enables new data providers to deliver data in a harmonised way.
D3.1 ver. 2, Minerals Inventory Report Final (M39), describes the efforts to update, supplement, and harmonise data from the many data providers contributing to the Minerals Inventory.

Task 3.2 Quality control of harvesting (M13-40)

Related to the tasks mentioned above, the harvesting system for collecting and validating mineral resources data has being improved. Online error identification tools as well as a Quality Control

Application (QCA) were developed enabling data providers to check the correctness of their latest reported data.
D3.3, was actually not a report but more a milestone (the finalisation of the Quality Control System for Harvesting, M39). However, it was decided to issue a report, Quality Control System for Harvesting Report, that gives an overview of the existing harvesting quality control system, and how it is developed to check the mapping of national data on mineral resources to the MIN4EU database.

Task 3.3 Training workshops (M10-28)

A MINTELL4EU workshop in Ljubljana was planned for May 2020, but this was cancelled due to the COVID-19 epidemic. Instead, an online workshop was held 26 October with several bilateral meetings on the 27th to follow up with individual data providers. The workshop built on experiences from the REESERVE project and from guidelines developed by the ORAMA project and prepared data providers for sharing updated data.

Task 3.4 Historical mine sites (M13-46)

This task focused on historical mine sites with a touristic component. Information on almost 500 sites across most of Europe has been collected and are shared at a map at EGDI. A 'story map' established by GSI will soon be assessible as well; this includes nice pictures and a short description of each site. Similar information will be published in a 'Coffee table book', also driven by GSI. This task actually attracted more partners than expected and the outcome can be an important tool in communication with the general public.
D3.4 (M39) was actually not a report but more a milestone (the delivery of the GIS layer/data to EGDI). However, it was decided to issue a small report, Tourist mine sites, describing the outcome of this task.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
3.1	Minerals Inventory Report (1)	GeoZS	Report	Public	M15-M39	Completed	Review completed with Midterm report.
3.1	Final Minerals Inventory Report	GeoZS	Report	Public	M39	Completed	
3.2	Technical Guidelines	GeoZS	Report	Public	M16	Completed	Review completed with Midterm report.
3.3	Quality control system for harvesting report	GeoZS	Others	Public	M39	Completed	A report was produced to document this deliverable
3.4	GIS database layer illustrating relevant historic mine features	GSI	Others	Public	M39	Completed	A report was produced to document this deliverable

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
3.1	Workshop in connection to ORAMA	M28	Completed	Workshop was held online 26 October 2020
3.2	Workshop in connection to REESERVE	M10-16	Completed	Review completed with Midterm report.

Work package 4: UNFC pilot

Task 4.1 Selection of relevant cases for application of UNFC to European resources (M1-4)
Completed, nothing to add.
Task 4.2 Case study pilots (M4-34)
19 case studies were selected for the UNFC pilot representing different mineral resource types including industrial minerals, construction aggregates, base and precious metals, dimension stone, rare earth elements (REE) and peat as an organic energy material. The first results and a few of these case studies were presented in an online workshop 29 October 2020. Partners in MINTELL4EU, also outside WP4, participated in the workshop, however, two partners (GeoInform and HSGME) that originally committed to this task, did not deliver one or more case studies.
D4.1, Case study review with guidance and examples for applying the UNFC to European mineral resources (M39), gives an overview of the case studies and how they were performed by the induvial partners. The deliverable also gives guidance on how to apply UNFC. The case studies themselves are available in an Appendix: UNFC pilot case studies compiled as part of MINTELL4EU WP4 (M39).
Task 4.3 Review of harmonization issues, data gaps and challenges (M12-36)
At the workshop in October 2020, advantages as well as the challenges by using UNFC were also discussed.
D4.2, Report on harmonization issues, data gaps and challenges, reviewing also the quality of Pan-European aggregated inventories for selected commodities (M39), describes harmonization issues, data gaps and challenges, reviewing also the quality of Pan-European aggregated inventories for selected commodities.
D4.3 has the character of a milestone: Supply data to WP2, 3 and 5 for inclusion in the electronic Minerals Yearbook, resource databases and information system (M39), however, it was decided to make a small report documenting that the case studies and an associated map had been delivered to EGDI. During the workshop, the need to work on how to visualise UNFC was also raised. This is described in an Appendix, GTK's proposal for visualisation of UNFC (M40), to D4.3.
Task 4.4 Pan-European aggregation pilot
It was unfortunately not possible to identify a Pan-European case study.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
4.1	Case study review with practical guidelines/work flows and examples for applying UNFC to European mineral resources	NGU	Report	Public	M39	Completed	
Appendix to D4.1	UNFC pilot case studies compiled as part of MINTELL4EU WP4	NGU	Report	Public	M39	Completed	
4.2	Report on harmonization issues, data gaps and challenges, reviewing also the quality of Pan-European aggregated inventories for selected commodities	GTK	Report	Public	M39	Completed	
4.3	Supply data to WP 2, 3 and 5, for inclusion in the European yearbook,	GEUS, NGU	Others	Public	M39	Completed	A report (incl. an appendix) was

	resource databases and information systems						produced to document this deliverable
Appendix to D4.3	GTK's proposal for visualisation of UNFC	GTK	Report	Public	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
4.1	Cases selected for pilot study, representing resources of metals, industrial minerals, aggregates and natural stone	M4	Completed	Review completed with Midterm report.
4.2	Case studies completed and classified	M32	Completed	Described in D4.1

Work package 5: Improvement of KDPs' applications and interaction with the RMIS and the GeoERA Information Platform

Task 5.1 Comparative analysis of KDPs resources versus RMIS 2.0 needs (M1-12)
Completed, nothing to add.

Task 5.2 Identification of architectural requirements and user needs (M1-18)
Continuous communication and coordination was carried out towards the GIP-P project in order to make sure that the requirements that were progressively arising in various tasks of MINTELL4EU were also taken into consideration in the design of the GeoERA information platform.

Task 5.3 Integration of e-Minerals Yearbook in Minerals4EU database (M1-39)
As described in D5.3.1 (M6), a new data model was developed to integrate the e-MYB into the same database as the Minerals Inventory. Work on the data model was conducted in collaboration with WP2, and the result of the successful integration of the e-MYB data into the new model is described in D5.3.2.
D5.3.2, Integration of the e-Minerals Yearbook into the MIN4EU database (M39), describes how the Minerals Inventory and e-MYB have been merged into one single database as defined in D5.3.1.

Task 5.4 Data exchange with RMIS (M10-37)
A number of meetings were held with Joint Research Centre to identify the needs and possibilities to exchange data between RMIS and MIN4EU. I early became clear that the main focus was to share data from MIN4EU with RMIS, and that the developement described in D5.5 and 5.6 (see below) would not be possible for RMIS to implement at this stage. A solution where RMIS links to the MIN4EU viewer at two separate pages were implemented.
D5.4, Review and data exchange prototype(s) (M39), is a short description of the outcome of the cooperation between JRC, GeoZS and GEUS on the interaction between MIN4EU and RMIS.

Task 5.5 KDP's applications delivery RMIS (M10-32)
Based on the recommendations made in D5.1, a prototype of API (Application Programming Interface) was developed to enable the JRC's RMIS 2.0 to have an efficient and selective access to data published by an external platform.
D5.5, Review and application delivery prototype(s)) (M32) describes an API for communication and interaction between RMIS and MIN4EU.
After the completion of deliverable D5.5 (and 5.6), it became clear that such APIs cannot be enabled in RMIS for the time being. Instead, as described above, dialogue about alternative solutions to facilitate the visibility/dissemination of up-to-date mineral resource data and information through the RMIS web portal was initiated, and another solution was found.

Task 5.6 Dedicated search in KDPs from RMS (M10-32)
In line with Task 5.5, and based on the recommendations made in D5.1, a protype of 'OpenSearch' API was released to enable the JRC's RMIS 2.0 to perform targeted searches in already established data

platform in addition to to classical searches conducted on the web.
D5.6, Review and dedicated search prototype (M32) presents the development of a search API enabling RMIS to perform targeted searches in other raw materials databases.
After the completion of deliverable D5.6 (and 5.5), it became clear that such APIs cannot be enabled in RMIS for the time being. Instead, as described above, dialogue about alternative solutions to facilitate the visibility/dissemination of up-to-date mineral resource data and information through the RMIS web portal was initiated, and another solution was found.
Task 5.7 Integration of data, search and other functionalities in GeoERA Information Platform (M6-40
This task has focused on integrating and visualizing data at EGDI. A dedicated map viewer integrate all data from the project - also utilising the special functionality developed in EGDI for the benefit of fulfilling the requirements of MINTELL4EU. Besides, the MINTELL4EU map viewer, all data were also integrated in the main EGDI map viewer for long-term sustainability.
D5.7.1, Description of how data and information from the project are integrated into the Information Platform and guidelines for future maintenance (M 18) put the minerals inventory and e-Minerals Yearbook into the context of the GeoERA Information Platform (EGDI) and outlined steps required for future maintenance of the system. The deliverable will also describe how the different dissemination interfaces are implemented, including portal solutions for end users and the various API's that are designed for integration with the RMIS. In this task the possibility of implementing UNFC codes into Minerals4EU is also being explored.
D5.7.2, Report and testing of integration into the Information Platform (M39) describes the process of testing the data integration and how the data are displayed at EGDI.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
5.1	Comparative analysis of KDPs resources versus RMIS 2.0 needs	BRGM	Report	Public	M12	Completed	Review completed with Midterm report.
5.2	Recommendations for integration of result into the GeoERA Information Platform	GEUS	Report	Public	M6	Completed	Review completed with Midterm report.
5.3.1	Specification of steps need for the integration of the e-Minerals Yearbook in the Minerals4EU database	GeoZS	Report	Public	M6	Completed	Review completed with Midterm report.
5.3.2	Report on the integration of the e-Minerals Yearbook into the Minerals4EU database	GeoZS	Report	Public	M39	Completed	
5.4	Review and data exchange prototype(s)	GeoZS	DEM	Public	M38	Completed	
5.5	Review and application delivery prototype(s)	BRGM	DEM	Public	M32	Completed	
5.6	Review and dedicated search prototype	BRGM	DEM	Public	M32	Completed	

5.7.1	Description of how data and information from the project are integrated into the Information Platform and guidelines for future maintenance	GEUS	Report	Public	M18	Completed	
5.7.2	Report on testing of integration into the Information Platform	GEUS	Report	Public	M39	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
5.1	Technical solutions outlined	M6	Completed	Review completed with Midterm report.
5.2	Prototype integration of results in the GeoERA Information Platform finished	M18	Completed	Review completed with Midterm report.
5.3	e-Minerals Yearbook transferred to Minerals4EU database	M28	Completed	
5.4	Demonstrator interfaces towards the RMIS ready	M38	Completed	
5.5	Results of project available through GeoERA Information Platform	M40	Completed	

11.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The COVID-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for two months, thus giving the projects a chance to complete project activities, specifically this project was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. A detailed list of changes is provided as part of the project documentation in the updated Project Description at the first pages 'History of changes'.	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	No, already handled by amendments implemented in the project description
During summer 2020, two partners (GSD and GeoInform) that they would decrease their budget. Therefore, the possibilities to move this budget to other partners were investigated. Four partners requested more budget to do extra work and the available budget was adequately distributed.	Four partners (AGS, GBA, GSI and GTK) increased their budget for adding extra efforts to their project input. Details can be found in the Project description at the first pages 'History of changes'.	No	No, already handled by amendments implemented in the project description

11.7 Communication and dissemination activities

	ABSTRACTS	BLOG	CONGRESS	INTERNAL PROJECT MEETING	LEAFLET	MEETING	MEETING WITH OTHER GEOERA PROJECTS	MEETING WITH OTHER PROJECTS	NON SCIENTIFIC PUBLICATION	ORAL PRESENTATION	OTHER	POSTER	SCIENTIFIC PUBLICATION	TWITER	WEBSITE	WORKSHOP	Total
EVENTS			1													2	3
MEETINGS				40		9	12	1									62
ONLINE_MEDIA		17												17	1		35
PUBLICATIONS	16				1				2	32	1	3	1				56
Total	**16**	**17**	**1**	**40**	**1**	**9**	**12**	**1**	**2**	**32**	**1**	**3**	**1**	**17**	**1**	**2**	**156**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	245		10	50	10	10	5		5		335
MEETINGS	750		36	14	552						1352
ONLINE_MEDIA	7300	7300									14600
PUBLICATIONS	124923	250	900	220	275	275	50	110	160	200	127363
Total	**133218**	**7550**	**946**	**284**	**837**	**285**	**55**	**110**	**165**	**200**	**143650**

11.8 Project management

The Project Board (PB) had regular teleconference meetings, approximately once per month, in total 34 meetings in 40 months, one of these was by physical attendance (in Copenhagen in October 2019). These were attended by the WP leaders, but all partners were invited and usually a few participated. At each PB meeting, progress by each WP as well as crosscutting issues, were presented and evaluated and if necessary, measures were agreed to improve progress in challenging tasks. Several bilateral informal working meetings, also online, were organised in parallel as well to solve specific issues.
The Project Assembly (PA) has had four meetings, two face-to-face, the first in connection with the kick-off of GeoERA in Brussel and the second in Month 16 in Copenhagen. The two last, in October 2020 and in October 2021, were arranged as online meetings as the COVID-19 situation made travelling and physical meetings impossible.
In April 2020, the Project Lead (GEUS) changed from David Whitehead to Lisbeth Flindt Jørgensen. As Lisbeth has been a part of the project from the beginning, this change did not cause any delays in project progress.
MINTELL4EU cooperated closely with the other three GeoERA Raw Materials projects, with the MREG group as well as with the EIT Raw Materials project RESEERVE on harmonizing classification of commodities and of code lists. MINTELL4EU also to a high degree collaborated with ORAMA and built on the results from this project. In addition, the cooperation with the GIP-project has also been very close.

11.9 General description of the cooperation over the duration of the project

Cooperation with external partners is described above. However, one successful outcome of the close cooperation between the four RM projects could be highlighted here as data from Kosovo is under preparation for inclusion into the MIN4EU as a result of a contact established in the FRAME projects for other tasks.

Internally, the cooperation extended beyond the 27 MINTELL4EU partners. For the electronic Minerals Yearbook, data were collected from 40 countries, adding value to the project by helping to provide data and in quality control. For the Minerals Inventory, geological surveys that were not a part of MINTELL4EU (e.g. Poland), contributed with updated information. In general, all 27 partners have been cooperative and responsive to requests on input to tasks or administrative issues as economic overviews, issuing approvals for a common licensing model, adding metadata for national datasets and services etc.

The participation and collaboration of all partners has been essential for the work in MINTELL4EU. Active participation of each individual partner is crucial as this is the only way to collect these data and capitalise MIN4EU. A positive surprise was the willingness of more partners than expected to contribute with input to the task on tourist mine sites. In contrast, two partners (BRGM and HSGME) did not succeed in updating their input to the Minerals Inventory as expected, likewise did we not get as large a coverage as expected in case studies for the UNFC pilot as two partners (GeoInform and HSGME) did not contribute with case studies. On the task for delivering data on resources, reserves and exploration, three extra partners than expected delivered data (AGS, GTK and NGU), while two partners (HSGME & SGIDS) failed in achieving and delivering these data.

11.10 Impact statement

The overall and most important impact of MINTELL4EU is that it offers a comprehensive mineral resource data platform for European primary and secondary mineral resources, including a user-friendly portal. This provides easy accessible and vital information for stakeholders and policy makers, for planning, investments, etc. Through close cooperation with EGDI, the sustainability of the database MIN4EU after GeoERA, the data collection routines, the network with IT-staff and raw materials specialists at the geological surveys across Europe are supported. EGS is currently working on a proposal for a Horizon Europe Coordination and Support Action to establish a Geological Service for Europe and if granted this will ensure the sustainability of EGDI (and therefore also MIN4EU) for the next five years. It is also the hope that the resulting Geological service will ensure this in the time after that.

More and further harmonised data on mineral occurrences and mines have been added to the MIN4EU database and are now made available across Europe (e.g. new data from six West Balkan countries, Luxembourg and the German State Baden-Württemberg besides from updated information from already existing data providers) adding to the Minerals Inventory, enabling better estimates of the raw materials potential in Europe. Updated data in the electronic Minerals Yearbook have been integrated with the Minerals Inventory, and all data are now stored in the central database MIN4EU. The electronic Minerals Yearbook is included in the EGDI platform making it easier and more user-friendly to view the data. Moreover, the pilot testing of UNFC as a classification system across a number of different commodities and scales across Europe has drawn quite some attention in the UNECE etc. and actually resulted in that eight partners added their resource and reserve data using the UNFC codes.

The visibility of results achieved in MINTELL4EU is even larger through the publication of selected data sets through a couple of dedicated viewers on the Raw Materials Information System (RMIS) made possible through cooperation with JRC. Tests towards sharing data with the European Plate Observing System (EPOS) have also been carried out.

Finally, as mentioned above, MINTELL4EU has worked closely together with the three other RM projects, facilitated by the RM Theme Coordinator. This, as well as the close connection to the MREG group, has enhanced cooperation and maximised project outputs as well as helped in focussing communication and dissemination activities towards the stakeholder society. In addition, the attention from DG GROW shows the interest from one of the main stakeholders of our results.

11.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontractiong	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. GEUS	244.482,84	2.220,14	0,00	61.675,75	308.378,73	29,70%	91.588,48	216.790,24
2. BRGM	35.808,77	0,00	0,00	8.952,19	44.760,96	29,70%	13.294,01	31.466,96
3. IGME	61.604,45	2.298,36	0,00	15.975,70	79.878,51	29,70%	23.723,92	56.154,59
4. GSD	18.857,00	0,00	0,00	4.714,25	23.571,25	29,70%	7.000,66	16.570,59
5. ISPRA	30.000,00	0,00	0,00	7.500,00	37.500,00	29,70%	11.137,50	26.362,50
6. NGU	44.149,06	963,92	0,00	11.278,25	56.391,23	29,70%	16.748,19	39.643,03
7. GeoZS	145.911,95	1.642,14	0,00	36.888,52	184.442,62	29,70%	54.779,46	129.663,16
8. SGU	30.875,80	0,00	0,00	7.718,95	38.594,75	29,70%	11.462,64	27.132,11
9. GeoInform	70.252,61	0,00	0,00	17.563,15	87.815,76	29,70%	26.081,28	61.734,48
10. SGIDS	44.494,87	0,00	0,00	11.123,72	55.618,59	29,70%	16.518,72	39.099,87
11. LNEG	7.567,60	0,00	0,00	1.891,90	9.459,50	29,70%	2.809,47	6.650,03
12. HSGME	22.320,00	0,00	0,00	5.580,00	27.900,00	29,70%	8.286,30	19.613,70
13. HGI-CGS	26.573,02	0,00	0,00	6.643,26	33.216,28	29,70%	9.865,23	23.351,04
14. GTK	67.487,11	803,94	0,00	17.072,76	85.363,81	29,70%	25.353,05	60.010,76
15. UKRI/BGS	99.235,31	641,94	0,00	24.969,31	124.846,56	29,70%	37.079,43	87.767,13
16. LGBR	6.224,80	0,00	0,00	1.556,20	7.781,00	29,70%	2.310,96	5.470,04
17. BGR	21.973,56	0,00	0,00	5.493,39	27.466,95	29,70%	8.157,68	19.309,27
18. GSI	65.961,49	0,00	0,00	16.490,37	82.451,86	29,70%	24.488,20	57.963,66
19. GSB-RBINS	113.112,14	0,00	0,00	28.278,03	141.390,17	29,70%	41.992,88	99.397,29
20. MBFSZ	2.106,15	0,00	0,00	526,54	2.632,69	29,70%	781,91	1.850,78
21. SGL	2.298,21	0,00	0,00	574,55	2.872,77	29,70%	853,21	2.019,56
22. GSS	17.443,80	0,00	0,00	4.360,95	21.804,75	29,70%	6.476,01	15.328,74

23. AGS	21.436,00	3.500,00	0,00	6.234,00	31.170,00	29,70%	9.257,49	21.912,51
24. CGS	16.183,11	779,53	0,00	4.240,66	21.203,30	29,70%	6.297,38	14.905,92
25. FZZG	26.946,70	0,00	0,00	6.736,68	33.683,38	29,70%	10.003,96	23.679,41
26. RU	1.360,00	0,00	0,00	340,00	1.700,00	29,70%	504,90	1.195,10
27. GBA	43.527,00	0,00	0,00	10.881,75	54.408,75	29,70%	16.159,40	38.249,35
					1.626.304,15		**483.012,33**	**1.143.291,82**

Date:	30.11.2021
Person responsible:	Lisbeth Flindt Jørgensen

12 PROJECT MUSE

12.1 Identification of the project

Project full title:	Managing Urban Shallow geothermal energy
Project acromyn:	MUSE
Project reference number:	GeoE.171.006
Project topic:	Geo-energy
Project specific recearch topic:	GE2 - GEOTHERMAL ENERGY
Project website address:	https://geoera.eu/projects/muse3/
Period covered from:	01.01.2020 to: 31.10.2021
Report submission date:	22.11.2021
Project coordinator:	Gregor Goetzl, GBA
Contact person for the project:	Gregor Goetzl
Tel:	+43 1 7125674 - 336
E-mail:	gregor.goetzl@geologie.ac.at

12.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Geologische Bundesanstalt	Geological Survey of Austria	GBA	Austria	998164145	Project Lead
2	UK Research and Innovation	British Geological Survey	NERC (UKRI)	United Kingdom	906446474	Project Partner
3	Institut Cartogràfic i Geològic de Catalunya	Institut Cartogràfic i Geològic de Catalunya	ICGC	Spain	935977542	Project Partner
4	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
5	Ceska Geologicka Sluzba	Czech Geological Survey	CGS	Czech Republic	999546783	Project Partner
6	Bureau de Recherches Géologiques et Minières	The French Geological Survey	BRGM	France	999993662	Project Partner
7	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner

8	Institut Royal des Sciences Natueelles de Belgique	Geological Survey of Belgium – Royal Belgian Institute of Natural Sciences	RBINS-GSB	Belgium	998437006	Project Partner
9	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
10	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
11	Sveriges Geologiska Undersökning	Geological Survey of Sweden	SGU	Sweden	995575991	Project Partner
12	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Partner
13	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	Polish Geological Insitute	PIG-PIB	Poland	999492463	Project Partner
14	Statny Geologicky ustav Dionyza Stura	State Geological Institute of Dionyz Stur	SGUDS	Slovakia	995391982	Project Partner
15	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner
16	Geological Survey of Denmark and Greenland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Partner

12.3 Publishable summary

The MUSE project investigated resources and possible conflicts of use associated with shallow geothermal energy in European urban areas. For a sustainable and efficient use, we propose an adaptive management process consisting of two cycles, 1) a regional management planning cycle and 2) an implementation cycle representing individual installations.
Our work for MUSE focused on the connection between the management and implementation cycle. We identified management strategies (WP3) and resource mapping (WP2) as important links. An assessment of the current legal framework and management strategies for the use of shallow geothermal energy in the participating countries revealed different regulation practices and challenges across Europe. Based on this evaluation, we derived a theoretical concept for this cyclic adaptive management approach.

Project partners from our 14 pilot areas all over Europe applied methods for resource mapping and provided their experience for general management strategies (WP4). From 2019 to 2021, the MUSE partners performed field measurements and assessed existing data. The activities covered the whole range from automatic and manual monitoring of observation wells (groundwater level and temperature), collection of data from borehole heat exchangers, geophysical prospecting (wire-logging and ground measurements), sampling outcrops and laboratory analysis for petrophysical characterization of thermal

parameters. Based on available geological and hydrogeological data, the partners prepared a total of 156 data sets based on a joint list of 50 output parameters. An extensive catalogue documents all methods and workflows applied. The methods are fit to be carried out in other regions and they set a good example for the assessment of resources.

Our MUSE webinformation system (WP5) was implemented on EGDI to feature results from our pilot areas and to serve as example for future applications. Such a webinformation system is not only useful to promote the applicability of shallow geothermal energy and raise its visibility, but also to provide all necessary information for detailed planning (implementation cycle) and to set-up management strategies (management cycle) for a sustainable and efficient use of shallow geothermal energy.

To demonstrate the variety of possible applications, we created fact sheets describing proven and prospective technical solutions for heating and cooling with shallow geothermal energy. Communication on social media, stakeholder activities and presentations at congresses also helped to disseminate the project results. The project results and blogs about pilot area activities are available at the MUSE website (https://geoera.eu/projects/muse3). Our experiences with stakeholder interaction are documented in a guideline for targeted stakeholder communication on local and international level. We also connected with projects from GeoERA and with international experts in knowledge exchange workshops (WP6).

12.4 Project contribution to GeoERA project

GeoERA-MUSE contributes to the topic GE2 - GEOTHERMAL ENERGY according to the doc no 9 of the joint call by the sub topic "Geothermal energy and groundwater in urban areas". It supports the expected impact of doc no 9 in the following way:
1) Improved and better harmonized European overview of prospective and identified geothermal energy resources: MUSE created local scale resource maps for up to 14 individual urban pilot areas, which were published at EGDI. Please note that MUSE did not produce large scale pan-European maps as questions related to the use of shallow geothermal are alwys related to small-scal local hydrogeological settings;
2) Provision of a consistent and data-driven knowledge base to aid in the formulation of policy tools and strategies aiming for large-scale geothermal energy developments across Europe: MUSE developed a methodological catalogue on mapping resources and limitations of use, which was published on the project's website. Harmonization included technical language (joint glossary of terms as project vocabularies), which is linked to joint workflows and connected to the data sets shown on the EGDI web interface.
3) A further stimulus for green thermal energy uptake in European urban regions: MUSE developed a stakeholder interaction strategy to raise awareness towards an efficient and sustainable use of shallow geothermal in urban areas. The collection of good practices, executed in all pilot areas and participating countries moreover aimed at promoting state of the art technological concepts and an exchange of technological experiences between well developed and emerging markets in Europe.
4) Increased confidence in the prospectivity and potential contribution of geothermal resources across Europe: This topic was supposed to be addressed mainly via stakeholder interviews including SWOT analyses on the use of shallow geothermal in the second half of MUSE, however it could not be achieved due to the pandemic. However, the spatial information based on our output data sets about possible resources of shallow geothermal energy on multiple webplatforms will boost the confidence in the prospectivity of geothermal resources accross Europe. Our results are not only included in the EGDI web interface, but they will also be implemented in local webplatforms of the project partners or connected stakeholders.
5) More effective and extended information support of the public-private-policy dialogue on geothermal energy resources in relation to the license to operate and the European Union’s energy and climate targets: MUSE developed an catalogue of different management strategies for the use shallow geothermal energy, which can feed into tailored local strategies in the MUSE pilot areas.

12.5 Work progress and achievements during the period

Work package 1: Project management, internal communication and general dissemination

Internal coordination and communication

To keep the project consortium updated about on-going and upcoming activities in MUSE, we had monthly webconferences of the Project Assembly. The WebEx account of GeoERA proved a very efficient and reliable tool for these monthly online meetings. In the second period of MUSE we had a total of 17 web-conferences of the project consortium. In November 2020 we had an extensive project midterm meeting spending over 4 days about the current status of the project and upcoming activities. Due to the COVID-pandemic it was not possible to hold any personal meetings. Nevertheless, the online communication via WebEx and e-mail enabled a swift and efficient completion of all tasks and deliverables.

Project control and reporting to the programme management

The project office had established a financial management tool to supervise the budget of MUSE. All project partners reported their spendings to the project office every year in the second reporting period.

External quality control

We invited external experts in the field of shallow geothermal energy to become members of the External Evaluation and Advisory Board (EEAB) for external quality control of the project. Two EEAB meetings were held online in the second half of the project due to the COVID-19 pandemic. The EEAB met in March 2020 online (instead of in person at the GeoERA mideterm events, which had to be canceled) for the first time and provided valuable feedback and ideas, which we integrated into further work inside the project. During the first meeting it was agreed that two EEAB meetings in total would be sufficient. The second EEAB meeting took place in November 2021, where the members of the EEAB acknowledged our work on resource mapping and management of urban shallow geothermal energy and recognized the impact of the project on integrating this topic into the work of GSOs and into the portfolio of EuroGeoSurveys. They also identified the necessity to expand the work in the future regarding geographical as well as thematic coverage.

General dissemination

MUSE Communication-Dissemination-Exploitation (C-D-E) activities had to be adapted due to the COVID-19 pandemic. Most of the dissemination activities in the second half of the project took place online. All planned dissemination activities were collected in an online C-D-E plan, which proved to be a useful tool to monitor the progress of the activities. It was regularly updated by the project partners and discussed during the assembly web conferences.

During the second half of the project, we realized a need for simple explanations about shallow geothermal energy. We produced a general leaflet showing the different systems and benefits of shallow geothermal energy. The project consortium decided it can be translated to national languages on a voluntary basis, and two partners (Gaelic and Polish) achieved that as well.

The MUSE Web site (https://geoera.eu/projects/muse3/) was updated on a regular basis with content about project events and blogs describing pilot area activities (42 in the second reporting period). Over the total course of the project the website had >80 370 views. The blogs of the website were promoted on facebook, linkedIN and twitter. On facebook and linkedIN we used accounts of staff members and project partners of MUSE. For twitter we generated an own account (@MuseGeoera) that reached 167 follower. Our project youtube channel (MUSE) had 8 subscribers and 121 total views of the videos. We published 8 videos, about interviews with our staff members and recordings of webinars.

The project partners put the project description and link to MUSE web site on their institutional web-sites.

Dissemination to scientific and expert communities was overachiving the targets of one cumulative research paper and five congress presentations. Two sientific article were published, the first one about governance of shallow geothermal energy resources in the journal Energy policy and the second one

"Defining the exploitation patterns of groundwater heat pump systems" in the journal Science of The total Environment in the second half of the project. Project results have been presented as six oral presentations on international and national events. This has led to four abstracts, three poster and four oral presentations.
Six knowledge exchange workshops were organized in the second half of the project. They are described in detail in WP6. The KEWs planned for Offenburg (March 2020) and Ljubljana (March 2020) in the framework of the GeoERA mid-term meeting in collaboration with GeoERA Groundwater projects on crossover topics had to be cancelled due to the pandemic

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D 1.1	Initial and updated Project Implementation Plans (3 reports	GBA	Report	CO	M2	Completed	The initial and updated reports have been completed as planned. Please note that updates of the project related Work Plan were organized by an online Google Doc based management table. The final update report also contains ex post management and lessons learned reflections on the implementation of MUSE.
D 1.2	Summary reports on the outcomes of the External Evaluation and Advisory Board meetings (3 reports)	GBA	Report	CO	M39	Completed	Two EEAB meetings have been organized and their outcomes are documented within the reports, including written statements of the EEAB and related comments by the MUSE team. The optional third EEAB meeting was not organized - for that reason no additional

							report was prepared.
D 1.3	Project leaflet	HGI-CGS	Leaflet	PU	M6	Completed	Review completed with Midterm report.
D 1.4	Project presentations at scientific and targeted events (>5 oral or poster presentations)	HGI-CGS	Presentations, Poster	PU	M40	Completed	19 oral or poster presentations have been given over the course of the entire project. They are documented in sheet 6. Communication, dissemination.
D 1.5	Cumulative research article published in a special journal issue on "shallow geothermal application in European urban areas" (1 cumulative research paper issue)	HGI-CGS	Article	PU	M40	Completed	Two scientific research articles have been published. The planned publication in a special journal issue was not realized.

Milestones					
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**	
M1	Project kick-off	1	Completed	Review completed with Midterm report.	Refers to WPs: all
M3	Project website online and general dissemination instruments available (e.g. joint layouts, project and consortium logo)	6	Completed	Review completed with Midterm report.	
M4	Joint project workshop #1: delivery of methods, workflows and guidelines for application in the pilot areas	9	Completed	Review completed with Midterm report.	Refers to WPs: all
M6	Project midterm	21	Completed	Project midterm meeting was held online in November 2020.	Refers to WPs: all
M7	Joint project workshop #2: Data delivery and feedback loop on methods and workflows	35	Completed	Multiple workshops were held ensuring a smooth application of the workflows and the data preparation and delivery.	Refers to WPs: all
M9	Cumulative research paper submitted	30	Completed	Two cumulative research articles were published.	

M12	Operational project closure	40	Completed	All project relevant operational activities were accomplished. The partners attended the last joint webconference in the operational phase in September 2021.	Refers to WPs: all
M13	Project closure (administration)	43	Pending	The joint GeoERA closure seminar will take place in January 2022. The final reports will delivered afterwards as planned.	Refers to WPs: all

Work package 2: Technical aspects of shallow geothermal energy use in urban areas

On-site exploration, assessment and mapping of resources and possible conflicts of use
Based on the list of output parameters, a preliminary collection of methods and a first structure of the document from the first half of the project, work focused on the elaboration of D 2.1 "Catalogue of evaluated methods and guidelines on exploration, assessment and technical monitoring of shallow geothermal use in urban regions". The catalogue was developed in parallel to the data preparation in WP4 for the EGDI platform in WP5. During the fall meetings in November 2020, a roadmap for an efficient preparation of the data sets and the catalogue of methods was agreed on by the MUSE partners. The previous idea of a preliminary creation of the data sets and a later application in the pilot areas, was changed to a more parallel approach, where singular test data sets were prepared for selected pilot areas. The preliminary version of the methods based on the test data sets was discussed with the project team in multiple webconferences and afterwards handed over to other pilot areas, which executed and reviewed them regarding their applicability. The lessons learned and possible alternative workflows found were implemented into the document as well. This iterative process enabled the creation of an extensive summary of state of the art methods for resource and conflicts of use mapping as well as for field measurements related to shallow geothermal energy. It is as divers as the MUSE pilot areas and considers a different quality of input data and different geological and hydrogeological conditions. The described methods are fit to be applied in other regions in Europe and beyond. Besides serving as role-model for future application, the catalogue provides a documentation of all methods that were carried out in the MUSE pilot areas. To provide top-quality documentation and description of the data sets from the pilot aras, templates of annotation forms were elaborated together with WP5, to be filled in for each data set prepared in WP4. WP2 provided the general descriptions of the parameters. This general descriptions also fed into the project vocabularies in WP5 to contribute to the GeoERA knowledge infrastructure.

Identification and charaterisation of proven and prospective technical solutions for SGE based heating and cooling supply
In the second half of the project, the extensive literature study continued and based on the collected information of international projects, professional organizations and scientific articles, the WP2 team created 8 two-page fact sheets that describe proven and prospective technical solutions for heating and cooling supply including heat storage based on shallow geothermal energy (D 2.2). One fact sheet shows a general overview of the different technological concepts that can be implemented in urban areas as well as a description of the main concepts of shallow geothermal energy. The remaining seven describe one application of shallow geothermal energy each. They include proven concepts, future concepts, good existing practices and lessons learned. The information of existing applications of shallow geothermal energy as best practice examples had been inquired by the partners and external organisations via a questionaire in the first half of the project. The MUSE team designed a subpage of the project web-site for an adequate publication of the fact sheets, which was implemented by the GIP-team. Here, all fact sheets are available for download as PDFs (Link: https://geoera.eu/projects/muse3/fact-sheets-of-shallow-geothermal-energy-concepts/).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D 2.1	Catalogue of evaluated methods and guidelines on exploration, assessment and technical monitoring of shallow geothermal energy use in urban regions (1 report)	GBA	Report	PU	M39	Completed	The catalogue describes all methods and workflows applied in the MUSE pilot areas and represents a summary of state of the art methods for resource and conflict of use mapping as well as for field measurements. The document contains the chapters input parameters, concept and workflow, limitations, alternative workflows, lessons learned and recommentations. It was kept as short as possible and as long as necessary. To ensure a good readability, extensive descriptions of the workflows were added as annexes.
D 2.2	Catalogue of factsheets of evaluated and characterised SGE concepts of use in urban areas (1 report)	ICGC	Report	PU	M30	Completed	The catalogue contains 8 fact sheets about different technological concepts of shallow geothermal energy. One of the fact sheets gives an overview of the different systems that can be applied to use shallow geothermal energy and describes the main concepts. The others focus on one technology each. They are all published and available for download at an own subpage of the MUSE website.

Work package 3: Management strategies and action plans for a sustainable and efficient use of shallow geothermal energy

Current legal status, procedures and policies dealing with shallow geothermal energy use
The partners submitted their answers to the partner questionnaire from the first half of the project about the legal framework for shallow geothermal energy referring to their country or region prepresented in the project. The WP3 team analysed and discussed the outcomes of the survey in the monthly webconferences, where the need for additional questions about existing registers and environmental monitoring of shallow geothermal energy was identified. Those topics were implemented in a small new part of the questionnaire and sent to the partners for their input. This additional feedback from the partners was included in the final version of the MUSE deliverable of D 3.1.

Integrating and managing the use of shallow geothermal energy in urban areas
A draft version of the deliverable D 3.2 was already prepared in the first half of the project, based on an extensive partner questionnaire about existing management measures in the MUSE countries. It was finalized in the second half of the project and it's findings were published in the paper "Governance of shallow geothermal energy resources" in the journal Energy policy. The deliverable includes a compendium of environmental management issues related to shallow geothermal energy and integrates all information from the partner survey. It describes policy principles of adaptive management approaches for the governance of shallow geothermal energy use in urban areas and provides a science based concept for different levels of management development.
A planned WP3 workshop to finalize the deliverable at IGME in Madrid could not take place due to the pandemic. During multiple webconferences the progress of the deliverable and a possible complimentary report to D 3.2, that would translate the derived theoretical concepts of the first report into a practical guideline addressing stakeholders outside the academic sector, was discussed. The idea was also to demonstrate the approach of the main report of D 3.2 in at least two MUSE pilot areas in collaboration with local stakeholders. For this purpose, a short partner survey on the adaptive management concepts proposed in the main report of D 3.2 was sent to the partners. However, there was only little feedback from the partners regarding the new questionnaire and the demonstration of the approach. The partners already had committed much time to answer extensive questionnaires for WP3 and therefore this complimentary report to D 3.2 was not realized.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D 3.1	Report on the current legal framework, procedures and policies on SGE use in selected European cities (1 report)	PIG-PIB	Report	PU	M18	Completed	The report analysis the current legal and administrative framework of shallow geothermal energy use at EU level and in the MUSE pilot areas. It provides a comprehensive summary of the EU energy policies, strategies, relevant documents and initiatives influencing the development of shallow geothermal energy systems. The project partners provided input to the report in form of answers to two questionnaires. The deliverable was approved by the project coordinator in December 2020.

D 3.2	Guideline for integrating and managing the use of SGE in urban areas (1 report)	IGME	Report	PU	M39	Completed	The deliverable proposes a theoretical concept for an adaptive management approach for the governance of shallow geothermal resources, harmonized by the MUSE partners, who contributed in form of answers to one extensive questionnaire. It represents a sound basis for future practical management procedures on urban shallow geothermal energy use and was disseminated via a scientific article.

Work package 4: Testing and implementation of developed methods and workflows in urban pilot areas across Europe

The overall objective of WP4 was to implement and test the methods defined in WP2 for assessing and mapping shallow geothermal energy resources and possible limitations and in WP3 for the implementation of management guidelines for shallow geothermal energy. Input data for these methods are partly already available and to some extent were collected through field measurements in the pilot areas.

Field work

Due to the COVID-19 pandemic, field work was interrupted in the first half of 2020. In order to make up for the missed time, the time period for field measurements was prolonged until end of March 2021. Field work was diverse and differed in each of the 14 MUSE pilot areas depending on their particular objectives (e.g. the study of conflicts between SGE facilities or between uses of groundwater resource; the assessment of shallow geothermal energy resources in a certain urban area; collection of data for the definition of management strategies, etc). Field works consisted of the implementation of instrumentation, monitoring observation wells or piezometers and collection of field data from observation wells and borehole heat exchangers, geophysical prospecting (wire-logging and ground measurements), sampling outcrops and laboratory analysis for petrophysical characterization of thermal parameters. Interaction with local users and stakeholders had been planned, but had to be cancelled largely due to the pandemic.

Preparation of output data sets

Together with already existing data sets, the data collected in the field served as input data sets for the creation of output data sets. The output data sets were created in a harmonized way. The workflows used to create them, were described in WP2 and the final data sets were prepared according to the standards defined in WP5. To align the work of the three workpackages, we had webconferences on a regular basis, where we discussed the preparation of the data sets and their submission. The task leaders of the pilot areas wrote individual reports on the pilot areas, including all activities undertaken in the pilot areas, and the results and impact achieved. The WP4 core team merged them in the report D 4.2., which also includes a recommendations chapter based on lessons learned of field measurements. Recommendations

and lessons learned about the application of the workflows were instead included in the catalogue of evaluated methods (D 2.1).

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D 4.1	Fact sheets on the pilot areas including the main findings of MUSE (13 fact sheets)	NERC	Fact sheet	PU	M31	Completed	In the first half of the project a first version of the fact sheets had been finalized and published on the GeoERA MUSE website: (https://geoera.eu/projects/muse3/pilot-urban-areas-in-the-muse-project/). The fact sheets can be downloaded in PDF format. Due to heavy workload and delays in the field work due to the pandemic, it was not possible to edit a planned 2nd version of the fact sheets with the first results of the field work during the operational time of MUSE.
D 4.2	Summary report about the outcomes in the pilot areas (1 report)	ICGC	Report	PU	M37	Completed	D 4.2 summarizes all activities including field measurements and preparation of output data sets in all pilot areas. Each pilot area is described in a separate chapter, that also contains a conclusion discussing the impact achieved in the pilot areas and the lessons learned of MUSE. A final recommendations chapter summarizes all lessons learned regarding the field measurements.
D.4.3	D.4.3 Documented thematic output datasets for web presentation of selected pilot area	GBA	Dataset	PU	M39	Completed	D 4.3 contains the final list of all 50 MUSE output parameters, in general, and all 156 data sets created in the pilot areas, in particular, which were transferred to the EGDI platform. The report also includes a brief statistical analysis of the final data sets (per pilot area and per data format) and describes deviations from the preliminary data delivery plan.

Milestones					
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**	
M2	Kick-off with Information Platform team	2	Completed	Review completed with Midterm report.	Refers to WPs: 4, 5
M8	Accomplishment of field measurements and elaboration of output datasets	33	Completed	Due to the pandemic, field measurements were conducted for a longer time period than anticipated in the beginning. But the field measurements as well as the data preparation was successful. In the end 156 output data sets were created for 50 different parameters.	
M10	Transfer of data form the pilot areas to the information platform	39	Completed	All data sets that were prepared for the pilot areas have been transfered successfully to the EGDI platform.	Refers to WPs: 4, 5
M11	Stakeholder workshops and trainings in the urban pilot areas	40	Completed	Due to the pandemic, stakeholder workshops could not take place in all pilot areas as planned.	Refers to WPs: 4, 5

Work package 5: Information systems, targeted communication and stakeholder interaction

WP5 supported targeted communication with external stakeholders in the pilot areas and the specific dissemination of the project outputs at the GeoERA Information Platform (GIP). The work was carried out in close collaboration the GIP team. It was the role of MUSE to produce input and set requirements for data structure and displaymode, as well as specifying special GIS tools releated to SGE data. In the second half of the project data sets were produced for selected parameters in close collaboration with WP2 and WP4. Joint online meetings were held to ensure an efficient data preparation (WP4) based on harmonized methods (WP2) and a smooth submission to the project's own-cloud. Templates for a harmonized description of the data sets from the pilot areas were set up for each parameter (called annotation forms), that had to be submitted together with each data set. The process of internal data submission is described in D 5.3 as guideline on the data delivery of geodata to the GeoERA Information Platform. After a thourough data check from the WP5 team, the data sets were uploaded to EGDI.

The data sets are shown in the best possible way on EGDI. To accomodate the high number of data sets and pilot areas of MUSE two maps were set up inside EGDI. One general map shows all data sets sorted by the parameters and 14 separate maps specific for the pilot areas, which is an important tool for stakeholder communication. Setting up the maps required adding parameter descriptions, assigning the parameters into subgroups for better visibility, changing legend colors and linking additional documents, such as PDFs describing the individual data sets (annotation forms) and specific add-on data (geological profiles or results from field measurements). Standardized parameter descriptions are based on the project vocabularies (described in D 5.6), that were elaborated for all MUSE output parameters. Furthermore, the upload of the data sets required a meta data description of all parameters, which was also done by the WP5 team. D 5.5 describes the process of uploading the data to EGDI and configuring

the MUSE webplatform and the guideline of D 5.4 describes the use and functionalities of the SGE web platform tools at the Information Platform.
Concerning targeted stakeholder communication, activities focused on a joint targeted communication strategy, which led to a communication guideline (D5.7). The planned activities on stakeholder interaction, that had been scheduled for the final half of MUSE needed to be reduced due to the COVID-19 pandemic. Nevertheless, the joint collaboration of the MUSE teams through workshops (Cardiff, March 2019 and online, November 2020) led to more than 35 individual stakeholder interaction activities in the pilot areas. The main focus of these activities was to raise the awareness of management concepts of shallow geothermal energy and instruments for local communities and authorities. The planned international stakeholder interaction event (Shallow Geothermal Energy Day event) could not take place due to the pandemic.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D 5.1	D 5.1 White Book of the web platform related to MUSE (1 report)	GEUS	Report	PU	M7	Completed	Review completed with Midterm report.
D 5.2	D 5.2 Data Management Plan for MUSE (1 report)	RBINS-GSB	Report	PU	M6	Completed	Review completed with Midterm report.
D 5.2	D 5.2 Data Management Plan for MUSE (2 report)	RBINS-GSB	Report	PU	M32	Completed	The initial data management plan organizes the use of geodata inside MUSE and describes the background, type and accessibility of background data. It also contains a joint approach how to deal with geodata (FAIR) and addresses data security aspects. The Data Management Plan was not updated during the further progress of MUSE, as there was no demand.
D 5.3	D 5.3 Guideline on the delivery of geodata and knowledge related to SGE to the GeoERA Information Platform (1 report)	RBINS-GSB	Report	PU	M9	Completed	The report provides information to MUSE's partners on how to prepare their data in terms of data formats, data standardization and metadata requirements.
D 5.4.	D 5.4. Guideline on the use of the SGE web platform	GEUS	Report	PU	M39	Completed	The report describes the functionalities of the WebGIS platform of MUSE developed in GeoERA. It is intended as manual for end-users and also as inspiration for future web information

	tools at the Information Platform (1 report)						systems about shallow geothermal energy in urban areas outside of MUSE.
D 5.5	D 5.5 Publically-accessible web platform inside the GIP on SGE use (1 web platform)	RBINS-GSB	Web tool	PU	M39	Completed	It provides an overview of the webservices created for MUSE and how the data will be visualised and shared with the public on EGDI. It also summarises the uploading process of MUSE data into EGDI, as well as the organisation and interlinks among the spatial data, the metadata and documents in EGDI maps, databases, metadatabase and document repository. See: https://data.geus.dk/egdiadmin/domap.jsp?id=10018 (Muse preview map)
D 5.6	D 5.6 Contributions to the joint GeoERA knowledge infrastructure (1 tool)	RBINS-GSB	Web tool	PU	M36	Completed	The project vocabularies describe all MUSE output parameters. They have been integrated into the WebGIS platform of MUSE on EGDI as additional description for the data sets.
D 5.7	D 5.7 Guideline on targeted communication to stakeholders on shallow geothermal use in urban areas (1 report)	GBA	Report	PU	M35	Completed	The report contains a guideline for targeted stakeholder communication based on the experiences of the project team in the MUSE in a twofold approach: 1) At a local to regional level at the MUSE pilot areas; 2) At an international level addressing international organizations including EU institutions, EuroGeoSurveys and Geological Survey Organizations outside MUSE. The final update of the document also contains a chapter on the impact achieved by targeted stakeholder interaction.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M5	Beta-version of the web platform ready to use	33	Completed	See: https://data.geus.dk/egdiadmin/domap.jsp?id=10018 (Muse preview map)

Work package 6: Cross-cutting issues and capitalising on knowledge inside GeoERA

In the second half of the project, the MUSE project team continued to identify relevant cross-cutting research topics and projects for capitalising synergies within the GeoERA programme and to organize knowledge exchange workshops (KEWs) and cross-project capitalisation activities. A total of 6 KEWs were prepared in the second half of the project, one of which was cancelled in the end due to the onset of COVID-19 pandemic and imposed travel restrictions. The events were: Offenburg, 2020 (cancelled); GeoERA webinar, 2020; Shallow Geothermal Energy Days, 2020; Webinar with GEOCOND, 2020; GPS2021 – Geothermal session; GPS2021 Side Event - Urban Geothermal energy. After the cancellation of the Offenburg event, the following events were all organised as online workshops. Recordings of the

presentations of the MUSE team given at the Shallow Geothermal Energy Days, the GEOCOND webinar and the GeoERA webinar were also published on the MUSE youtube channel. Topics of the KEWs span from environmental monitoring, temperature measurements to resource mapping and market development. One highlight of the KEWs were the GPS events, which were organized together with experts from USGS. They allowed us to gain insight into the market situation and barriers of shallow geothermal energy use in the United States and get new perspectives. The topics, contents and speakers of all KEWs are described in detail in the D 6.1, while the lessons learned through the exchanges are described in D 6.2.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D.6.1	Knowledge exchange workshops on cross cutting topics relevant for MUSE (at least 3 workshops)	BRGM	Workshop	PU	M40	Completed	The report describes the schedule, location, aim and content of all 9 KEWs. An online annex provides the agendas, participation lists and powerpoint presentations.
D.6.2	Activity report on capitalising activities with other project teams inside GeoERA (1 report)	HGI-CGS	Report	PU	M40	Completed	The report summarizes all identified cross-cutting topics and contacted project teams and describes the benefits and lessons learned through the activities.

12.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, MUSE was extended by 4 months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	The following deliverables and milestones have been extended due to the project prolongation: D 1.2, D 1.4, D 1.5 D 2.1, D 2.2 D 3.2 D 4.2, D 4.3 D 5.4, D 5.5, D 5.6, D 5.7 D 6.1, D 6.2 M07 - M13	No	The changes of the work plan have been approved by GeoERA
Financial adaptations of the partner budgets due to the withdrawal of GEOINFORM from GeoERA and an additional budget reduction from SGIDS.	Update of the MUSE Financial Management Tool	No	The changes of the work plan have been approved by GeoERA

12.7 Communication and dissemination activities

	BLOG	CONGRESS	FACEBOOK	INTERNAL PROJECT MEETING	LEAFLET	LINKEDIN	MAGAZINE	MEETING	MEETING WITH OTHER GEOERA PROJECTS	ORAL PRESENTATION	OTHER	OTHER	POSTER	SCIENTIFIC PUBLICATION	TWITER	WEBINAR	WEBSITE	WORKSHOP	YOUTUBE	INSTAGRAM	TWITTER	Total
EVENTS		6														3		4				13
MEDIA							3															3
MEETINGS				36				2	2		2							1				43
ONLINE_MEDIA	45		40			16						8			58		1		1	31	40	240
PUBLICATIONS					2					4			3	5								14
Total	**45**	**6**	**40**	**36**	**2**	**16**	**3**	**2**	**2**	**4**	**2**	**8**	**3**	**5**	**58**	**3**	**1**	**5**	**1**	**31**	**40**	**313**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	573	450	9	8	70	6	12		20	45	1193
MEDIA	250	600			50	50				550	1500
MEETINGS	597	100		9	77	19	5	15	13	55	890
ONLINE_MEDIA	50	214489									214539
PUBLICATIONS	3127	1120	3				5		30	60	4345
Total	**4597**	**216759**	**12**	**17**	**197**	**75**	**22**	**15**	**63**	**710**	**222467**

12.8 Project management

Progress on coordination activities
The communication and project coordination tools, which were established in the first half of the project, ensured an efficient project management. During monthly webconferences, the workpackage leaders gave a status update and upcoming tasks were discussed and work was distributed between the partners. The establishment of core teams for different tasks proved to be helpful as well. Progress of the current tasks was monitored via an online to-do-list, that was set-up in Google Sheets. The workplan including the list of deliverables was included in this online document as well to be upated more easily by the partners. The project office (PO) consisting of the project coordinator and the deputy coordinator, who also took over the duties as finance manager, was responsible for internal communication, communication towards GeoERA and controlling and monitoring of the implementation of MUSE. The PO serviced the online MUSE workplan, the Own Cloud based document exchange platform and the MUSE contact lists and organized the webconferences. It was supported by a Project Board consisting of WP leaders (permanent members) and task leaders (ad-hoc members). All management aspects inside MUSE are summarized in the Project Implementation Plan (D 1.1)

Communication and cooperation between the partners
In addition to the general monthly web conferences, the project team organized smaller webconferences related to workpackages or deliverables on demand. Due to the COVID-19 pandemic, all meetings had to be held online in the second half of the project. It was tried several times to organise in-person meetings. However, they could never be realized because of travel restrictions. In the second half of the project one large project meetingwas organized in November 2020 for several days, two EEAB meetings to evaluate the progress and the results achieved of MUSE and 12 monthly web conferences of the Project Assembly took place. In addition we had at least 19 smaller workpackage and deliverable related webconferences, most of them (7) dedicated to the WP2/WP4/WP5 cross-cutting topic of data preparation and delivery. The PO coordinated the communication towards the Project Assembly, the GIP-team and supported the Project Board in organizing communication between the different work packages.
Communication was also supported by an Own Cloud document exchange platform and joint E-mail contact lists.

Cooperation with other projects
In the second reporting period, MUSE organized 5 knowledge exchange workshops (KEW) involving other GeoERA projects (Geoconnect3D) and international research projects (Geocond) and GSOs (USGS) outside GeoERA (Geocond). In 2020, MUSE co-hosted the European "Shallow Geothermal Energy Days" as online event, organized a webinar about geothermal resource mapping together with the project GEOCOND, contributed to the GeoERA webinar. In 2021, MUSE organized the Geothermal session at the GPS2021 event and the side event about urban geothermal energy together with USGS.

12.9 General description of the cooperation over the duration of the project

The MUSE project partners gave the following statements regarding the added value of the transnational aspect of the project:
GBA: Big benefit was the possibility to compare different aspects related to shallow geothermal energy of the countries, for example the state of the art for resource mapping. The large and international project consortium enabled an enhanced feedback to the methods. Furthermore, with MUSE it was possible to introduce the topic of shallow geothermal energy to EuroGeoSurveys.
GSI: GSI profited highly from best practice examples and state of the art approaches. Now they have knowledge to tap into. MUSE is seen as beginning of a strong international network for future collaboration.

TNO: The transnationality of MUSE revealed different challenges and made the project partners aware of the differences between their countries regarding the use of shallow geothermal energy.
GeoZS: It was interesting to see the different issues of already mature markets. This allows to prepare for upcoming challenges, which can be expected once Slovenia reaches a higher market maturity of shallow geothermal energy.
PGI-NRI: It was possible to learn different techniques and approaches for field work, data analysis and resource mapping from the project partners. It was also interesting to compare different views regarding regulation of shallow geothermal energy use.
BGS: It was interesting to learn about different workflows and approaches for resource mapping and field work. The project led to the realization that GSOs have a unique role and view in shallow geothermal energy. They are the only organizations with nation-wide views and data sets. MUSE highlighted where the strengths and weaknesses of GSOs are and provides transnational examples about how to better quantify resources. The transnationality of the project consortium raised the aspiration of BGS. It was also realized that some comparable elements of policies run through different countries and some ideas could be picked-up.

12.10 Impact statement

MUSE addresses measures to enhance and manage sustainable and efficient use of shallow geothermal energy in European urban areas for prompoting green energy uptakes.
According to the MUSE project application, the following activities have been planned to maximize the impact of the project:
C-D-E plan: The preliminary C-D-E plan submitted at the project application, was further developed during the initial phase of MUSE and is updated on a regular basis. The C-D-E plan plans and monitors all activities related to external communication.
Web platform on the use of shallow geothermal energy: A dedicated web interface addressing shallow geothermal energy inside EGDI was developed. One general map shows all output data sets produced for the pilot areas sorted by the parameters (for international stakeholders) and 14 separate maps were set-up specific for the pilot areas (for local stakeholders). The webplatforms serve as example for future applications. To enhance the impact of our results, our final data sets were transferred partly to already established webportals of the pilot areas. In some pilot areas the results of the pilot areas provided useful input for the elaboration of management strategies for shallow geothermal energy and for follow-up projects e.g. dealing with more detailed resource assessment (project "Heat below the city" in Vienna).
Developing of joint quality standards and approaches for managing shallow geothermal energy use: In the first reporting period, the different approaches and methodologies for mapping resources and limitations of use have been assessed inside the MUSE team and are currently harmonized to a joint catalogue of methods. Furthermore, different management approaches and management requirements associated to the use of shallow geothermal energy have been assessed and compiled to a catalogue of management approaches, which will be finalized in the second reporting period. The MUSE team also assessed and is currently evaluating the legal framework for the use of shallow geothermal energy. A joint evaluation will be published in the second reporting period.
Identifying and promoting promising concepts and approaches how to use shallow geothermal: In the first reporting period, fact sheets on the gesocientific and market related conditions for the use of shallow geothermal had been created for all 14 MUSE pilot areas. The fact sheets were published at the MUSE website. in 2019, the MUSE team started to collect good practice examples on the use of shallow geothermal energy in all pilot areas. The good practice examples were included in fact sheets about proven and prospective technical solutions for shallow geothermal energy based heating and cooling supply that were elaborated and published on the MUSE website in the second reporting period.
Targeted stakeholder communication: In MUSE a joint guidelines on targeted stakeholder communication was developed and published in the Deliverable D5.7. Targeted communication intended to raise awareness towards the use of shallow geothermal, management aspects to ensure sustainability and

efficiency and role Geological Survey Organizations should play in managing urban shallow geothermal energy use. In total, more than 40 individual targeted stakeholder interaction activities were reported for the MUSE pilot areas. Most activities focused on consultation meetings with local authorities and communites for raising awareness and initiating strategic cooperation. Several national spin-off projects were started linked to the activities performed in MUSE. Moreover, the produced resource and limitation of use maps were adopted by local stakeholders in several MUSE pilot areas like Vienna, Cardiff, Cork, Ljubljana, Brussels, Linköping and Warsaw. On an international level, MUSE successfully interacted with the European Geothermal Energy Council, the EU COST Action CA18219 Geothermal-DHC and several US Geological Surveys in the framework of the GPS 2021 event. MUSE also endorsed and co-organized the international Shallow Geothermal Energy Days events in 2020 and 2021. The SGE Days event 2022 will be co-organized by the MUSE partners GBA and ICGC and will take place in Barcelona.

Knowledge exchange and capitalization: In the second reporting period, MUSE contributed to 5 knowledge exchange activities. The events were: GeoERA webinar, 2020; Shallow Geothermal Energy Days, 2020; Webinar with GEOCOND, 2020; GPS2021 – Geothermal session; GPS2021 Side Event - Urban Geothermal energy. To enhance the impact of the events, recordings of the presentations were also published on the MUSE youtube channel. Furthermore, strategic cooperation was initialized with other European networks like JPI, EGEC, RHC and IAH.

12.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontractiong	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. GBA	68.676,66	435,07	0,00	17.277,93	86.389,66	29,70%	25.657,73	60.731,93
2. NERC (UKRI)	47.311,42	740,64	0,00	12.013,02	60.065,08	29,70%	17.839,33	42.225,75
3. ICGC	71.802,32	944,44	0,00	18.186,69	90.933,45	29,70%	27.007,23	63.926,22
4. HGI-CGS	25.359,35	1.439,74	0,00	6.699,77	33.498,86	29,70%	9.949,16	23.549,70
5. CGS	4.143,96	0,00	0,00	1.035,99	5.179,95	29,70%	1.538,45	3.641,50
6. BRGM	21.124,36	5,48	0,00	5.282,46	26.412,30	29,70%	7.844,45	18.567,85
7. GSI	57.920,05	0,00	0,00	14.480,01	72.400,06	29,70%	21.502,82	50.897,24
8. RBINS-GSB	84.052,06	0,00	0,00	21.013,02	105.065,08	29,70%	31.204,33	73.860,75
9. GeoZS	16.149,40	62,19	0,00	4.052,90	20.264,48	29,70%	6.018,55	14.245,93
10. IGME-Sp	78.459,00	5.327,22	8.609,71	20.946,55	113.342,48	29,70%	33.662,72	79.679,76
11. SGU	42.266,18	916,10	0,00	10.795,57	53.977,85	29,70%	16.031,42	37.946,43
12. TNO	6.836,20	695,00	0,00	1.882,80	9.414,00	29,70%	2.795,96	6.618,04
13. PIG-PIB	39.827,82	2.417,50	0,00	10.561,33	52.806,65	29,70%	15.683,58	37.123,07
14. SGIDS	19.405,37	0,00	0,00	4.851,34	24.256,71	29,70%	7.204,24	17.052,47
15. GEOINFORM	0,00	0,00	0,00	0,00	0,00	29,70%	0,00	0,00
16. GEUS	76.417,98	1.498,73	0,00	19.479,18	97.395,89	29,70%	28.926,58	68.469,31
					851.402,51		252.866,54	598.535,96

Date:	22.11.2021
Person responsible:	Cornelia Steiner

13 PROJECT RESOURCE

13.1 Identification of the project

Project full title:	Resources of groundwater, harmonized at Cross-Border and pan-European Scale
Project acronym:	RESOURCE
Project reference number:	
Project topic:	Groundwater
Project specific recearch topic:	GW3 - HARMONIZATION OF GROUNDWATER RESOURCES INFORMATION AT CROSS-BORDER TO PAN- EUROPEAN SCALE
Project website address:	https://geoera.eu/projects/resource9/
Period covered from:	01.01.2018 to: 31.10.2021
Report submission date:	15.10.2021
Project coordinator:	H.P. Broers, TNO
Contact person for the project:	H.P. Broers
Tel:	3146966183
E-mail:	hans-peter.broers@tno.nl

13.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Lead
2	Stichting Deltares, affilitated or linked to TNO	Deltares	DLT	Netherlands	999520302	Third Party
3	Per Sherbimin Gjeologjik Shqiptar	Albanian Geological Survey	AGS	Albania	951811337	Project Partner
4	Geologische Bundesanstalt	Geological Survey of Austria	GBA	Austria	998164145	Project Partner
5	Vlaamse Milieumaatschappij	Flanders Environment Agency	VMM	Belgium	953383125	Project Partner
6	Studiecentrum voor Kernenergie/Centre d'Etude de l'Energie	Belgian Nuclear Research Centre	SCK/CEN	Belgium	999986775	Third Party

	Nucléaire (affiliated or linked to VMM)	SCK•CEN (Third party of VMM)				
7	Federalni Zavod Za Geologiju Sarajevo	Geological Survey of Federation of Bosnia and Herzegovina	FZZG	Bosnia and Herzegovina	947831524	Project Partner
8	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
9	Ministry of Agriculture, Natural Resources and Environment of Cyprus	Cyprus Geological Survey Department	GSD	Cyprus	999434845	Project Partner
10	Ceska Geologicka Sluzba	Czech Geological Survey	CGS	Czech Republic	999546783	Project Partner
11	Geological Survey of Denmark and Greenland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Partner
12	Geologian Tutkimuskeskus	Geological Survey of Finland	GTK	Finland	999432614	Project Partner
13	Bureau de Recherches Géologiques et Minières	The French Geological Survey	BRGM	France	999993662	Project Partner
14	Magyar Bányászati és Földtani Szolgálat	Mining and Geological Survey of Hungary	MBFSZ	Hungary	967592364	Project Partner
15	Islenskar Orkurannsoknir	Iceland GeoSurvey	ISOR	Iceland	993296006	Project Partner
16	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner
17	Agenzia Regionale per la Protezione Ambientale del Piemonte	Regional Agency for the Protection of the Environment	ARPAP	Italy	999468892	Project Partner
18	Regione Umbria	Servizio Geologico	RU	Italy	997980233	Project Partner
19	Latvijas Vides, Geologijas Un Meteorologijas Centrs Sia	Latvian Environment, Geology and Meteorology Center	LEGMC	Latvia	986071446	Project Partner
20	Lietuvos geologijos tarnyba prie Aplinkos ministerijos	Lithuanian Geological Survey	LGT	Lithuania	991988058	Project Partner
21	Administration Des Ponts et Chaussees Direction; Service Géologique du Luxembourg	National geological survey	SGL	Luxemburg	983408408	Project Partner
22	Office of Prime Minister / Ministry for Transport and Infrastructure	Office of Prime Minister	OPM	Malta	953280111	Project Partner

23	Państwowy Instytut Geologiczny – Państwowy Instytut Badawczy	Polish Geological Insitute	PIG-PIB	Poland	999492463	Project Partner
24	Laboratorio Nacional de Energia e Geologia I.P.	The National Laboratory of Energy and Geology	LNEG	Portugal	994187921	Project Partner
25	Institutul Geologic al României	Geological Institute of Romania	IGR	Romania	998906874	Project Partner
26	Geological Survey of Serbia	Geological Survey of Serbia	GSS	Serbia	919767678	Project Partner
27	Geološki zavod Slovenije	Geological Survey of Slovenia	GeoZS	Slovenia	999466370	Project Partner
28	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
29	Institut Cartogràfic i Geològic de Catalunya	Institut Cartogràfic i Geològic de Catalunya	ICGC	Spain	935977542	Project Partner
30	Sveriges Geologiska Undersökning	Geological Survey of Sweden	SGU	Sweden	995575991	Project Partner
31	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner
32	UK Research and Innovation	British Geological Survey	NERC (UKRI)	United Kingdom	906446474	Project Partner
33	Eesti Geoloogiakeskus (non-funded partner)	Geological Survey of Estonia	EGT	Estonia	996572763	Project Partner
34	Regione Toscana	Regional geological survey	RT	Italy	998823842	Project Partner
35	Geologischer Dienst Nordrhein-Westfalen	0	NRW	Germany	0	Non-funded partner

13.3 Publishable summary

Although EU member states generally have a comprehensive overview of the groundwater resources in their own homeland and have delineated groundwater bodies for the EU Water Framework Directive, a coherent overview of all fresh groundwater over Europe was not available for policy development and evaluation. The RESOURCE project aimed 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 was compiled and integrated to produce a digital quasi 3D map of the fresh groundwater resources of Europe. The set of deliverables of the RESOURCE project provides good practices in providing harmonized data and information across borders for assessments of the 3D structure of aquifers, the water volumes available, and the water fluxes and water quality of the resource. Harmonization of such hydrogeological information is a prerequisite for any transboundary groundwater management. A range of regional and national stakeholders were involved in the work in order to ensure both interaction with authorities that manage and protect groundwater resources and with end-users, thus maximizing dissemination of the results and providing them with easy-access tools through the cooperation with the GeoERA Information Platform Project, jointly prioritizing the information products that are most beneficial for society. The information products that were delivered will serve as a first prototype example of information to be accessible within a Geological Service for Europe.

WP2 provided the link of the RESOURCE project with the Information Platform project and was responsible for dissemination activities. The main impact derived from the project is that the general public and stakeholders will have access to information of groundwater resources at Pan-EU by means of the EGDI webservice. Impact was further enhanced by a dissemination strategy that is actively making use of social media, national and international conferences and reaching out to the scientific community, policy makers and regional and national stakeholders and the general public.

WP3 built on the established 3D transboundary geological structure that was inherited of previous Flemish-Dutch-German projects, but extending those with harmonized information on hydraulic properties, groundwater heads, groundwater quality and age, in strong cooperation with regional stakeholders that play an active role and provided guidance to the work process and who have now access to a cross-border visualization tool. The stakeholders hope to use the provided information for new transboundary groundwater management and the project provided independent information that forms the basis for such groundwater planning.

WP4 established the first- Polish-Lithuanian hydrogeological transboundary harmonization in order to assess cross-border flow and flux patterns. The work performed included the harmonization of available geological information and schematization, but also assess field data on cross-border surface water flow for calibration purposes.

WP5 worked towards a common tool for the interpretation of data time series from karst aquifers. The tool will allow sharing a common, harmonized and up to date way of classifying karst aquifers regarding several management issues such as (i) water reserves evaluation, (ii) flow regulation and (iii) vulnerability assessment.

WP6: The project has delivered a first harmonized pan-European assessment of the 3D structure of aquifers and the volumes of water involved for the land surface covered by the participating surveys. The surveys that participate in RESOURCE found a common language and developed a common tool to collect the data on the fresh groundwater resources. The result of this work will be distributed through EGDI and the general public will be able to assess volumes and depths of groundwater resources using the EGDI map viewer. This will help to appreciate the possible role of groundwater in water supply, while making the public community aware of the protection measures necessary for sustainable use of the resource.

13.4 Project contribution to GeoERA project

The GeoERA groundwater projects respond to groundwater research needs described in the call for the ERA-NET on Applied Geoscience (LCE-26-2016), which was partly inspired by and elaborated based on a Concept Note on Groundwater Research Needs previously developed by the Water Resources Expert Group (WREG) of the EuroGeoSurveys in collaboration with science and policy officers of DG Research and DG Environment. The Concept Note intended to assist and realize climate proof and resilient groundwater management and contribute to bridging the gap between science and policy and sustainable use of the subsurface.

Competing uses of the subsurface are expected to increase as a result of secondary impacts of climate change such as CO2 storage, and exploitation of raw materials and geoenergy. Integrated and sustainable management of the subsurface is imperative for the success and implementation of the European Green Deal, the UN sustainable development goals, the UN Framework Classification (UNFC) for groundwater and the new UN Resources Management System (UNRMS). Sustainable management of natural resources requires FAIR and easy access to geodata including geological, physical, biogeochemical and ecological characteristics of groundwater bodies and their link to surface water and dependent terrestrial and associated aquatic ecosystems.

The four GeoERA groundwater projects: HOVER, RESOURCE, TACTIC and VoGERA all contribute with data and knowledge to build a geological service for Europe that via the European Geological Data Infrastructure provide easy access to geodata for all stakeholders. The groundwater data support implementation of the EU and UN policies mentioned above as well as the Water Framework and Groundwater directives according to associated guidance.

The RESOURCE project addressed the Specific Research Topics of the call, such as addressed under GW3 (GeoERA 2017). The set of deliverables provides good practices in providing harmonized data and information across borders for proper assessments of water volumes, fluxes and water quality at a cross-border scale, which were nearly absent but are needed for successful water planning and management in Europe, especially in a transboundary setting. The Pan-EU mapping approach and the cross-border demonstration projects under RESOURCE have led to example products of a harmonized pan-European assessment of the 3D structure of aquifers and the volumes of water involved. The RESOURCE project included the following elements of research and development that address the scope of the call:

- Two cross-border demonstration projects have set a new standard for harmonization across borders, not only for 3D geological structures but also for hydrological characteristics such as groundwater heads, fluxes and water quality; these demonstration projects may be considered as a first step towards harmonization at European scale.
- Involvement of stakeholders in the cross-border demonstration projects in order to show and evaluate how synchronized cross-border information adds value to cross-border aquifer management and promotes sustainably prioritizing of different uses of shallow and deep groundwater resources.
- A truly pan-European effort to create a consistent pan-European information product that yields a spatial overview of the volume and depth of Europe's fresh groundwater resources, including a first estimate of the water balance terms from the resource at NUTS level and the identification of deep paleo waters that may function as strategic reserves
- Creation of a common methodological framework for characterization of karst aquifers and their vulnerability, with a guidance for managing and protecting various karst aquifer types.

13.5 Work progress and achievements during the period

Work package 1: Organisational and Scientific Coordination

This WP comprised the day-to-day coordination of the RESOURCE project. WP1 has organized the Project Board meetings (Budapest) and Project Assembly (Zagreb) and subsequently through online meetings followed up on these meetings by controlling the timely realization of project results. All deliverables have been delivered, only one with a significant delay, and milestones have been met. The interaction with the GIP project was included in the RESOURCE PA meeting and led to a sound D2.2 that describes the interaction (see under WP 2). A small number of minor adaptations to the DOW have been addressed twice and approved by the GeoERA Executive Board. A contingency plan was in place to deal with delayed or no-response by a small numbers of partners, which was described in the minutes of the meeting of the PA. WP1 kept GeoERA Executive Board updated on the project progress, and is currently performing the final reporting.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Midterm activity report and financial and management report	TNO	R	CO	M19		
D1.2	Summary reports about annual progress rules	TNO	R	PU	M12, M31	Completed	Review completed with Midterm report.
D1.3	Final management report and financial report following overall GeoERA rules	TNO	R	CO	M41	Completed	

Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M1	Project Assembly (Kick-off)	M1	Completed	Review completed with Midterm report. All WP
M2	Workshop of all WP's and Project Board Meeting	M6	Completed	Review completed with Midterm report. All WP
M3	Project Assembly (PA), Project Board meeting and Workshops	M13	Completed	Review completed with Midterm report. All WP
M6	Project Meeting (PA), Advisory Board Meeting, Project Board meeting and Workshops of the 6 WP's	M31	Completed	Review completed with Final report. All WP
M8	Final online meeting of RESOURCE	M40	Pending	Meeting is scheduled for Dec 2nd. Review Meeting on Dec 8th.

Work package 2: IP & CT coordination, Data management and dissemination

WP2 combined the data management of RESOURCE and the dissemination and communication of the project. WP2 succesfully developed the data management plan (DMP) and further elaborated towards the important D2.2 deliverable that describes and fines the prioritized information products for RESOURCE. In the project the choice has been made to prioritize for the development of the Pan-EU groundwater resources map of WP6 as the main harmonized product of RESOURCE. Strong cooperation was achieved through the GIP project liaison of IGME, which guarantees feasibilty of the eventual product. WP2 further developed a project communication, dissemination and exploitation plan including social media, the project web site and scientific journals. The communication strategy has been aligned with that of the other GeoERA groundwater projects, as the WP coordinator is active in this role in all these projects. The WP2 has achived a strong social media and web output, through groundwater blogs, news feeds on the webpage and social media posts under the GeoERA Groundwater blog in Wordpress (www.geoera-groundwater.com), which posts simultaneously on facebook, twitter and linkedin. Typically the posts on the social media receive more than 1000 views on each platform. The WP has organized workshops for stakeholders in the cross-border and methodological demonstration projects, and has achieved dissemination by establishing organizing meetings in conjunction with stakeholder groups at European level, including the CIS Working Group C on Groundwater. Presentations were given at important conferences including EGU, AGU, IAH and UNECE and a publication in Water Resources Research with results from WP3 has been achieved. The WP coordinator assures alignement with the other GeoERA groundwater projects, in order to maximize the output of the project and stimulating the cross-cooperation.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	First draft of data management plan	GEUS	R	CO	M6	Completed	Review completed with Midterm report.
D2.2	Definition and prioritized Information Products for the GeoERA Information Platform as input for the GIP meeting on Groundwater	GEUS	N	CO	M16	Completed	Review completed with Midterm report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M4	Combined workshop with the GeoERA Information Platform to discuss templates and data delivery	M17	Completed	Review completed with Midterm report.
M5	Internal Workshop for streamlining the information Flow towards the GIP (M24)	M21	Completed	Review completed with Final report.
M7	Testing the GIP prototype for RESOURCE products providing feedback towards GIP project	M35	Completed	Review completed with Final report.

Work package 3: H3O-PLUS: Harmonized information for subsurface spatial planning and management in a transboundary lowland aquifer system

H3O-PLUS: Achieved Harmonized information for subsurface spatial planning and management in a transboundary lowland aquifer system. The objective of the cross-border demonstration project H3O+ is to create harmonized information over te Dutch, Flemish and Germand area of the Roer Valley Graben - a heavily used cross-border asuifer system, where many subsurface activities strive for prioritization- for the following aspects: - hydraulic properties of cross-border aquifers and aquitards, - stratification of groundwater composition (such as fresh-salt interface and base line quality), - groundwater age distribution within the moest important aquifers used for drinking water supply and water balances of these individual, cross border aquifers including quantification of recharge fluxes, recharge patterns and discharge routes, - common cross-border analysis of depletion patterns due to abstractions and mining activiteis based on harmonizes methods, - a harmonized cross-border overview of groudnwater protection and utilization strategies on different sides of common borders. The H3O-PLUS work package created a cross-border webtool to analyze groundwater information about groundwater composition and groundwater heads, enabling map views and cross-sectional views of groundwatre quality and groundwater depletion patterns.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	Report describing the criteria set for cross-border harmonisation of groundwater data	VMM	R	PU	M12	Completed	Review completed with Midterm report.
D3.2	Report with associated database of hydraulic properties of prime aquifers and aquitards and fault zones	TNO	R/D	PU	M34	Completed	timely delivered
D3.3	3D visualisation of groundwater composition and age	TNO	R,M, webtool	PU	M34	Completed	timely delivered
D3.4	Report describing the water balances, recharge and discharge fluxes and routes	TNO	R	PU	M34	Completed	timely delivered
D3.5	3D visualisation of cross-border patterns of groundwater depletion and recharge	TNO	R, M, webtool	PU	M36	Completed	timely delivered
D3.6	Report with overview of groundwater management strategies on different sides of common borders	VMM	R	PU	M39	Completed	timely delivered
D3.7	Introducing the GeoERA Groundwater Viewer: analysing groundwater depletion signals in the Roer Valley Graben	TNO	R,M, webtool	PU	M39	Completed	extra deliverable after finishing the newest version of the webtool

Work package 4: TRANSFLUX: Harmonization of data, monitoring and modelling in a transboundary setting

WP4 TRANSFLUX: Harmonization of data, monitoring and modelling in a transboundary setting. WP4 aimed to develop a numerical hydrodynamic model for the Lithuanian-Polish cross-border area that covers the Quaternary multi-aquifer system for the transboundary river basins. The project had two fundamental research aims: the determination of the transboundary groundwater flow directions in the cross-border area and the estimation of the volume of groundwater, which flows through the state border between Poland and Lithuania. This research is directed on the identification and harmonisation of the hydrogeological system, integrating the information through a numerical model in order to examine the groundwater regime in the area covering the eastern border area of Poland and the western boundary zone of Lithuania. In the framework of the project a transboundary workshops were organized, focusing on the comparison of data and the development of a comparative table template, which was filled afterwards by the contributing partners. The scope of the workshop covered the common findings, best practices and solutions for defined for the groundwater modelling in Poland and in Lithuania. The second workshop focused on the collection and preperation of geological, hydrogeological and other data useful for groundwater modelling purposes, adjusting them to the GIS requirements following a common geometric projection. The study area was then discretized, model boundaries were defined, and the BC were determined and layer geometry and extents have been elaborated. The cross-border groundwater flow model was ready in 2021 and successfully identified transboundary groundwater flow directions and associated fluxes.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Comparison and unification of methods applied in groundwater modelling in Poland and in Lithuania. Choosing and development of best methodology	PIG	R	CO	M6	Completed	Review completed with Midterm report.
D4.2	Integration of data in a common dataset	PIG	R	PU	M15	Completed	Review completed with Midterm report.
D4.3	Harmonized hydrogeological dataset and model input	PIG	D	PU	M24	Completed	timely delivered
D4.4	Report describing the hydrodynamic model for the Polish-Lithuanian cross-border area and map showing the transboundary groundwater flow directions and fluxes in the multi-aquifer system	PIG	R	PU	M36	Completed	timely delivered

Work package 5: CHAKA: Typology of karst aquifers and recommendations for their management

Work package 5 of GeoERA RESOURCE project focused on typologies for karst and chalk areas based on measured time series of karst and chalk springs. The WP investigated methods of classifying karst aquifers with regard to management issues: (i) water reserves evaluation, (ii) flow regulation capacity and (iii) vulnerability assessment. The classification methodology has been developed to allow its usage with varying data availabilities, although the amount and variability of available data will increase the reliability level of the resulting class obtained using the methodology. Three classification methods were compared and resulted in a promising first attempt at karst classification aimed at water management issues and were tested in 16 case studies that were available for the CHAKA project in the participating countries. A database was created describing the available metadata and the available time series.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1	Karst typology in Europe: state of the art	BRGM	R	PU	M18	Completed	Review completed with Midterm report.
D5.2	Detailed conceptual hydrogeological models for pilot areas and case studies	BRGM	R	PU	M30	Completed	timely delivered
D5.3	Karst aquifer typology tool	BRGM	R	PU	M33	Completed	timely delivered after a change in the DOW approved by the EB of GeoERA
D5.4	Water management recommendations in relation with the typology	BRGM	R	PU	M36	Completed	timely delivered
D5.5	Database with time series data of the pilot areas	BRGM	D	PU	M39	Completed	timely delivered

Work package 6: Pan-EU Groundwater Resources Map

WP6 aimed to deliver the concept and realisation of the Pan-EU map of the volume and depth of Europe's groundwater resources. The process towards this product include three dedicated 1-2 days workshops in Vienna, Budapest and Zagreb mutually developing the concepts and fine tuning the template that will be used to collect the data. In between the workshops, countries have been testing the template using their own country grid which led to considerable improvements in the conceptualization. The new template was used to collect the data by the individual surveys under task 6.2. In taks 6.3 the resulting excel sheets were compiled into an overall netcdf file which was used to discuss the EGDI webtool with the GIP project: for that reason a special deliverable was made describing the use cases and requirements, aggregating the ideas for visualisation of the data in the EGDI environment (Deliverable 2.2 for the GIPmproject). A simplified, dedicated version of the netcdf was transferred to the EGDI to enable interactive menus to show data on groundwater volumes, depth and transmissivities in the webviewer for different type of rocks (hydrogeofacies) and for formations of different geological age. The test version of the EGDI

webservicde has recently brought to production. Moreover, the volumes of groundwater have been used to judge the sustainability of groundwater abstractions in relation to groundwater recharge, groundwater buffer capacity and turnover times in the deliverable D6.5 which was completed recently.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D6.1	Template that can be used by all participating surveys to collect the required data	TNO	R	CO	M12	Completed	Review completed with Midterm report.
D6.2	Database with information on volumes and depths at 10x10 and/or 25x25 km grids	GZS	D	PU	M24	Completed	timely delivered
D6.3	Maps showing the depth and volume of fresh groundwater	TNO	M	PU	M34	Completed	timely delivered
D6.4	Dataset to be included in the Information Platform	IGME	D	PU	M36	Completed	timely delivered
D6.5	Report describing water balance terms for the EU fresh groundwater grid	DLT	R	PU	M39	Completed	timely delivered

13.6 Deviations

Has the project partnership identify any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by __ months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes. (please delete: this is Monitoring team's proposal to report on prolonged delays. You are free to modify / delete / keep the text provided).	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	

Table 3.1b: the sum of person months of all partners was updated in order to be consistent with the numbers in the work package descriptions (Table 3.1a), which were already consistent with the financial table of Table 3.3c. Please note that there was no change in any of the person months allocated to individual partners	see left	No	
Table 3.3a: the sum of person months of all partners was updated in order to be consistent with the numbers in the work package descriptions (Table 3.1a), which were already consistent with the financial table of Table 3.3c. Please note that there was no change in any of the person months allocated to individual partners	see left	No	
The timing of 2 out of 3 deliverables 1.1 is out of line with the other funded GeoERA projects. It is proposed to keep the "Annual activity reports and financial and management report" to be delivered in M19 as mid-term report and skip the reports originally scheduled for M7, and M31as they are redundant and not in line with the GeoERA work flow.	see left	No	
The funding that was reserved for Regione Toscana will be transferred to Regione Umbria , effectively changing the status of Regione Toscana to become "non-funded" and Regione Umbria to become funded. The plan is accordingly adapted	see left	No	
The title of deliverable 5.1 was changed into Karst Typology in Europe: state of the art. The delivery date is unchanged. This deliverable is now reporting on Tasks 5.1 and partly on 5.2 of the WP description	see left	No	
A new deliverable 5.3 was added that reports on the tasks 5.2, 5.3 and 5.4. The delivery date is month 30. This way the ordering of deliverables and reporting is better inn line with the tasks that were defined. The contents of the work will not change due to this change, but we feel that the work is reported more efficiently now.	see left	No	
The title of deliverable 5.1 was changed into Karst Typology in Europe: state of the art. The delivery date is unchanged. This deliverable is now reporting on Tasks 5.1 and partly on 5.2 of the WP description	see left	No	
Given the delays due to the COVID pandemic, a number of deliverables have been delayed and have been rescheduled in this new Description of Work. Most delays are 2 months, with some exceptions of 4 months. This way, we make optimal use of the overall extension that was awarded to the GeoERA projects. Some WP's will stay on the original schedule (WP's 2 and 4), whereas for WP's 3, 5 and 6 we will use the full 4 month extension to achieve the original project goals.	see left	No	
Partner GIU (GEOINFORM) did complete its activities on 31-12-2019 and is no longer active part of the RESOURCE consortium as was approved by the GeoERA Executive Board. As such GIU is not able to actively contribute to the making of the Pan-EU map under WP6. Given the large spatial extent of Ukraine,	see left	No	

the partner reached the conclusion that the necessary effort would not fit under GeoERA RESOURCE.			
Deliverable 2.3 was rearranged in the proposal to become Milestone M5. The workshop that was aimed for under D2.3 happened as a Teams meeting on April 1st 2020. During the Teams workshop we discussed the way to integrate the RESOURCE results into the EGDI and decided to work with a netcdf as exchange medium.	see left	No	
A number of partners have increased their efforts in the project to achieve the aimed deliverables (IGME, GBA,SGU,OPM, LEGMC, TNO) whereas other partners decreased their efforts (GSI, GEOINFORM). VMMand linked 3rd party SCK decided to interexchange work load for WP3 with a larger share of work; this does not lead to a change in the total Belgian in-kind contribution or EU-funding. The overall budget and requested EU contribution for GeoERA RESOURCE did not change relative to the original proposal, nor does the redistribution of finances alters the expected outcomes and aims.	see left	No	
An extra deliverable D3.7 was added which describes the newest version of the GeoERA groundwater web viewer, analyzing groundwater depletion patterns in the Roer Valley Graben as an illustration. The report builds on the D3.5 deliverable, but has new functionalities for aggregated trend analysis.	see left	No	

13.7 Communication and dissemination activities

	ABSTRACTS	BLOG	CONGRESS	FACEBOOK	INTERNAL PROJECT MEETING	LINKEDIN	MEETING	MEETING WITH OTHER GEOERA PROJECTS	MEETING WITH OTHER PROJECTS	OTHER	PITCH EVENT	POSTER	SCIENTIFIC PUBLICATION	SEMINAR	TWITER	WEBINAR	WEBSITE	WORKSHOP	Total
EVENTS			15								1			1		4		10	31
MEETINGS					14		7	7	2	2									32
ONLINE_MEDIA		1		1		1									2		4		9
PUBLICATIONS	4											3	4						11
Total	**4**	**1**	**15**	**1**	**14**	**1**	**7**	**7**	**2**	**2**	**1**	**3**	**4**	**1**	**2**	**4**	**4**	**10**	**83**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	6795	10	110	140	110	100	30	100	30		7425
MEETINGS	940	30	51	15	30	31		10	10	15	1132
ONLINE_MEDIA	41600	2350	80	80	80	80	80	80	80	80	44590
PUBLICATIONS	5550	250	30		10	10		10			5860
Total	**54885**	**2640**	**271**	**235**	**230**	**221**	**110**	**200**	**120**	**95**	**59007**

13.8 Project management

Project management was part of WP1 . WP1 comprises the day-to-day coordination of the RESOURCE project. WP1 has organized the Project Board meetings (Budapest) and Project Assembly (Zagreb and subsequnetly online) and followed up on these meetings by controlling the timely realisation of project results. All deliverables have been delivered without any delays, except one which was approved by the GeoREA EB, and milestones have been met. The interaction with the GIP project was included in the RESOURCE PA meeting and led to a sound D2.2 that describes the interaction (see under WP 2). A small number of minor adaptations to the DOW have been addressed and approved by the GeoERA Executive Board. A contingency plan was in place to deal wih delayed or no-response by a small numbers of partners, which was described in the minutes of the meeting of the PA. WP1 kept GeoERA Executive Board updated on the project progress, and is currently perfroming the final reporting. Links to the 3 other GeoERA groundwater projects were continuously established through monthly GeoERA Groundwater Board video conference meetings, and through mutual attendance of workshops between the groundwater projects and the Information Platform project.

13.9 General description of the cooperation over the duration of the project

WP1: A good cooperation was achieved for coordinating the RESOURCE project. TNO, VMM, GEUS and BRGM had regular meetings an lost of email communications for streamlining the project.
WP2: GEUS took al leading role in the dissemination activities and TNO, VMM and BRGM actively supported the process of getting our results into the EGDI system
WP3: A nice cooperation was established for the Dutch-Flemish-German cross-border study. VMM organized a large number of workshops which included large numbers of regional and national stakeholders, including ones specifically addressing groundwater management and policy strategies. TNO and SCK were very active in creating new methodologies and data interpretations and NRW helped to collect data and gave input to groundwater management strategies. Data and interpretations were harmonized and two webtools were developed which help to assess regional patterns of groundwater heads and groundwater quality.
WP4. PIG and LGT worked closely together, including common fieldwork, to make a first model of groundwater flow in the cross-border region. PIG did most of the modelling and organized the common workshops, also inviting GIU to join in. The WP was successful in incorporating stakeholders in their work whom may benefit from the cross-border product in future.
WP5. A large number of surveys were involved, each bringing their own case studies. BRGM took the lead to come up with a common karst typology, which was hampered by the large variance in available data. BRGM developed a typology tool which was applied by TNO, GBA, FZZG, HGI, CGS, BRGM, MBFSZ, GSI, IGR, GZS, IGME, ICGC and NERC, which enabled comparison of the different karst and chalk aquifers over Europe. The work package created a network of scientist within the surveys which brings karst and chalk research at a higher level in future.
WP6: TNO took the lead to develop a harmonized approach for the assessment of volumes and depths of European aquifers. A common template was improved and optimized based on the feedback of all participating surveys, and TNO, AGS, GBA, VMM, HGI, CGS, GEUS, EGT, GTK, BGM, MBFSZ, ISOR, GSI, ARPA, RT, RU, LEGMC, LGT, SGL, MTI, PIG, LNEG, IGR, GSS, GZS, IGME, ICGC, SGU and NERC all collected and harmonized their data to create the Pan-EU product. TNO created the aggregated information and TNO and GEUS worked together to create the interactive EGDI tool to assess the data through the map viewer. Deltares and TNO cooperated to create a report on the water balance terms for the EU grid. The great achievement of the project is that hydrogeologists from all these surveys worked together and discussed their conceptualizations, creating a network of European colleagues that know to find each other once the project ends.

13.10 Impact statement

The RESOURCE project aimed 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 was compiled and integrated to produce a map of the fresh groundwater resources of Europe. WP2 provided the link of the RESOURCE project with the Information Platform project and was responsible for dissemination activities. The main impact derived from the project is that the general public and stakeholders will have access to information of groundwater resources at Pan-EU by means of the EGDI webservice. Impact was further enhanced by a dissemination strategy that is actively making use of social media, national and international conferences and reaching out to the scientific community, policy makers and regional and national stakeholder and the general public. WP3 built on the established 3D transboundary geological structure that was inherited of previous Flemish-Dutch-German projects, but extending those with harmonized information on hydraulic properties, groundwater heads, groundwater quality and age, in strong cooperation with regional stakeholders that play an active role and provide guidance to the work process and will have access to a new cross-border visualization tool. The stakeholders hope to use the provided information new transboundary groundwater management and the project provides independent information that forms the basis for such groundwater planning. WP4 established the first- Polish-Lithuanian hydrogeological transboundary harmonization in order to assess cross-border flow and flux patterns. The work performed included the harmonization of available geological information and schematization, but also assessed field data on cross-border surface water flow for calibration purposes. WP5 worked towards a common tool for the interpretation of data time series from karst aquifers. The tool allows sharing a common, harmonized and up to date way of classifying karst aquifers regarding several management issues such as (i) water reserves evaluation, (ii) flow regulation and (iii) vulnerability assessment. WP6: The project has delivered a first harmonized pan-European assessment of the 3D structure of aquifers and the volumes of water involved. The surveys that participate in RESOURCE found a common language and developed a common tool to collect the data on the fresh groundwater resources, The result of this work will be distributed through EGDI and the general public will be able to assess volumes and depths of groundwater resources using the map viewer. The results of the panEU assessment was inrerpreted in the framwork of substainable groundwater management, estimating water balance terms and ratios between groundwater recharge, groundwater volumes and abstractions.This will help to appreciate the possible role of groundwater in water supply, while making the public community aware of the protection measures necessary for sustainable use of the resource.

13.11 Financial statement

		A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontracting	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
		Actual			(0,25*A+B)				
1	TNO	252.061,78	46.683,57	0,00	74.686,34	373.431,69	29,7%	110.909,21	262.522,48
2	DLT	23.996,24	0,00	0,00	5.999,06	29.995,30	29,7%	8.908,60	21.086,70
3	AGS	5.878,40	0,00	0,00	1.469,60	7.348,00	29,7%	2.182,36	5.165,64
4	GBA	30.239,98	0,00	0,00	7.560,00	37.799,98	29,7%	11.226,59	26.573,38
5	VMM	63.981,82	0,00	0,00	15.995,46	79.977,28	29,7%	23.753,25	56.224,02
6	SCK/CEN	65.624,26	79,32	0,00	16.425,90	82.129,48	29,7%	24.392,45	57.737,02
7	FZZG	2.380,50	0,00	0,00	595,13	2.975,63	29,7%	883,76	2.091,86
8	HGI-CGS	25.471,07	0,00	0,00	6.367,77	31.838,83	29,7%	9.456,13	22.382,70
9	GSD	12.600,00	0,00	0,00	3.150,00	15.750,00	29,7%	4.677,75	11.072,25
10	CGS	16.042,22	0,00	0,00	4.010,56	20.052,78	29,7%	5.955,67	14.097,10
11	GEUS	72.117,26	673,17	0,00	18.197,61	90.988,04	29,7%	27.023,45	63.964,59
12	GTK	8.371,60	0,00	0,00	2.092,90	10.464,50	29,7%	3.107,96	7.356,54
13	BRGM	89.704,48	1.372,90	0,00	22.769,34	113.846,73	29,7%	33.812,48	80.034,25
14	MBFSZ	11.916,68	0,00	0,00	2.979,17	14.895,85	29,7%	4.424,07	10.471,78
15	ISOR	31.004,52	0,00	0,00	7.751,13	38.755,65	29,7%	11.510,43	27.245,22
16	GSI	36.498,50	0,00	0,00	9.124,63	45.623,13	29,7%	13.550,07	32.073,06
17	ARPAP	11.383,00	0,00	0,00	2.845,75	14.228,75	0,30	4.225,94	10.002,81
18	RU	1.025,21	0,00	0,00	256,30	1.281,51	29,7%	380,61	900,90
19	LEGMC	2.635,04	961,89	3.025,00	899,23	7.521,16	29,7%	2.233,79	5.287,38
20	LGT	6.300,00	0,00	0,00	1.575,00	7.875,00	29,7%	2.338,88	5.536,13
21	SGL	1.485,71	0,00	0,00	371,43	1.857,14	29,7%	551,57	1.305,57
22	OPM	3.200,00	0,00	0,00	800,00	4.000,00	29,7%	1.188,00	2.812,00

23	PIG-PIB	28.710,27	0,00	0,00	7.177,57	35.887,84	29,7%	10.658,69	25.229,15
24	LNEG	13.839,53	938,60	0,00	3.694,53	18.472,66	29,7%	5.486,38	12.986,28
25	IGR	27.243,97	214,89	0,00	6.864,72	34.323,58	29,7%	10.194,10	24.129,47
26	GSS	553,56	0,00	0,00	138,39	691,95	29,7%	205,51	486,44
27	GeoZS	22.849,35	24,60	0,00	5.718,49	28.592,44	29,7%	8.491,95	20.100,48
28	IGME-Sp	84.004,06	2.385,65	0,00	21.597,43	107.987,14	29,7%	32.072,18	75.914,96
29	ICGC	81.755,78	0,00	0,00	20.438,95	102.194,73	29,7%	30.351,83	71.842,89
30	SGU	1.048,22	0,00	0,00	262,06	1.310,28	29,7%	389,15	921,12
31	GEOINFORM	0,00	0,00	0,00	0,00	0,00	29,7%	0,00	0,00
32	NERC (UKRI)	32.528,80	0,00	0,00	8.132,20	40.661,00	29,7%	12.076,32	28.584,68
33	EGT	0	0	0	0	0	29,7%	0	0
34	RT	0	0	0	0	0	29,7%	0	0
35	NRW	0	0	0	0	0	29,7%	0	0
						1.402.758,00		**416.619,13**	**986.138,88**

14 PROJECT TACTIC

14.1 Identification of the project

Project full title:	Tools for Assessment of ClimaTe change ImpacT on Groundwater and Adaptation Strategies
Project acronym:	TACTIC
Project reference number:	GeoE.171.008
Project topic:	Groundwater
Project specific recearch topic:	GW2 - TOOLS FOR CLIMATE CHANGE IMPACT ASSESSMENT AND ADAPTATION
Project website address:	https://geoera.eu/projects/tactic9/
Period covered from:	01.01.2020 to: 31.12.2021
Report submission date:	23.11.2021
Project coordinator:	Peter van der Keur, GEUS
Contact person for the project:	Peter van der Keur
Tel:	4529893192
E-mail:	pke@geus.dk

14.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	Geological Survey of Denmark and Greenland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Lead
2	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Partner
3	Stichting Deltares, affilitated or linked to TNO	Deltares	DLT	Netherlands	999520302	Project Partner
4	Hrvatski geoloski institut	Croatian Geological Survey	HGI-CGS	Croatia	972614345	Project Partner
5	Geologian Tutkimuskeskus	Geological Survey of Finland	GTK	Finland	999432614	Project Partner
6	Bureau de Recherches Géologiques et Minières	The French Geological Survey	BRGM	France	999993662	Project Partner
7	Bundesanstalt für Geowissenschaften und Rohstoffe	Federal Institute for Geosciences and Natural Resources	BGR	Germany	999429413	Project Partner
8	Magyar Bányászati és Földtani Szolgálat	Mining and Geological Survey of Hungary	MBFSZ	Hungary	967592364	Project Partner
9	Department of Communications, Climate Action and Environment	Geological Survey of Ireland	GSI	Ireland	996559280	Project Partner

10	Istituto Superiore per la Protezione e la Ricerca Ambientale	Italian Institute for Environmental Protection and Research	ISPRA	Italy	997905349	Project Partner
11	Regione Emilia Romagna (Servizio Geologico, Sismico e dei Suoli della Regione Emilia Romagna)	Geological, seismic and soil survey, Emilia Romagna Region	SGSS	Italy	999482375	Project Partner
12	Latvijas Vides, Geologijas Un Meteorologijas Centrs Sia	Latvian Environment, Geology and Meteorology Center	LEGMC	Latvia	986071446	Project Partner
13	Office of Prime Minister / Ministry for Transport and Infrastructure	Office of Prime Minister	OPM	Malta	953280111	Project Partner
14	Laboratorio Nacional de Energia e Geologia I.P.	The National Laboratory of Energy and Geology	LNEG	Portugal	994187921	Project Partner
15	Geological Survey of Serbia	Geological Survey of Serbia	GSS	Serbia	919767678	Project Partner
16	Instituto Geológico y Minero de Espana	Geological Survey of Spain	IGME-Sp	Spain	998737803	Project Partner
17	Institut Cartogràfic i Geològic de Catalunya	Institut Cartogràfic i Geològic de Catalunya	ICGC	Spain	935977542	Project Partner
18	Sveriges Geologiska Undersökning	Geological Survey of Sweden	SGU	Sweden	995575991	Project Partner
19	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner
20	UK Research and Innovation	British Geological Survey	NERC (UKRI)	United Kingdom	906446474	Project Partner

14.3 Publishable summary

Climate change (CC) already have widespread and significant impacts in Europe, which is expected to increase in the future. To reduce the damage, detailed assessments, based on a thorough understanding of the hydrological system, are required for the planning of optimal adaptation strategies. Groundwater plays a vital role for the land phase of the freshwater cycle and has the capability of buffering or enhancing the impact from extreme climate events causing droughts or floods. Understanding and taking the hydrogeology into account is therefore essential in the assessment of climate change impacts.

The Geological Survey Organizations (GSOs) in Europe compile the necessary data and knowledge of the groundwater systems. TACTIC has enhanced the utilization of these data and knowledge of the subsurface system in CC impact assessments, and the identification and analyses of potential adaptation strategies for supporting EU policy making. For this an infra-structure among European GSOs has been developed to advance and harmonize CC assessments within the GSOs. The infra-structure consists of: (i) The TACTIC Toolbox, consisting of methodology, relevant tools and data required for CC impact assessments; (ii) TACTIC guidelines that will guide in the selection of appropriate tools and their use.

TACTIC addressed several critical geohazards that may have profound costs both economically, environmentally, and socially. These include groundwater-dependent floods and droughts, groundwater-surface water interactions including groundwater dependent eco-systems and sea/saltwater intrusion

problems, changes in groundwater recharge and groundwater depletion. TACTIC advanced the identification and assessment of potential adaptation strategies and their impacts on groundwater resources.
The project is centered around pilot studies covering the variety of CC challenges across Europe under different hydrogeological settings and different management systems and ensured harmonized and comparable results across pilots. Further, a guidance document has been developed from synthesized pilot data and methodologies, described in detail in the pilot reports to encourage and assist GSOs to undertake CC impact assessments
Pilot studies
Pilots are areas with aquifers where TACTIC methodologies have been applied and assessed. Pilot assessments reports have been compiled for:

- Integrated groundwater – surface water assessments of climate change, assessed at the local and regional scale to large country scale through (i) the application of a large variety of integrated hydrological models as tool to the climate change assessments which produced spatially distributed results of the investigated aquifer(s); (ii) application of the TACTIC standard climate change scenarios
- Assessing (i) groundwater recharge and vulnerability to climate change using multiple tools and TACTIC standard climate change scenarios; (ii) vulnerability of water resources to climate change impacts. The pilot scale varied from borehole scale to local and regional scale to large country scale.
- Assessing salt-/sea water intrusion status and vulnerability at aquifer scale, including (i) a large variety of different approaches to estimate spatially distributed results;(ii) an approach to estimate Chloride Natural Background levels, needed to estimate the dynamic of sea water intrusion.
- Assessing groundwater adaptation strategies including (i) impacts of such strategies on groundwater and associated surface water conditions, illustrated by case studies related to sea water intrusion

14.4 Project contribution to GeoERA project

The GeoERA groundwater projects including TACTIC “Tools for assessment of climate change impacts on groundwater and adaptation strategies” responds to groundwater research needs described in the ERA-NET on Applied Geoscience (LCE-26-2016), which was partly inspired by and elaborated based on a Concept Note on Groundwater Research Needs previously developed by the Water Resources Expert Group (WREG) of the EuroGeoSurveys in collaboration with science and policy officers of DG Research and DG Environment. The Concept Note intended to assist and realize climate proof and resilient groundwater management and contribute to bridging the gap between science and policy and sustainable use of the subsurface. Competing uses of the subsurface is expected to increase as a result of secondary impacts of climate change such as CO2 storage and geothermal energy and requires improved understanding of the geological, physical and chemical characteristics of the subsurface.
The TACTIC project focused on the issues related to climate change impact and adaptation as described in the LCE-26-2016 and the corresponding final GeoERA proposal. focusing on (i) groundwater quantity issues (groundwater recharge, availability, droughts and floods), and (ii) salt water intrusion in primarily coastal aquifers e.g. in relation to requirements and guidelines of the Water Framework and Groundwater directives and guidelines
TACTIC contributes to GeoERA by considering and contributing to most (in bold) of the following goals and deliverables requested by the original LCE-2016 call in Horizon 2020 for an ERA-NET on Applied Geoscience and it makes the results from the assessments in the pilots available at the GeoERA Information Platform complying with FAIR data and INSPIRE principles – including (extracts from the original call):

develop and enhance the knowledge and the predictive capacity needed to assess the impact of climate change and human activities on groundwater resources and dependent surface waters and ecosystems, and the consequences for groundwater quantitative and chemical status assessed according to the Water Framework and Groundwater directives. High quality models including estimated simulation and projection uncertainties are required tools for decision support systems that allow e.g.:
Elaboration of cost-effective measures and assessment of their (cost) effectiveness; sustainable decision making taking into account the water-food-energy nexus;
And provide the following deliverables:
Improved tools and models for subsurface characterisation, risk assessment and assessment of the impact of climate change, human activities and other uses of the subsurface on groundwater resources and dependent terrestrial ecosystems;
3D maps of groundwater resources;
Groundwater and surface water flooding risks;
Saltwater / seawater intrusion and the resulting impact on dependent terrestrial ecosystems;
Groundwater abstraction needs for water supply and irrigation and the resulting impact on dependent terrestrial ecosystems (including soils), surface waters, and groundwater associated aquatic ecosystems, the groundwater ecosystem itself, and the built environment (e.g. damage of infrastructure due to land subsidence.

14.5 Work progress and achievements during the period

Work package 1: Project coordination

The objective of WP1 is to ensure an effective management of the project with respect to the administrative, financial, organisational and scientific aspects. This have been achieved by monthly online Project Board meetings, with specific focus on monitoring project progress and cross-WP activities. WP1 activities have further included the organization of the kick-off meeting in Copenhagen and the second Project Assembly meeting at the Joint Research Centre of the European Commission in ISPRA, Italy. WP1 also ensures contact to the advisory board and development of project summary reports for the advisory board prior to the PA meetings. Finally, all contact to the GeoERA secretariat is coordinated in WP1, which includes meetings among PLs for all GeoERA projects, coordination of the midterm meeting and development of the project amendments.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Summary report for the second TACTIC Advisory Board meeting	GEUS	Report	Confidential	11	Completed	
D1.2	Summary report for the	GEUS	Report	Confidential	28	Completed	

	third TACTIC Advisory Board meeting						
D1.3	Project progress report	GEUS	Report	Public	20	Completed	
D1.4	Final project report (M43)	GEUS	Report	Public	43	pending	Present report
D1.5	Cumulative expenditure report 2018	GEUS	Report	Confidential	7	Completed	Cumulative expenditure report for 2018, 2019 and 2020 included in project proposal as D1.5, D1.6, D1.7, but are handled by GeoERA secretariat
D1.6	Cumulative expenditure report 2019	GEUS	Report	Confidential	19	Completed	
D1.7	Cumulative expenditure report 2020	GEUS	Report	Confidential	31	Completed	Cumulative expenditure report for 2018, 2019 and 2020 included in project proposal as D1.5, D1.6, D1.7, but are handled by GeoERA secretariat
D1.8	Final financial report	GEUS	Report	Confidential	43	Completed	To be updated

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
M1	Kick-off meeting; project running	1	Completed	Minutes from kick-off meeting approved by the PA
M2	Draft version of requirements to GIP	4	Completed	Input provided to the first meeting with the GIP project
M3	Draft pilot studies descriptions	8	Completed	Draft pilot descriptions approved by WP-leaders
M4	Draft version of best practise	8	Completed	Draft version uploaded to TACTIC fileshare and circulated to partners

Work package 2: Cross coordination, data management, interaction with GeoERA Information Platform and dissemination

Work package 2 has a coordinating role internally in the project and to other GeoERA projects, especially to the GIP project (GIP-P) developing the GeoERA Information Platform (GIP). Part of WP2 is coordinated by the GeoERA groundwater theme coordinator in all GeoERA groundwater projects ensuring coordination between the groundwater projects, GIP-P and the projects of the other GeoERA themes. The WP participants are the theme coordinator and the project lead together with the WP-leaders in TACTIC. External responsibilities in the WP includes the development of a data management plan and a communication, dissemination and exploitation plan. Internally, the WP is coordinating several tasks to streamline the activities by the partners in the pilots, which is crucial for the ability of cross-comparing and synthesizing the results at the end of the project. This coordination has involved the development of several templates including templates for the TACTIC Toolbox and the “Pilot description and assessment reports”.

WP2 activities during the first 18 months include:
• Development of a data management (D2.1)
• Development of a protocol/template, for collecting information on tools and models to the TACTIC Toolbox from the TACTIC partners. The protocol categorises the different tools into several categories: Functionality, Tool type (e.g. physical based, lumped, analytical, etc.), Intended users/user friendliness, Scale, User rights and access, Extent of documentation, Relevance for TACTIC and whether it is a generic or site-specific tool. TACTIC partners have populated the Toolbox with tools used at their institution. A draft version of the TACTIC Toolbox was ready in month 8 (milestone M4), which provided the basis for partners to select a tool appropriate for their pilot given the climate change challenges and data availability. The Toolbox will be further developed throughout the project.
• A questionnaire, to survey data in the GSOs has been developed, based on the data required to setup and execute the tools in the TACTIC Toolbox. A survey on groundwater related data has been/are similarly carried out in two of the other GeoERA groundwater projects; RESOURCE and HOVER. Given that all three projects are related to groundwater issues, a significant overlap in data requested from the partners has been identified. In RESOURCE groundwater related data, such as aquifer dimensions and hydrological properties (hydraulic conductivities and porosity), are collected in a 3D grid. In TACTIC it has thus been decided to put less effort in motivating partners to upload data, unless this is readily done by WMS/WMF, and instead focus on establishing information on the accessibility of other data types that are needed to undertake the assessments, but not necessarily owned by the GSOs. This survey will provide an overview for future projects, especially relevant in defining future collaboration and projects. The questionnaire additionally addresses to what extent the GSOs are or have been involved in groundwater assessments, including CC impact assessments. The questionnaire has been sent to all GeoERA partners.
• Collaboration with the GIP project on defining type and formats for the GIP platform. TACTIC partners have identified the type and formats of data collected in the project as well as results produced by the assessments, which are to be uploaded to GIP. Furthermore, functionalities for the visualisation and data up-/and download have been specified. Formats for data and results has been discussed internally and several meetings have been organised with the GIP project. The task is finalised with deliverable D2.2.
• Cross-comparison of tools. In selected pilot areas, more than one tools is applied in the assessment of climate change impact. This work is coordinated in WP2 to ensure that the results obtained from the different tools can be compared and analysed across the pilot sites covering a wide variety of the hydro- and climatic conditions in Europe.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	Data management plan	GEUS	Report	Public	6	Completed	
D2.2	Definition of requirements to GIP following recommendations from the GIP project	GEUS	Report	Public	16	Completed	
D2.3	Questionnaire to survey GSOs on data and tools	BRGM	Other	Public	12	Completed	
D2.4	Protocol for best practice descriptions of tools	GEUS	Other	Confidential	6	Completed	
D2.5	Protocol for guidelines	GEUS	Report	Public	40	Completed	Includes D3.5, D4.5, D5.5 and D6.5

D2.6	Communication, dissemination and exploitation plan	GEUS	Report	Public	6	Completed	

Work package 3: Integrated groundwater - surface water assessment of climate change

The aim of WP3 is to investigate different aspects of the interaction between groundwater and surface waters related to a changing climate. This is done in three tasks with focus on the interaction affecting the shallow groundwater, groundwater dependent ecosystems, and groundwater flooding and droughts. The work package also has three generic tasks analysing how groundwater – surface interaction under changing climate conditions can be assessed by the use of integrated models to propagate estimates of future climate. Ten partners are involved in WP3 (Denmark [lead], the Netherlands, Ireland, France, Spain, Hungary, Ukraine, Croatia, Hungary and Ireland). Pilots from Ireland was not included in the proposal, but has been added to the portfolio on the initiative from the Irish Geological Survey and has its main focus on flooding. The partners in WP3 covers together eleven pilots, covering from Denmark in north to Spain in south and Hungary in east to Ireland in west. The pilots similarly span the entire spatial range from local (e.g. Sunds in Denmark), regional (e.g. France, Spain, Ireland, Croatia) and national studies (in Denmark, the Netherlands and Hungary).

WP3 activities during the first 18 months include:
• Contributed to the common task of reviewing existing tools and methods.
• Following this, the main activities in WP3 have been associated to the work and assessments in the different pilots with focus on the three topics included in the work packages, i.e. shallow groundwater, groundwater dependent ecosystems, and groundwater flooding and droughts. These tasks are presently ongoing, see below. For each pilot, the first part of D3.2 “Pilot description and assessment report” has been finalised and include a general pilot description, assessment of data availability and evaluation of specific climate change challenge.
• Task 3.5 focus on propagation of climate scenarios in integrated models, and identifying standardised climatic scenarios that can be used across all pilots. D3.4 “Technical note on propagation of climate change projections in integrated models”, are partly done. A memorandum of the selection of climate change scenarios in a harmonised way and with a methodology enabling pilot inter-comparison on a pan-European scale has been developed. The proposed methodology has been presented and agreed upon at the second project meeting in ISPRA. The methodology should be used by all pilots in TACTIC across different work packages and assessment tools.
Specific activities in pilots for WP3 partners include:
• Drava, Croatia: A numerical groundwater flow model is developed and data to construct and run the models have been collected in addition to data for calibration.
• Denmark: the Danish water resources model used for the Denmark Pilot has been calibrated and the model has been applied for current and future conditions using climate scenarios developed at GEUS. The model is ready to run climate scenarios developed in TACTIC.
• Storåen and Sunds, Denmark: The Storåen and Sunds models were setup and calibrated during the spring of 2019. Hereafter selected climate change scenarios were run and the model output results analyzed. During summer 2019, 3 scenarios for climate change adaptation were tested using the model: 1) Installing the so-called third drainage string below the city of Sunds, where issues of high shallow groundwater threatens the city infrastructure and housing. 2) Using existing wells to lower the groundwater level. 3) Manage the lake level to a constant low level in order to affect the hydraulic connected shallow groundwater level in Sunds City.
• Hungary: The hydrological model for the entire Hungary has been setup and calibrated (prior to TACTIC) and assessments of CC has now been performed based on local climate change scenario. The pilot awaits the TACTIC WP3 standard scenarios.
• Avre, France: The integrated hydrogeological model of this basin developed in 2012 has been updated with recent data (precipitation, water abstraction …) and its calibration has been improved. This model is now ready for application of climate change forcing data. The next step will be to perform a historical

simulation (1958-2019) and analyze the droughts occurrence.
• Gort lowlands, Ireland: Based on historical flooding images (mainly the 2015 event), a map of a 1000 yr flooding has been generated.
• Segura River Basin, and Upper Guadiana Basin, Spain: The two Spanish pilots, used in assessments of CC groundwater droughts and groundwater dependent ecosystems, have worked on designing and calibrating a modeling framework defined by a chain of auxiliary models. The approaches have been already calibrated with the historical data and some future scenarios have been already simulated. The model is also ready to run climate scenarios developed in TACTIC. In combination with WP6 work has been done to define details of the adaptation scenarios.
• Nederland and De Raam: The Hydrological National Instrument used for assessments in the Nederland's is currently undergoing updates. These updates affect both two Dutch pilots. The update will commence until 2020 where CC scenarios will be applied, and the new TACTIC assessments done.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	Inventory on data and results for groundwater-surface water	GEUS	Note	Public	7	Completed	
D3.2	Pilots description and assessment report for groundwater – surface water	GEUS	Report	Public	33	Completed	
D3.3	Journal paper on climate change assessment in EU	GEUS	Journal manuscript	Public	40	Completed	Preview document of manuscript submitted to J. Hydrol.
D3.4	Technical note on propagation of climate change projections in integrated models to assess future groundwater conditions	TNO	Note	Public	33	Completed	
D3.5	Guideline for integrated modelling	GEUS	Report	Public	40	Completed	Included in D2.5

Work package 4: Assessing groundwater recharge and vulnerability to climate change

Work package 4 addresses the groundwater recharge and vulnerability to climate change. The aim is to identify principal aquifers in the involved countries and using numerical and analytical tools to quantify the amount of infiltrating recharge over these aquifers. These tools will also be used to assess the vulnerability of groundwater recharge by estimating future recharge volumes using projected weather information. Combining results from the pilot studies and background information, a pan-European map of recharge will be developed and made accessible via GIP. Finally, satellite data will be used to assess the subsidence linked with groundwater pumping. Thirteen partners are involved in WP4 (France [shared lead], United Kingdom [shared lead], Denmark, Netherlands, Finland, Germany, Ireland, Italy, Serbia, Spain, Sweden, Ukraine, and Hungary). The partners run 16 pilots in WP4, which varies greatly in their spatial coverage. In some pilots, the assessments are based on time series from a single well, selected as representative for an aquifer. Other studies include time series from several wells in the same aquifer and thus provide some information on variability. At the other end of the scale is the pan-European scale, for which a recharge map is to be developed, and in between, national estimates are carried out for some

countries. The tools applied similarly varies, from time-series analysis to lumped modelling approaches and index approaches.

WP4 activities during the first 18 months include:

• Review of relevant tools and methods for the assessments carried out in WP4 together with a survey on required data to apply the tools.

• Following this, the main activities in WP4 have been associated to the work and assessments in the different pilots with focus on the topics included in the work packages. These tasks are presently ongoing, see below. For each pilot, the first part of D3.2 “Pilot description and assessment report” has been finalised and include a general pilot description, assessment of data availability and evaluation of specific climate change challenge.

• Knowledge exchange. While all work packages have focus on knowledge exchange, this is in particularly true for WP4 that includes the largest number of partners that have not previously been involved in groundwater assessments focussing on climate change impacts. WP4 has organised several videoconference calls, and task leaders and contributing partners have provided detailed descriptions of their tools to partners over two video conference sessions. These sessions were recorded and saved and have been made available to all TACTIC partners.

• Building on the results from the pilots combined with existing satellite and model results from Europe, WP4 will construct a pan-European recharge map. The approaches employed to develop the map has been discussed on online and face2face meetings. As the recharge map should rely on pilot results were possible, an important aspect has been to agree on the terms used to describe recharge/infiltration, as this differs among partners as well as tools. To clarify this, a small note has been developed and circulated to all partners, and the tools identified in the TACTIC toolbox has similarly been categories according to the type of recharge/infiltration estimated by the tools.

Specific activities in pilots for WP4 partners include:

• BGS are working with AquiMod to calculate recharge at a number of boreholes where they already have calibrated models. The models are rerun and calibrated when necessary, and model parameter sensitivities are investigated. BGS has also demonstrated the tools on videoconferences and supported other partners on the use of the tool

• Both ISPRA in Italy and GSS in Serbia entered TACTIC with no previous experience in using tools for CC impact assessments. They have both chosen the AquiMod tool and have spent time learning the tool. Input data has also been collected and the model calibration is in progress

• IGME in Spain is contributing to WP4 by both estimates of recharge using different lumped models, and in the estimation of land subsidence. Several pilots are used and historical results have been already obtained for all of them. A method has been proposed to assess future impacts of climate change on subsidence.

• In Denmark, GEUS are using the national water resources model to estimate recharge for the entire country. Four additional tools are currently being applied using long time-series for principal aquifers to compare results from these models and the national model.

• BRGM applied statistical tools to calculate trends (hypize) and other scripts to characterize the time series of groundwater levels over the French territory. An attempt of classification of homogeneous zones, i.e. with similar behavior according to hydrogeology, to evaluate climate vulnerability was done but was not conclusive at national scale. The difficulties result in the fact that there is a few number of non-influenced piezometers with long chronicles on the same period of observation. Therefore, BRGM proposes to contribute to the pan-European recharge map working on a national map of potential recharge and using climate change scenario to estimate future potential recharge and estimate vulnerability.

• GTK are applying the method used by GSI (Ireland) to calculate the recharge map of Finland. They have collected the required data and are currently working on the identification of an appropriate approach to validate the resulting map

• GSI focus on updating the Irish national scale groundwater recharge map and groundwater levels database. Updated input datasets for national scale recharge map and currently working on the application of projections of future climate data. Also established structured GWL database for use in

TACTIC and other projects.
• SGU apply HYPE, a tool that has been developed by SMHI (Swedish met office) but modified for groundwater levels, to produce a 1-D precipitation-runoff hydrological model at catchment-scale. Model has been calibrated to historic weather/GW data at the two Swedish pilot sites
• TNO applies statistical tools to analyse groundwater level time series for long-term trends and for system identification, in the latter all piezometers in the Netherlands are used.

Besides the activities mentioned above, which are all described and planned in the proposal, additional funding from Innovation Fund Denmark also promoted the development of new web services that allows for initiation of a Pan European network of on-line near real-time sensors measuring groundwater tables. The work has been initiated primarily in TACTIC WP4 in collaboration with the GIP-P project in GeoERA and the Swedish Geological Survey, SGU. SGU has developed a national network of near real-time sensors, which has been in operation for more than five years. Such networks are important for assessment of climate change and exploitation impacts on groundwater tables e.g. decreasing and increasing water tables due to droughts and cloud bursts, respectively.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Inventory on data and results for recharge and groundwater vulnerability	BRGM	Note	Public	7	Completed	
D4.2	Pilots description and assessment report for recharge and groundwater vulnerability	NERC	Report	Public	33	Completed	
D4.3	Journal paper on aquifer recharge variability and trends	BRGM	Journal manuscript	Public	40	Completed	Manuscript to J. Hydrol.
D4.4	Pan-European net-preciptation map	GEUS	Map in GIP	Public	34	Completed	uploaded to GIP
D4.5	Guideline for groundwater recharge and vulnerability	NERC	Report	Public	40	Completed	Included in D2.5

Work package 5: Assessment of salt-/sea water intrusion status and vulnerability

Work Package 5 is focused on a quantitative assessment of salt/sea water intrusion (SWI). The intention is to advance in the assessments by developing harmonised approaches to summarise results on status and vulnerability with respect Sea Water Intrusion (SWI) at groundwater body scale, which will allow the comparison between assessments by different European countries. Ten partners are involved in WP5 (Spain-IGME [lead], Denmark, Croatia, Italy-SGSS, Latvia, Malta, Portugal, Spain-ICGC, and Ukraine), which all together have 10 pilots, covering most of the EU countries with coastal areas. A Pilot from Netherland has been added on the initiative of DELTARES-TNO, although it was not in the original proposal. All the pilots correspond to regional studies covering different aquifer typologies (detrital and karstic aquifers, island and not island aquifers, etc).
WP5 activities during the first 18 months include:
• Review on relevant tools, information and approaches to assess salt/sea water intrusion status and vulnerability together with a survey on required data to apply the tools/approaches.

• Following this, the main activities in WP4 have been associated to the work and assessments in the different pilots with focus on the topics included in the work packages. These tasks are presently ongoing, see below. For each pilot, the first part of D3.2 "Pilot description and assessment report" has been finalised and include a general pilot description, assessment of data availability and evaluation of specific climate change challenge.
• Development of a method to summarize in a harmonized way SWI status and vulnerability at groundwater body scale by using different visual approaches. The global dynamic of the problems is analysed by time series plots of lumped indices, complimented by quantifying the percentage of affected area using steady pictures, including maps and 2D conceptual cross sections.
Specific activities in pilots for WP5 partners include:
• In Spain IGME demonstrated the proposed methodology on the videoconferences organized about tools within the project. The method for harmonised assessment has been applied to the Plana de Oropesa-Torreblanca aquifer. The distributed information required to apply the method has been obtained by applying both, simple interpolation approaches and density dependent flow models. We assessed historical scenarios but also future potential impacts.
• In Portugal (NLEG) data have been collected to update a detailed 3D geological used in the flow model. Fieldwork are carried out also to get an up-to-date overview on seawater intrusion status. Calibration of a density dependent flow model is ongoing.
• Time series analyses and conceptual approaches are used in Croatia (HCI-CGS) to assess the dynamic of seawater intrusion (salinity of the lakes included within their case study, flow in some springs). Additional data are collected (monitoring of brackish springs, started in March 2019).
• ICGC in Spain have applied the proposed method for a specific date. They intend to extend it to the assessment of a longer period and study the sensitivity of their results with respect to the threshold used to define see water intrusion problems. A statistical data analyse is planned to establish the NBL for the Cl- concentration in the pilot area, in order to use it as a new threshold value for the identification of the affected area.
• BGS in UK are collecting data, expected to be ready for the assessment at the beginning of the second year.
• SGSS in Italy have developed a detailed 3D geological model and are working in on assessment of the maps (inputs) required to apply the method.
• The Netherlands (DELTARES) are working on a density dependent flow model at country scale. They will work on the National fresh-salt water model this coming year, compiling different salinity and geologic databases. They already have regional and local variable-density models for local knowledge questions.
• MTI on Malta have collected all data and performing the needed calculation to apply the adapted version of the method for the analyses of the island's aquifers. A research paper on the topics is planned in the coming months.
• GEUS, Denmark has installed near real-time sensors for monitoring of water tables, temperature, electrical conductivity and chloride at the pilot study site on Falster in and close to a water supply well affected by salt water intrusion. This work was made possible by additional funding for TACTIC and the GeoERA groundwater projects from Innovation Fund Denmark. GEUS receives data from these sensors directly to GEUS databases, and the data will be visualised on the TACTIC website and in the GeoERA Information platform during 2020.

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D5.1	Inventory on data and results for sea/salt water intrusion	IGME-Sp	Note	Public	7	Completed	
D5.2	Harmonised method for	IGME-Sp	Report	Public	15	Completed	

	assessing status and vulnerability						
D5.3	Pilots description and assessment report for sea/salt water intrusion	IGME-Sp	Report	Public	33	Completed	
D5.4	Journal paper demonstrating the application of the method in pilots	IGME-Sp	Journal manuscript	Public	40	Completed	Published in Environmental Earth Sciences
D5.5	Guideline for assessment of salt/sea water intrusion	IGME-Sp	Report	Public	40	Completed	Included in D2.5

Work package 6: Groundwater adaptation strategies

Work Package 6 is focused on the assessment of adaptation strategies. An inventory of general potential adaptation strategies and methods/data employed to select and assess them are developed. The WP further seeks to advance the definition of local scenarios, downscaling global climatic and socio-economic scenarios. WP6 includes nine partners (Spain-IGME [lead], Croatia, Denmark, France, Hungary, Italy-SGSS, Malta, Serbia, and Ukraine) operating nine pilots (Figure 2). The pilots in WP6 are all pilots in which CC impact assessments are carried out as well in WP3-5. The topics of the pilot site covers the various CC challenges addressed in the project and represent varies types of tools. Spatially, the pilots cover most of Europe, and a wide range of aquifer typologies with different management particularities and data and information available.

WP6 activities during the first 18 months include:
As the assessments in WP6 are based on tools that are developed in WP3-5 and these are currently under development, the assessments in WP6 has not started, but overarching tasks have been completed.
• Base on a literature review, a list of specific measures has been produced together with a repository of papers/reports related with this issue. TACTIC partners have contributed with measures to a draft version of the list, which is subject to further extension during the project. The list does not only included measures that are directly related with groundwater management, but also measures that can have an indirect impact on groundwater status.
• Classification of adaptation strategies: measures on 1) demands, i.e. measures that seeks to reduce the water demand, 2) the offer, which is measures to manage the resource, and 3) mixed measures, which is a combination of the two. A detailed list of specific measures ranked in accordance with that classification has been developed.
• A classification of data/methods to assess adaptation strategies (Top-down, bottom-up and mixed approaches) and to identify potential strategies to be assessed (a selection of measures) and strategic GW bodies.
• Definition of local climatic and socio-economic scenarios by downscaling global scenarios. In this task, emphasis is given to the social assessment and in the definition of socio-economic scenarios, which is studied in the pilot “Upper Guadiana Basin” with input from stakeholder workshops. The method further intends to improve the definition of local climate scenarios from the RCM simulation considering not only basics but also drought statistics. A SCI journal paper has been published on the topic.
• Initiation of new real-time monitoring approaches required for optimisation of adaptation strategies for controlling and managing saltwater intrusion in coastal and inland aquifers e.g. by managed aquifer recharge and the use of SCADA (supervisory control and data acquisition) systems.

Deliverables

Deliverable no.	Deliverable name	Short name of lead participant	Type	Dissemination level	Delivery date from Contract	Progress	Comments
D6.1	Inventory on data and results for adaptation	IGME-Sp	Note	Public	7	Completed	
D6.2	Scenarios development	IGME-Sp	Report	Public	15	Completed	
D6.3	Pilots description and assessment report for adaptation	IGME-Sp	Report	Public	33	Completed	
D6.4	Journal paper on adaptation strategies to reduce impacts on droughts	IGME-Sp	Journal manuscript	Public	40	Completed	Manuscrip submitted to J. Total Environ (STOTEN)
D6.5	Guideline on adaptation strategies	IGME-Sp	Report	Public	40	Completed	Included in D2.5

14.6 Deviations

Has the project partnership identify any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
WP1: "D1.1 Summary report for the second TACTIC Advisory Board meeting" postponed from M11 to M16. The summary report is developed to provide an overview of the TACTIC activities up to the project meetings, where this is discussed with the advisory board members. It was not possible to find a suitable date for the project meeting before the summer holiday and the project meeting was thus moved from June to October 2019. For the summary report to reflect the most recent activities, it should be developed close to the project meetings, and the report has thus been postponed. Partner: GEUS		No	Included in amendment improved by GeoERA secretariat 6-12-2019
WP1: Deadline for D1.2: Figure 3.2 – Gantt; Table 3.1a – WP description, Deliverables WP1; Table 3.1c List of deliverables; Partner: GEUS	changed from M23 to M28	No	Included in amendment improved by GeoERA secretariat 20-12-2020
WP2: Deliverabel "D2.3 Questionnaire to survey GSOs on data and tools", was delayed. Partner: BRGM	Postpostment of deadline from M10 to M12	No	Included in amendment improved by GeoERA secretariat 6-12-2019
WP3,4,5 &6. Deadline for D3.2, D4.2, D5.3 and D6.3; Figure 3.2 – Gantt Table 3.1a – WP description, Deliverables WP3, WP4, WP5 and WP6	Deadline postponed due to Covid19 project extension	No	Included in amendment improved by GeoERA secretariat 20-12-2020

Table 3.1c List of deliverables; Partner: GEUS, NERC, BRGM, IGME			
WP3,4,5 &6. Deadline for D3.3, D4.3, D5.4 and D6.4; Figure 3.2 – Gantt Table 3.1a – WP description, Deliverables WP3, WP4, WP5 and WP6 Table 3.1c List of deliverables; Partner: GEUS, NERC, BRGM, IGME	Deadline postponed due to Covid19 project extension	No	Included in amendment improved by GeoERA secretariat 20-12-2020
WP3,4,5 &6. Deadline for D3.5, D4.5, D5.5 and D6.5; Figure 3.2 – Gantt Table 3.1a – WP description, Deliverables WP3, WP4, WP5 and WP6 Table 3.1c List of deliverables; Partner: GEUS, NERC, BRGM, IGME	Deadline postponed due to Covid19 project extension	No	Included in amendment improved by GeoERA secretariat 20-12-2020
WP4. Deadline for D4.4. Figure 3.2 – Gantt Table 3.1a – WP description, Deliverables WP4 Table 3.1c List of deliverables; Partner: NERC	Covid19/ Meeting among partners participating in task 4.6	No	Included in amendment improved by GeoERA secretariat 20-12-2020
WP5. Deadline for D5.2. Figure 3.2 – Gantt Table 3.1a – WP description, Deliverables WP5 Table 3.1c List of deliverables; Partner: IGME	New version of D5.2 was requested at midterm review	No	Included in amendment improved by GeoERA secretariat 20-12-2020
All pilots and assessments in the pilots are described in a Pilot description and assessment report. For each of the technical works packages a specific deliverable is dedicated to this task: D3.2, D4.2, D5.3 and D6.3	deadline for these deliverables have been moved to M 33.	No	Included in amendment improved by GeoERA secretariat 20-12-2020
The 'Protocol for guidelines' D2.5 is delayed related to the deadline in guidelines D3.5, D4.5, D5.5 and D6.5 which all are input to D2.5	deadline moved from M29 to M40	No	Included in amendment improved by GeoERA secretariat 20-12-2020
A pan-European recharge map is developed in WP4 utilising satellite data. During the establishment of the recharge map a method was developed that in addition to satellite data also can incorporate data and results obtained from the pilot assessments. In order to achieve this, the pilot assessments must be finalized, and the deadline for the recharge map has thus been postponed to after the deadline of the pilot reports	deadline moved to M34	No	Included in amendment improved by GeoERA secretariat 20-12-2020
The first version of deliverable "D5.2 Harmonised method for assessing status and vulnerability" was delivered on time. However, it was delivered as a journal paper and not as a technical note as stated in the DoW, and the deliverable was not accepted at the TACTIC midterm meeting. A new version of D5.2 as a technical note was requested, and a new deadline was set for this	deadline moved to M27	No	Included in amendment improved by GeoERA secretariat 20-12-2020

14.7 Communication and dissemination activities

	ABSTRACTS	BLOG	CONGRESS	FACEBOOK	LINKEDIN	MEETING	MEETING WITH OTHER PROJECTS	POSTER	RESEARCHGATE	SCIENTIFIC PUBLICATION	TECHNICAL REPORT	TWITER	WEBINAR	WEBSITE	Total
EVENTS			5										3		8
MEETINGS						5	1								6
ONLINE_MEDIA		1		1	1				1			2		1	7
PUBLICATIONS	7							4		16	1				28
Total	**7**	**1**	**5**	**1**	**1**	**5**	**1**	**4**	**1**	**16**	**1**	**2**	**3**	**1**	**49**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	1700	5	120	70	30	30	30	25	35	25	2070
MEETINGS	205		125	20	20	15	5	5	15	15	425
ONLINE_MEDIA	42100	5000	51	50	50	50	50	50	50	240	47691
PUBLICATIONS	21600	100	40	140	200	150	170		130	130	22660
Total	**65605**	**5105**	**336**	**280**	**300**	**245**	**255**	**80**	**230**	**410**	**72846**

14.8 Project management

'Close communication between partners within the projects has successfully been achieved through:
1. Monthly online meetings in the Project Board, with fixed agenda topics on a) experience sharing on WP activities, b) coordination of cross-cutting topics and c) status on progress according to the Gantt diagram, and d) overview and follow-up on deliverables
2. Online WP-meetings arranged by WP-leaders to monitor progress and discuss possible challenges or shortcomings. The meeting frequency is organised in accordance with the needs in the individual WPs
3. Organisation of webinars to demonstration tools
4. Establishing on ad-hoc theme workgroups for coordination and development of cross-wp activities, such as definition of climate change scenario and assessment approach, definition of recharge types, and coordination of multiple tools in selected Pilots.
5. Organisation of Project Assembly meetings with participation of all TACTIC partners

For coordination with the other GeoERA groundwater projects, the PL of TACTIC has joined coordination meetings with the groundwater theme coordinator and the PLs of the other groundwater projects.

Cooperation with other projects:
'- Collaboration with other project: Online monthly meetings with GW projects
- There has been a coordination with HOVER and RESOURCE on the content of the TACTIC questionnaire with questionnaires/surveys to limit possible overlap on the data/information requested from the GeoERA partners
- Collaboration between TACTIC WP5 and HOVER WP7, where the method developed in TACTIC has been adapted for assessments in HOVER.
- There has been significant synergies with the project Monitoring and assessing impacts of global change in water resource systems depending on natural storage from groundwater and/or snowpacks (MASS-IGLOO or SIGLO-AN in the Spanish version of the tittle), funded by the Spanish National Research Program. For example, the activity to define adaptation strategies with a bottom-up approach is included in both of them. Although they were planned in different case studies (Upper Gudiana Basin in TACTIC and Segura Basin in MASS-IGLOO) they have similarities from a methodological pint of view.
- Collaboration has been established between TACTIC and the Interreg – North Sea Region project TOPSOIL. Collaboration includes the development of complementary climate scenarios and common climate change adaptation strategies.

14.9 General description of the cooperation over the duration of the project

/

14.10 Impact statement

The expected impact of TACTIC was first and foremost to provide: “Improved 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 consistent across the different European countries”.
To achieve this, TACTIC contributed to the population of the common GeoERA Information Platform (GIP), whereby data and results from the project were made findable, accessible, interoperable and reusable data according to the “FAIR” principles. Results included standard results from assessments e.g. in the form of tables of hydraulic parameters, maps, cross sections and model results. In addition to this, results included a TACTIC toolbox with tools relevant for climate change impact assessments and evaluate effect of adaptation strategies as well as a guidance document for undertaking the assessments. Through GIP data and results from the project were made easily accessible primarily for stakeholders involved in the

development of sustainable management of Europe's water resources and climate change adaptation. Hence, it provided 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 promoted 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.

In addition to the impact to the external stakeholders and future users, an important impact for TACTIC is to advance the climate change impact assessments and adaptations in the individual GSOs and harmonise the assessments among the GSOs. This is achieved through the development of a TACTIC Toolbox, common protocols and guidelines, as well as direct contacts through physical project and online meetings, with experience sharing, discussion of progress and demonstration of tools and approaches.

The impacts to the external community can only be realised at the end of the project, were project products have been finalised and made accessible in the information platform. The impact among the TACTIC partners are, on the contrary, experienced during the project. Through online webinars various tools have been demonstrated and taken up by TACTIC partners with no previous experience in climate change impact assessments, and 11 partners are working with multiple tools in their pilots. Common climate change scenarios have further been developed making it possible for all TACTIC partners to estimate effect of future climate changes. The project has thus already had a significant impact in advancing and harmonising the assessments among the partners.

14.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontracting	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. GEUS	251.180,22	1.948,39	0,00	63.282,15	316.410,76	29,70%	93.974,00	222.436,77
2. TNO	38.691,58	0,00	0,00	9.672,90	48.364,48	29,70%	14.364,25	34.000,23
3. DELTARES	27.356,81	0,00	0,00	6.839,20	34.196,01	29,70%	10.156,22	24.039,80
4. HGI-CGS	19.675,95	0,00	0,00	4.918,99	24.594,94	29,70%	7.304,70	17.290,24
5. GTK	19.940,00	0,00	0,00	4.985,00	24.925,00	29,70%	7.402,73	17.522,28
6. BRGM	76.781,83	1.247,01	0,00	19.507,21	97.536,05	29,70%	28.968,21	68.567,84
7. BGR	1.234,56	0,00	0,00	308,64	1.543,20	29,70%	458,33	1.084,87
8. MBFSZ	5.306,19	0,00	0,00	1.326,55	6.632,74	29,70%	1.969,92	4.662,81
9. GSI	74.332,93	0,00	0,00	18.583,23	92.916,16	29,70%	27.596,10	65.320,06
10. ISPRA	19.130,19	2.600,00	0,00	5.432,55	27.162,74	29,70%	8.067,33	19.095,40
11. SGSS	7.751,70	0,00	0,00	1.937,93	9.689,63	29,70%	2.877,82	6.811,81
12. LEGMC	534,94	345,91	4.840,00	220,21	5.941,06	29,70%	1.764,50	4.176,57
13. OPM	14.924,00	0,00	0,00	3.731,00	18.655,00	29,70%	5.540,54	13.114,47
14. LNEG	21.012,86	0,00	0,00	5.253,22	26.266,08	29,70%	7.801,02	18.465,05
15. GSS	5.123,25	0,00	0,00	1.280,81	6.404,06	29,70%	1.902,01	4.502,06
16. IGME-Sp	202.334,01	10.400,29	0,00	53.183,57	265.917,87	29,70%	78.977,61	186.940,26
17. ICGC	9.900,37	0,00	0,00	2.475,09	12.375,46	29,70%	3.675,51	8.699,95
18. SGU	17.171,16	0,00	0,00	4.292,79	21.463,95	29,70%	6.374,79	15.089,16
19. GEOINFORM	0,00	0,00	0,00	0,00	0,00	29,70%	0,00	0,00
20. BGS	46.768,54	5,16	0,00	11.693,43	58.467,13	29,70%	17.364,74	41.102,39
					1.099.462,31		**326.540,31**	**772.922,00**

Date:	30.11.2021
Person responsible:	Peter van der Keur

15 PROJECT VOGERA

15.1 Identification of the project

Project full title:	Vulnerability of Shallow Groundwater Resources to Deep Sub-surface Energy-Related Activities
Project acronym:	VOGERA
Project reference number:	EC 2018 04 006
Project topic:	Groundwater
Project specific recearch topic:	GW4 - CONTRIBUTE TO GROUNDWATER MANAGEMENT WHEN INTERACTING WITH ENERGY AND MINING
Project website address:	https://geoera.eu/projects/vogera1/
Period covered from:	01.06.2018 to: 31.10.2021
Report submission date:	30.11.2021
Project coordinator:	Marco Bianchi, BGS
Contact person for the project:	Marco Bianchi
Tel:	+44 (0)1159363136
E-mail:	marcob@bgs.ac.uk

15.2 Project participants

	Participant Legal name	Participant (eng)	Short name	Country	PIC	Role in the project
1	UK Research and Innovation	British Geological Survey	NERC (UKRI)	United Kingdom	906446474	Project Lead
2	Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	The Netherlands Organisation for applied scientific research	TNO	Netherlands	999988909	Project Partner
3	Vlaamse Milieumaatschappij	Flanders Environment Agency	VMM	Belgium	953383125	Project Partner
4	Studiecentrum voor Kernenergie/Centre d'Etude de l'Energie Nucléaire (affiliated or linked to VMM)	Belgian Nuclear Research Centre SCK•CEN (Third party of VMM)	SCK/CEN	Belgium	999986775	Project Partner
5	Magyar Bányászati és Földtani Szolgálat	Mining and Geological Survey of Hungary	MBFSZ	Hungary	967592364	Project Partner
6	Geological Survey of Denmark and Greenland	Geological Survey of Denmark and Greenland	GEUS	Denmark	999459677	Project Partner
7	State Research and Development Enterprise State Information Geological Fund of Ukraine	State Research and Development Enterprise State Information Geological Fund of Ukraine	GEOINFORM	Ukraine	947331392	Project Partner

15.3 Publishable summary

Groundwater is a fundamental natural resource not only for providing fresh water to natural ecosystems and human livelihoods, but also for supporting economic development and ecological diversity. Human activities in the deep subsurface pose a risk of introducing or releasing pollutants that may reach shallow groundwater resources. The impact of these activities on groundwater is not completely understood, and there is a lack of information and systematic practices for a range of hazards to groundwater from these activities. The VoGERA ("Vulnerability of shallow Groundwater resources to deep sub-surface Energy-Related Activities") Project focussed on improving the scientific understanding of the vulnerability of shallow groundwater from deep sub-surface industrial energy-related activities such as geothermal energy production, unconventional oil and gas exploitation, sub-surface storage, and disposal of wastes. Possible pollutants related to these activities include the resource itself, such as oil, gas, or brine, as in the case of geothermal energy, chemicals used in the extraction processes, such as acids or drilling muds, or contaminants released from deep rock formations. For risk and vulnerability assessments, the location from which these pollutants are released is considered as the source the source, while the groundwater resource requiring protection is considered as the receptor. Contamination occurs when there is a pathway from the source to the receptor.

As part of the research activities conducted in the first erm of the VoGERA project (June 2018 – December 2019), conceptual models of shallow groundwater vulnerability to deep sub-surface energy activities were developed using existing data and knowledge from the GeoERA partners and previous projects (report D4.1). These conceptual models were key to understand for each type of activity the potential pathways from source to the receptor and to identify similarities and differences between the different activities. A detailed characterisation of possible pathways was also conducted for four selected pilot areas (report D3.1) including the Pannonian Basin (Hungary), the Vale of Pickering (UK), the Peel Boundary fault, Veghel (the Netherlands), and the Rauw Fault (Belgium).

In the second term of the project (January 2020 – October 2021), two major milestones/technical deliverables were completed and submitted. Work package 4 produced a technical report describing a novel methodology for assessing the vulnerability of shallow groundwater to deep industrial activities (Technical report on the common methodology for characterizing the vulnerability of shallow groundwater to deep industrial activities and methodology evaluation, report D4.2). Building on the previously developed conceptual models, this methodology called "3D Groundwater Vulnerability - 3D GWV" is designed to quantify the intrinsic (i.e. related to the geological and hydrogeological setting) and specific (i.e. related to the specific underground activity) vulnerabilities of groundwater resources to deep sub-surface energy related activities. This methodology can be applied by means of a spreadsheet tool, which is available for download from the GeoERA webpage. The 3D Groundwater Vulnerability methodology was designed to be used as a preliminary "qualitative" (Tier 1) groundwater risk screening tool during the planning phase or when evaluating the impact of new or hypothetical deep sub-surface activities.

The second major deliverable was a report titled "Characterization of pathways and groundwater vulnerability assessments due to deep energy related activities for the pilot studies" (report D3.2). This study, which was part of the activities of Work package 3 evaluated possible effects of deep energy related activities on groundwater resources for the four pilot sites and applied the GWV 3D approach for each study area. The report presents detailed geological and hydrogeological information for the each pilot which were used to evaluate possible pathways of contamination. This information was also used for the vulnerability assessment using the spreadsheet tool developed in Work Package 4. In general, results of this study suggest that there is no direct evidence of pathways from deep geological units to shallow groundwater receptors, which could lead to a deterioration of the quality of these resources due

to the presence of energy related activities in the deep subsurface. These include conventional oil and gas extraction in the Pannonian Basin (Hungary), geothermal energy extraction in the Veghel (Netherlands) and Rauw Faults area (Belgium), and shale gas extraction in Vale of Pickering (UK).

Although because of the global COVID-19 pandemic a number of originally planned face-to-face meetings involving the Partners and dissemination activities were not allowed to take place, a virtual stakeholders meeting was held in at the end of September 2021. During the meeting, which was attended by 15 professionals from Europe and North America from a wide range of organisations including national environment agencies, water companies, academia, and energy regulatory authorities, the developed vulnerability approach was presented together with results of the investigations at the pilot sites. Stakeholders acknowledged the importance of assessing vulnerability of groundwater resources to deep activities and showed appreciation for the simplicity of use of the developed tool.

Results of the research activities were also presented at the 2020 and 2021 EGU General Assemblies and at an IAH Europe Webinar in May.

15.4 Project contribution to GeoERA project

The GeoERA groundwater projects respond to groundwater research needs described in the call for the ERA-NET on Applied Geoscience (LCE-26-2016), which was partly inspired by and elaborated based on a Concept Note on Groundwater Research Needs previously developed by the Water Resources Expert Group (WREG) of the EuroGeoSurveys in collaboration with science and policy officers of DG Research and DG Environment. The Concept Note intended to assist and realize climate proof and resilient groundwater management and contribute to bridging the gap between science and policy and sustainable use of the subsurface.
Competing uses of the subsurface are expected to increase as a result of secondary impacts of climate change such as CO2 storage, and exploitation of raw materials and geoenergy. Integrated and sustainable management of the subsurface is imperative for the success and implementation of the European Green Deal, the UN sustainable development goals, the UN Framework Classification (UNFC) for groundwater and the new UN Resources Management System (UNRMS). Sustainable management of natural resources requires FAIR and easy access to geodata including geological, physical, biogeochemical and ecological characteristics of groundwater bodies and their link to surface water and dependent terrestrial and associated aquatic ecosystems.
The four GeoERA groundwater projects: HOVER, RESOURCE, TACTIC and VoGERA all contribute with data and knowledge to build a geological service for Europe that via the European Geological Data Infrastructure provide easy access to geodata for all stakeholders. The groundwater data support implementation of the EU and UN policies mentioned above as well as the Water Framework and Groundwater directives according to associated guidance.

The main objective of GeoERA is to contribute to the optimal use and management of the subsurface. The VoGERA project helped achieve by delivering the following:
1) An improved understanding of the relationship between deep energy activities and shallow groundwater resources, and in particular the contaminant pathways in a range of different hydrogeological settings.
2) A series of conceptual models to characterize groundwater vulnerability and identify potential contaminant pathways between industrial activities in the deep sub-surface (and associated infrastructure) and shallow groundwater resources (potable water and/or water for other human uses, less than 400m below ground level).
3) A series of groundwater vulnerability assessments for four pilot areas across Europe, with maps or 3D models showing relevant geological factors, such as the presence of faults and the vertical separation

distance between shallow groundwater and targets for potential industrial activity in the sub-surface (e.g. hydrocarbon source rocks, geothermal sources).
4) A consistent and novel methodology for assessing the vulnerability of shallow groundwater from deep industrial activities that can be universally applied across Europe.

15.5 Work progress and achievements during the period

Work package 1: Co-ordination and management

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D1.1	Kick-off meeting summary	NERC	Report	Confidential	Month 3	Completed	Review completed with Midterm report.
D1.2	Project review report	NERC	Report	Confidential	Month 20	Completed	Review completed with Midterm report.
D1.3	Final project review report	NERC	Report	Confidential	Month 40	Completed	
D1.4	Cumulative expenditure report	NERC	Report	Confidential	Month 7, 19	Completed	Review completed with Midterm report.
D1.4	Cumulative expenditure report	NERC	Report	Confidential	Month 31	Completed	
D1.5	Final financial report	NERC	Report	Confidential	Month 40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
1	Kick-off meeting	Month 1-3	Completed	Review completed with Midterm report.
2	Final Review meeting	Month 40	Completed	

Work package 2: Crosse thematic coordination, data management, interaction with GeoERA Information Platform

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D2.1	Data management plan	GEUS	Report	Confidential	Month 6	Completed	Review completed with Midterm report.
D2.2	List of prioritized Information Products for the GIP	GEUS	List of prioritised data	Confidential	Month 16	Completed	Review completed with Midterm report.
D2.3	Prioritised data to GIP	GEUS	Data	Confidential	Month 38		
D2.4	Communication, Dissemination and Exploitation Plan	TNO	Report	Confidential	Month 12	Completed	Review completed with Midterm report.
D2.5	Workshops for European and regional stakeholders (1)	TNO	Workshop outputs	Public	Month 1	Completed	Review completed with Midterm report.
D2.5	Workshops for European and regional stakeholders (2)	TNO	Workshop outputs	Public	Month 36	Completed	
D2.6	Open access scientific publicatios and presentations at national and international conferences (continuous)	TNO	Abstract / presentation/ punclications	Public	Continuous	Completed	Review completed with Midterm report.

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
4	Data management plan (DMP)	Month 6	Completed	Review completed with Midterm report.
5	Workshop for streamlining the Information Flow and final data input towards the GIP	Month 24	Completed	

Work package 3: Process understanding

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D3.1	Technical report on evidence for potential pathways for groundwater contamination from sub-surface energy activities and data collection plan	TNO	Report	Public	Month 12	Completed	Review completed with Midterm report.
D3.2	Report on the characterization of pathways and vulnerability assessments for the pilot studies	TNO	Report	Public	Month 40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
6	Data review	Month 12	Completed	Review completed with Midterm report.
7	Investigation/data collection plan	Month 12	Completed	Review completed with Midterm report.
8	Investigation/data collection plan	Month 24	Completed	
9	Groundwater vulnerability assessments for pilot study sites	Month 36	Completed	

Work package 4: Conceptual framework for vulnerability characterization

Deliverables							
Deliverable no.	**Deliverable name**	**Short name of lead participant**	**Type**	**Dissemination level**	**Delivery date from Contract**	**Progress**	**Comments**
D4.1	Expanded diagrams of conceptual models identifying potential pathways for industrial activity in the deep sub-surface and shallow groundwater vulnerability	BGS	Diagrams	Public	Month 12	Completed	Review completed with Midterm report.

D4.2	Common methodology for characterizing the vulnerability of shallow groundwater to deep industrial activities.	BGS	Report	Public	Month 40	Completed	

Milestones				
Milestone no.	**Milestone name**	**Delivery date from Contract**	**Progress**	**Means of verification**
10	Conceptual models	Month 12	Completed	Review completed with Midterm report.
11	Common methodology for characterizing the vulnerability of shallow groundwater to deep industrial activities	Month 40	Completed	

15.6 Deviations

Has the project partnership identified any deviations from proposal / work plan? *(select:)*			Yes
If yes, please fill out the table below:			
Description of the deviation (indicate also WP and/or Project partner where the deviation occured)	Description of **corrective measures** adopted:	Does the deviation have an **impact on project outputs**?	Are changes to workplan / budget / … needed? If yes, please specify:
The Covid-19 epidemic had an impact on the course of our project, as well as GeoERA as a whole. As a result, the GeoERA programme was extended for 2 months, thus giving the projects a chance to complete project activities, specifically this project was extended by __ months. The postponed project activities have been adequately communicated to the GeoERA Executive board, which has reviewed and approved the changes with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes. (please delete: this is Monitoring team's proposal to report on prolonged delays. You are free to modify / delete / keep the text provided).	Some activities, deliverables and milestones have been delayed and partners' budgets adapted with regards to achieving project results. Detailed list of changes is part of the project documentation in the Project plan History of changes.	No	no
GEOINFORM has been removed from the list of participants.		No	Yes. Amendment approved by the Partners and submitted to the GeoERA secretariat
The number workshops for European and regional stakeholders (Deliverable 2.5) has been reduced to two due to the impact of COVID-19 pandemic.	Workshop held at the end of month 39 to present the results	No	Yes. Amendment approved by the Partners and submitted to the GeoERA secretariat

Deliverables 3.2 (report on pilot characterization) and 3.3 (report on pilot vulnerability assessment) have been merged together.	This change will simply provide a more inclusive and logical way to present the results of the activities in WP3. The change did not affect the number of tasks performed or the scientific output.	No	Yes. Amendment approved by the Partners and submitted to the GeoERA secretariat

15.7 Communication and dissemination activities

	ABSTRACTS	BLOG	CONGRESS	FACEBOOK	LINKEDIN	MEETING	POSTER	RESEARCHGATE	TWITER	WEBINAR	WEBSITE	WORKSHOP	Total
EVENTS			6							4		2	12
MEETINGS						1							1
ONLINE_MEDIA		5		1	1			1	2		1		11
PUBLICATIONS	7						4						11
Total	**7**	**5**	**6**	**1**	**1**	**1**	**4**	**1**	**2**	**4**	**1**	**2**	**35**

	SCIENTIFIC COMMUNITY	GENERAL PUBLIC	POLICY MAKERS	EUROPEAN INSTITUTION	NATIONAL INSTITUTION	REGIONAL INSTITUTION	INTERNATIONAL INSTITUTION	LOCAL INSTITUTION	PRIVATE COMPANIES	OTHER	Total Target Group reach
EVENTS	64221			5							64226
MEETINGS	15			5							20
ONLINE_MEDIA	42810	5800	51	50	50	50	50	50	50	240	49201
PUBLICATIONS	5500		40		40	10	30				5620
Total	**112546**	**5800**	**91**	**60**	**90**	**60**	**80**	**50**	**50**	**240**	**119067**

15.8 Project management

VoGERA employed a robust management structures and procedures in order to successfully complete the project. To ensure effective management and coordination of the WP's the following governance bodies were established:
- Project Assembly: The Project Assembly is the ultimate decision-making body of the consortium where all participants have one vote. They provide top-level strategic decision making and experience to ensure successful project delivery having decision making powers to modify the project plan and consortium.
- Project Board: The Project Board was chaired by Prof. Rob Ward (NERC) and comprised a representative from each participation organization. Their responsibilities include overseeing outputs, quality assurance, dissemination, exploitation, data management, innovation management, conflict resolution and risk review for VoGERA as a whole. They met via Skype and Zoom and a briefing note was distributed for disseminating information and asking for feedback.
- Project Lead: The Project Lead was responsible for the day-to-day management of the project and acted as the contact for communication between the overall consortium, Project Board and overarching GeoERA management. Dr. Marco Bianchi took over the role of Project Lead from Dr. Sian Loveless in August 2019.
- Work Package Lead: Each WP had a leading organisation and staff member who oversaw the work from their organisation and other participants towards achieving the outlined deliverables. They ensured completion of the outline tasks and deliverables; liaised with and provide report contents to the Project Lead; ensured effective communication throughout WP staff; solved technical issues where possible and monitor and maintain high quality outputs.
- Theme Coordinator: The Project Lead and other relevant staff liaised with the appointed GeoERA groundwater theme coordinator (Mr. Klaus Hinsby), providing detail and updates to facilitate exploitation of synergies between all projects in the theme.

Periodic consortium meetings have been held for the duration of the project. Regular online meetings were held since the beginning of the project with the aim of discussing project work, technical outputs, dissemination/exploitation/communication outputs, risks, innovation management, interaction with the GIP and other relevant issues.

The VoGERA WP2 coordinated dissemination, communication and the relationship with the GeoERA Information Platform (GIP). VoGERA adhered to the overall dissemination, communication and exploitation plan of the GeoERA project. Results were disseminated via the wider GeoERA network and presented to the groundwater scientific and consultancy community at European and International conferences.

15.9 General description of the cooperation over the duration of the project

The consortium comprised sub-surface research organizations and regulators with extensive knowledge of hydrogeology and geology, both nationally and internationally. All of the partners provided key experience acquired from leading or participating in EU projects.
NERC and TNO have been actively involved with the development of the Water Framework Directive and Groundwater Directive and its associated guidance. At a national scale, VMM and MBFSZ provided experience in policy development concerning groundwater protection and in groundwater monitoring. VMM is also involved in groundwater policy development at EU scale by participating in the CIS Working Group on Groundwater. TNO has close ties with Provincial Governments and water supply companies who will provide the additional data for use in the Dutch pilot study. NERC have strong links to the Environment Agency (the regulator in England) having worked with them extensively for shale gas monitoring, a study of abandoned wells, methane baseline and a previous 3D groundwater vulnerability

project looking at hydrocarbon activities. These close links to local and national government and water companies were important to provide stakeholders to review conceptual models, pilot study results, and the vulnerability approach.

Consortium partners provided experience in investigating and monitoring sub-surface pathways for contaminants to groundwater from CO2 storage (NERC, TNO), methane (NERC, GEUS) and geothermal waters (MBFSZ) using geochemical and geophysical monitoring techniques. TNO, SCK•CEN provided expertise in site characterization and monitoring of fluid flows along fault zones including the cross-border Rauw fault and the Peel Boundary Fault, while NERC shared the knowledge acquired from conducting groundwater investigations into the baseline chemistry and geology at the Vale of Pickering. MBFSZ shared the results of previous investigations at the geothermal Great Hungarian Plain for several years and therefore have access to a large quantity data with which to assess potential contamination pathways and groundwater vulnerability. NERC provided a prototype of a methodology to assess the vulnerability of groundwater resources to shale gas activities in the sub-surface. The prototype was updated and expanded during the VoGERA project.

15.10 Impact statement

The outcomes of the project have generated the following impact:

1) Research activities improved the cooperation and communication between national/regional sub-surface research institutes and European stakeholders that deal with groundwater resource management.

2) The deliverable 3.1 “Technical report on evidence for potential pathways for groundwater contamination from subsurface energy activities and investigation/ data collection plan technical report” improved knowledge-sharing across Europe, in particular in relation to intercalibration procedures and standards for geophysical and monitoring equipment used for sub-surface characterization and designing investigations to assess groundwater vulnerability to deep sub-surface industrial activities. The beneficiaries of this knowledge are sub-surface research institutes and other research communities, but also regional and local authorities and stakeholders such as drinking water supply companies can benefit from the increased understanding of the geology at the pilot sites.

3) The deliverable 4.1 “ Expanded diagrams of conceptual models identifying potential pathways for energy activity in the deep sub-surface and shallow groundwater vulnerability” presents conceptual models of groundwater vulnerability to deep sub-surface energy activities and possible contamination pathways. These models harmonized understanding and management of the groundwater vulnerability. The beneficiaries are Sub-surface research institutes and groundwater resource managers in relation to energy, Groundwater Directive and EU Energy Policy. Institutes may also benefit from a common understanding of groundwater vulnerability from deep sub-surface activities and will be able to use these in communication with the public.

4) The deliverable 3.2 presented for four pilot areas a common framework for investigating possible pathways of contamination from the deep subsurface. The resulting understanding could be used for evaluating the possible impacts of future deep subsurface activities in those areas. Again, the beneficiaries of this knowledge are regional and local authorities as well as stakeholders in the water industry.

5) The deliverable 4.2 presented a novel methodology called 3D Groundwater Vulnerability (3D GWV) for characterising the vulnerability of shallow groundwater resources to deep sub-surface energy related

activities. The vulnerability method can be applied using the spreadsheet tool accompanying the report. The tool is targeted at regional and local environment authorities and other stakeholders for being used as a “qualitative” (Tier 1) high-level groundwater risk screening tool when considering energy related activities in the deep sub-surface or as a complement to other established vulnerability and risk assessment tools.

15.11 Financial statement

	A. Direct personnel costs	B. Other direct costs	C. Direct costs of subcontracting	D. Indirect costs	TOTAL COSTS	Reimbursement rate	GeoERA contribution	Partner in-kind contribution
	Actual			(0,25*A+B)				
1. NERC	26.587,21	984,38	0,00	6.892,90	34.464,49	29,70%	10.235,95	24.228,53
2. TNO	72.642,96	11.049,91	0,00	20.923,22	104.616,09	29,70%	31.070,98	73.545,11
3. VMM	25.553,57	0,00	0,00	6.388,39	31.941,96	29,70%	9.486,76	22.455,20
4. SCK•CEN	49.575,60	0,00	0,00	12.393,90	61.969,50	29,70%	18.404,94	43.564,56
5. MBFSZ	6.143,06	0,00	0,00	1.535,77	7.678,83	29,70%	2.280,61	5.398,21
6. GEUS	2.593,26	0,00	0,00	648,32	3.241,58	29,70%	962,75	2.278,83
7. GEOINFORM	0,00	0,00	0,00	0,00	0,00	29,70%	0,00	0,00
					243.912,44		**72.441,99**	**171.470,44**

Date:	30.11.2021
Person responsible:	Marco Bianchi