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

Technical review report for project GARAH

This report is part of a project that has received funding by the European Union's Horizon 2020 research and innovation programme under grant agreement number 731166.

INTRODUCTION

Technical review report is part of GeoERA's Monitoring and evaluation process for co-funded projects (*hereinafter: project*). The aim of a technical review is to assess the work carried out under the project over a certain period and provide recommendations. Such technical review evaluates the project reports and deliverables, the proper use of resources, the management of the project and the expected impact.

Technical review report consists of four sections, each representing one level of monitoring and/or evaluation of the project:

Level	Monitor / Reviewer	Input	Aim
1 – Monitoring of progress indicators	Monitoring and reporting officer (GeoZS)	MPPR* FPPR**	Monitoring of the effectiveness of implementation of selected projects with respect to finance, time and administration.
2 – Scientific review	Reviewers (GeoZS)	Submitted deliverables MPPR FPPR	Quality review of the deliverables and review of achieving scientific and professional goals.
3 – Review of the theme progress	Theme coordinators	MPPR FPPR	Review of achieving theme objectives.
4 – GeoERA Progress evaluation	Stakeholder Council member(s)	Sections 1 and 2 of this report Review meetings	Overall project progress and general recommendations.

*MPPR = Midterm Project Progress Report (see PI doc no 2)
**FPPR = Final Project Progress Report (see PI doc no 2)

Monitoring and evaluation process:

M0 = End of reporting period
M1 = Submitted (Final) Project progress Report (MPPR / FPPR)
M2 = 1 – Monitoring & 2 – Evaluation
M3 = 3 – Evaluation of the theme progress
M3 = (Final) Review Meeting & 4 – Progress evaluation

Each project will be reviewed twice: for first project period M1-M18 – Technical review report, and second project period M19-M36 – Final review report.
Technical review report is based on Horizon 2020 templates but adopted to GeoERA needs. Technical reviews of projects shall be carried out on a confidential basis.

GENERAL INFORMATION

ERA-NET Cofund Grant Agreement:	731166
ERA-NET Cofund acronym:	GeoERA
Call identifier:	H2020-LCE-2016-2017/H2020-LCE-2016-ERA
Project full title:	Geological Analysis and Resource Assessment of selected Hydrocarbon systems
Project acronym:	GARAH
Project reference number:	GeoE.171.002
Project topic:	GeoEnergy
Project specific topic:	GE1-Fossil energy, energy security and climate action
Lead partner:	GEUS Geological Survey of Denmark and Greenland
Project website:	https://geoera.eu/projects/garah4/

☐ Technical review report
☒ Final review report

Period covered	01/01/2020 – 31/10/2021
Review meeting date	06.12.2021, start at 13:30

Contributor:	Role:	Approved on:
Barbara Simić	Monitoring and reporting officer	6.12.2021
Aleksandra Trenchovska	Monitoring and reporting officer	7.12.2021
Miloš Markič	Scientific reviewer	7.12.2021
Jasna Šinigoj	Scientific reviewer	15.12.2021
Matija Krivic	Scientific reviewer	15.12.2021
Serge van Gessel	Theme coordinator	22.12.2021
Christoph Gauert	GeoERA Stakeholder	30.12.2021
Harikrishnan Tulsidas	GeoERA Stakeholder	25.01.2022

1 LEVEL 1 – MONITORING OF PROGRESS INDICATORS

In this section the project is monitored "remotely" on the basis of the respective reports. This part is filled in by Monitoring and reporting officer with aim to monitor the effectiveness of implementation of the selected projects with respect to finance, time and administration, based on submited MPPR and FPPR.

	Yes	Partially (comment needed)	No
PROJECT MANAGEMENT			
Has the MPPR / FPPR report been submitted on time?	☒	See comment no. 1	☐
Have there been any changes in project partnership?	☒	See comment no. 2	☐
Has the project management been performed as required?	☒		☐
Has the collaboration between partners been effective?	☒		☐
Do you identify evidence of underperforming partners, lack of commitment or change of interest of any partners?	☐ (see comment)		☒
DELIVERABLES and MILESTONES			
Have the planned deliverables for the period been submitted on time according to timeline in Project Agreement?	☐	See comment no. 3	☒
Have the planned deliverables for the period been completed (from MPPR / FPPR, sheet 4)	☒		☐
Have any changes to deliverables occurred (type/ dissemination level)? (from MPPR / FPPR, sheet 4 and 5)	☒		☐
Have planned milestones been achieved for the reporting period? (from MPPR / FPPR, sheet 4)	☒		☐
Have the project partnership identify any difficulties achieving any of the deliverables / milestones?	☐		☒
DEVIATIONS (from MPPR / FPPR, sheet 5)			
Has the project partnership identify any deviations that will not affect projects outputs?	☒		☐
Have any deviations occur on the project, with impact on project outputs?	☐		☒
In case of deviations, have the project adopted corrective measures?	☒		☐

DISSEMINATION, COMMUNICATION			
Has the project adopted its dissemination plan?	☒		☐
Have the planned dissemination activities been completed for the reporting period? (from MPPR / FPPR, sheet 6)	☒		☐
Have the partners' disseminated project results and information adequately?	☒		☐
Is the project following dissemination plan?	☒		☐
Is the project interacting in a satisfactory manner with other GeoERA projects?	☒		☐
Is the project interacting in a satisfactory manner with national/international bodies?	☒		☐

FINANCE			
To the best of your estimate, have the resources used been utilised for achieving the project? (according to MPPR / FPPR, sheet 9)	☒		☐
To the best of your estimate, have the resources used been in a manner consisted with the principle of economy, efficiency and effectiveness? *	☒		☐
Are there any major deviations in the budget consumptions from the financial plan? (zero consumption in M18; deviation from plan exceeding 20% in M36)	☒	See comment no. 4	☐
Are there any major deviations in the Person - Months consumptions from the plan? (zero consumption in M18; deviation from plan exceeding 20% in M36)	☒		☐
Are any budget modifications for the project needed? (from MPPR / FPPR, sheet 5)	☐		☒

***The principles of economy, efficiency and effectiveness** refers to the standard of "good housekeeping" in spending public money effectively. Economy can be understood as minimising the costs of resources used for an activity (input), having regard to the appropriate quality and can be linked to efficiency, which is the relationship between the outputs and the resources used to produce them. Effectiveness is concerned with measuring the extent to which the objectives have been achieved and the relationship between the intended impact and the actual impact of an activity. Cost effectiveness means the relationship between project costs and outcomes, expressed as costs per unit of outcome achieved.

Comments (highlighting the project progress) / deviations / recommendations:

The Project GARAH dealt with the identification of new potential areas for hydrocarbon exploration with the aim to give further information regarding basin development and evolution, and the hydrocarbon resources assessment. The main outcome of the project is a harmonized, science-based geological analysis and assessment of conventional and unconventional offshore hydrocarbon resources in the North Sea and an assessment of gas hydrate distribution beneath the European continental shelf. The assessment will be used by planners and policy makers to develop commercial exploration strategies and to identify remaining knowledge gaps that can inform further academic research or exploration programs funded by member states. Overall, the project has contributed to sustainable and affordable energy resources and energy security.

The Covid 19 epidemic had an impact on the progress of the GARAH project. In December 2020, the project was extended by 4 months, from 30.6.2021 until 31.10.2021. The postponed project activities were appropriately communicated to the GeoERA Executive board, which has reviewed and approved the changes in terms of achieving the project outcomes. A detailed list of changes is part of the project documentation in the Project plan History of changes.

The project management structure was well defined and efficient. The pandemic situation required a high degree of flexibility of the partnership and adaptability of their participation in the project activities. Overall, the project consortia spent slightly less than the planned budget due to the constraints imposed by the pandemic. Nevertheless, the overall objectives set were achieved. Only one partner, GEOINFORM, discontinued its activities in the second reporting period without any impact on project work. The reserved and unspent contribution from EC was used to increase the project's reimbursement rate from 22% to 22.498133%, as the project has a lower reimbursement rate than other projects and the partner's activities were completed.

A communication and dissemination plan was adopted and a detailed description of activities with timetable was provided. The main target audience was the scientific community and policy makers, and efforts were mainly put into scientific publications. The project's communication and dissemination activities have adhered to the plan, although some activities for policy makers have been slowed down due to the pandemic. Collaboration with other GeoERA projects, in particular HIKE, 3DGEO-EU and GIP -P. The project has built knowledge on the completed EUOGA project and collaborated with few projects outside GeoERA.

Comment no. 1: The Final Project Progress Report was submitted on time in draft form. Partners still have the opportunity to recalculate their financials by the end of

the calendar year to include the final data, so minor variations can be expected. The changes will not affect the content of the project.

Comment no. 2: During the implementation of the project, the partner IGME-Sp Geological Survey of Spain was integrated into the CSIC Agencia Estatal Consejo Superior de Investigaciones Científicas. At the end of reporting period 1, the project partner GEOINFORM State Research and Development Enterprise State Information Geological Fund of Ukraine ended its activities and did not participate in the second period. In the last year of the project, the Project lead Mr Peter Britze has been replaced with Mr Niels Hemmingsen Schovsbo, who took the project over without difficulties. None of the changes has impacted project's ability to reach its goals and results.

Comment no. 3: Due to the pandemic situation, some activities were delayed, and results had to be submitted later than planned. The revised dates were communicated to the Monitoring team and the GeoERA Secretariat by amending the project plan.

The deliverable changes in the project implementation period are:

Reporting period 1:
D2.1 postponed from M9 (31.3.2019) → M10 (30.4.2019)
D1.4 postponed from M18 (31.12.2019) → M21 (31.3.2020)

Reporting period 2:
D2.4 postponed from M21 (31.3.2020) → M32 (28.2.2021)
D2.2 postponed from M32 (28.2.2021) → M35 (31.5.2021)
D2.3 postponed from M33 (31.3.2021) → M38 (31.8.2021)
D2.5 postponed from M33 (31.3.2021) → M38 (31.8.2021)
D3.3 postponed from M33 (31.3.2021) → M39 (30.9.2021)
D4.5 postponed from M34 (30.4.2021) → M39 (30.9.2021)
D4.4 postponed from M35 (31.5.2021) → M39 (30.9.2021)
D1.6 postponed from M36 (30.6.2021) →M40 (31.10.2021)
D1.7 postponed from M36 (30.6.2021) → M40 (31.10.2021)
D2.6 postponed from M36 (30.6.2021) → M40 (31.10.2021)

Comment no. 4: Some project partners spent 20% more than their planned budget, others spent less than 80%. The partners that have exceeded their budget are BGR and IGME-SP / CSIC. Partner that spent less than their planned budget is NERC. The consumption of man-months followed the EUR consumption.

The project has coped well with the negative external factors and has overcome its challenges in such a way that it has achieved its planned objectives and project results. For this reason, the project is rated "excellent" at level 1 and thus receives a rating of 4 - Objectives and targets fully achieved.

Overall assessment of the project:

☐ 5 - **Overachiever** (the project has achieved all objectives and goals for the period and has even exceeded expectations)

☒ 4 - **Excellent progress** (the project has fully achieved its objectives and goals for the period)

☐ 3 - **Good progress** (the project has achieved most of its objectives and goals for the period with relatively minor deviations)

☐ 2 - **Acceptable progress** (the project has achieved some of its objectives)

☐ 1 - **Unsatisfactory progress** (the project has failed to achieve critical objectives)

Summary of dissemination activities:

	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**

	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**

Are the dissemination activities adequate?

☐ 5 - **Overachieved** (the projects dissemination activities have exceeded expectations)
☐ 4 - **Excellent** (the projects dissemination activities have fully achieved its expectations)
☒ 3 - **Good** (the projects dissemination activities are adequate)
☐ 2 - **Acceptable** (the projects dissemination activities are acceptable)
☐ 1 - **Unsatisfactory** (the project has failed to disseminate)

Cummulative financial statement:

	Person months	**Total eligible costs**	**Reimbursement rate**	**GeoERA contribution**	**In-kind contribution**
Plan	**113,87**	**1.037.245,03**	22,498133 %	**233.360,77**	**803.884,26**
1st period consumption	49,34	406.518,35	22,498133 %	91.459,04	315.059,31
2nd period consumtion	67,61	586.500,73	22,498133 %	131.951,71	454.549,01
TOTAL	**116,95**	**993.019,08**		**223.410,75**	**769.608,32**

The non-funded partner NPD is not included in the financial statement.

2 LEVEL 2 – SCIENTIFIC REVIEW

In this section the project is reviewed ”remotely” on the basis of the respective reports. This part is filled in by reviewer with aim to review the quality of the deliverables and review of achieving scientific and professional goals. Scientific review is based on submitted deliverables and reported Impact statement in MPPR/FPPR.

Impact statement (from MPPR / FPPR, sheet 8):

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.

Expected impact (from Project Agreement):

A variety of different evaluation methods have been employed to assess the hydrocarbon resource in different areas of the EU. Consistent evaluation methods and data processing on newly released and legacy data will help rationalize the resource estimates across the EU, allowing for improved planning for the exploration, development and closure of hydrocarbon reservoirs. Technology improvements may result in resources previously considered uneconomic (e.g., shale gas and methane hydrates) to be considered viable exploration targets in areas with little exploration history. The identification of these areas and quantification of resource will contribute to the development of planning strategies for member states in terms of licensing and policy development. A consistent estimation of hydrocarbon resource will be a first step in assessing and quantifying the hydrocarbon reserves in the main hydrocarbon basin in Europe. The GARAH project idea will result in the identification of new potential areas for hydrocarbon exploration, directly addressing the requirement for identifying secure energy HC sources. This will give further information regarding basin development and evolution, and the HC resources will be systematically assessed. Outcomes will therefore feed into planning and policy (licensing of areas for exploration) by Member States, commercial exploration strategies and also highlight remaining knowledge gaps which may inform about further academic research or programmes of exploration sponsored by member states. The datasets generated will also highlight areas of potential risks associated with exploitation of fossil fuels and the closure of mature fields. Areas with the potential for multiple uses of the subsurface that may require the development of appropriate legislation or guidance will also be identified, therefore partially mitigating delays in bringing energy to market that are related to those issues. The generated catalogue of the multiple-use (or sequential-use) potential and impacts of hydrocarbon reservoirs will enable the European community to improve efficient, sustainable, and foster climate friendly use of the subsurface.

Our mission is to generate a catalogue of the multiple use, enabling synergies between various uses and securing a sustainable development, whilst reducing overall climate impact of fossil fuel use. For example, utilizing the infra structure and the potential of associated geothermal-shale and or depleted reservoir schemes could enable the possibility of a climate neutral HC production. The identification of potential hydrate resources in the European margins and provide a unified database and maps detailing potential distribution of gas hydrates (energy source), potential geohazard areas. In addition, we will aim to identify zones could be used to store CO2 as a hydrate (subsurface CO2 storage resource) within the European offshore and onshore areas. The results will foster the development of new HC technologies in Europe and will feed into planning, policy (licensing of areas for exploration) by Member States, and commercial exploration strategies. By mapping zones of interest, there will be a contribution to marine spatial planning, including possible conflicts between deep hydrocarbon resources; gas storage (i.e. CO2, Hydrogen) positioning and impacts of deep-sea infrastructure; fishing activities and deep-sea habitats; national security issues. The GARAH project will contribute to the development of appropriate legislation and guidance (e.g., storage vs. production, preservation). The outcomes of this project idea will inform EU Member States of potential frontier plays in a pan-EU perspective, allowing for the currently poorly understood offshore methane hydrate and shale gas/oil resource to be acknowledged in developing legislation and regulation.

Evaluation of deliverables

No.	Title	Status (Approve/ Reject)	Comments
D1.4	Midterm Project Progress Report	Approved	Level 1 MT
D1.5	Annual progress reports 2020	Approved	Level 1 MT
D1.6	Final Project report	Approved	Very well done
D1.7	Project review with EU stakeholders – Formal presentation	Approved	Very well done
D2.2	Petroleum system report and GIS maps	Approved	Very well done with up-to day knowledge inputs
D2.3	Resource assessment „EUOGA“	Approved	See row below
	Great harmonization in resource assessments achieved. EUOGA principles were ascertained to a high degree.		
D2.4	Resource assessment 3D pilot Unconventional	Approved	See row below
	The assessment of unconventional resources (GIIP and OIIP) presented in maps based on relevant data and evaluation criteria was studied and clearly published and is well understandable to stakeholders		
D2.5	Resource assessment 3D pilot Conventional	Approved	See row below
	Trans-boundary compilation of data and assessment criteria between the three countries (DK, D, NL) as in 2.4, reached the main aims of the project, but also expressed that refinement and supplements can be expected during further work. The project represents an excellent example how to geologically analyze and assess HC reserves in other parts of EU.		
D2.6	Alternatives + risks	Approved	See row below
	This deliverable weighs connections between technologies and hazards which alternate with new developments of technologies and subsurface usage of energy resources and storage in different geological plays. Such a complex approach as good as it was possible at the time is highly welcome.		
D3.2	Hydrates GISdatabase	Approved	See row below
	Good description of the structure and content of datasets in Hydrates GISdatabase		
D3.3	Gas Hydrate overview report	Approved	See row below
	The authors made a huge overview of the state of both knowledge and gaps, advantages and risks about gas hydrates in locations and offshore areas from W Greenland Sea to Barents Sea, North Sea, and Irish margin, to Gulf of Cadiz, E Mediterranean, Marmara and the Black Seas. A very broad geography (not only North Sea) and reference list significantly support the overview made. Gas hydrates represent an enormous geo-energy resource but are connected still with many knowledge gaps. To solve them in the near and middle future is of a pan-European interest.		

D4.2	Description of Extensions - EGDI	Approved	
D4.3	Assist in HC planning	Approved	See row below
	This deliverable points out the need to keep the scientific and information knowledge in the domain of the whole palette of energy reserves and resources and storage plays even though we do not know at present very definitely what the future of production and the needs will be due to green transition, environmental issues, risks and hazards, prices etc. A harmonized well established operational database has been reached and is still going on based on the EGDI platform.		
D4.4	Online available results	Approved	See row below
	Results are available on GeoERA map viewer complete with metadata descriptions		
D4.5	Data input to IP	Approved	See row below
	Results are available on GeoERA map viewer complete with metadata descriptions		

Has the quality as a whole been achieved according the objectives? Has the project as a whole been making satisfactory progress?

☐ 5 - **Overachiever** (the project has achieved all objectives and goals for the period and has even exceeded expectations)

☒ 4 - **Excellent progress** (the project has fully achieved its objectives and goals for the period)

☐ 3 - **Good progress** (the project has achieved most of its objectives and goals for the period with relatively minor deviations)

☐ 2 - **Acceptable progress** (the project has achieved some of its objectives)

☐ 1 - **Unsatisfactory progress** (the project has failed to achieve critical objectives)

Comments (highlighting the project progress) / deviations / recommendations:

The GARAH project was successfully carried out according to the whole plan. Partners cooperated very effectively and on time.

3 LEVEL 3 – REVIEW OF THE THEME PROGRESS

In this section the project is reviewed ”remotely” on the basis of the respective reports. This part is filled in by Theme coordinator with aim to review the achieved scientific goals in accordance with theme objectives, on the basis of Sheet 3 in MPPR / FPPR – Project contribution to GeoERA project.

Project contribution to GeoERA project (from MPPR / FPPR, sheet 3):

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.

Theme objectives:

General Theme objectives: (Excellent)
With the WP2 and WP3 deliverables, the GARAH project in the first place delivers a harmonized, scientifically based, geological analysis and assessment of the conventional and unconventional offshore hydrocarbon resources that may support the transition to a sustainable and affordable energy system. Besides that, the project evaluates the possibilities to redeploy subsurface formations, data, knowledge and methods developed by the E&P to unravel and identify possibilities for CO2 storage and energy storage

Deliverable D2.6 and D3.3: The GARAH project has evaluated the natural hazard of deep sea gas hydrates. These types of deposits are a new topic that is being investigated in the European context. Furthermore, the GARAH project conducted a comprehensive evaluation of potential re-use options for offshore hydrocarbon reservoirs. This endeavor also illustrates the huge potential of data, knowledge and methodologies established by the E&P industry during decades of exploration and production.

Theme scope and approach/methods: Excellent
With the work and results from in WP2 and WP3, contributed to new and extended overviews of conventional and unconventional hydrocarbons as well as gas hydrates in Europe's offshore regions. Deliverables D2.6 and D3.3 present a comprehensive evaluation of re-use / multiple-use options for offshore hydrocarbon fields (energy storage, CCS, offshore geothermal) as well as novel conceptual ideas for CO2 sequestration via deep sea CO2 gas hydrates.

The project follows/incorporates frameworks from earlier EU projects (EUOGA). This approach ensures that previous EC projects are valorized and improved (WP2). Common resource assessment methodologies (conform industry standards) are used and will be a valuable asset for future research on various resource types at the geological surveys. The project includes a trans-national 3D pilot area for advanced HC assessment and modelling. Correlation schemes are part of the assessment. Much of the 3D modelling was done in collaboration with the 3DGEO-EU project. WP4 deliverables: A regional/national scale is used as basis for the assessments Methodologies are generally in compliance with industry standards. WP4 presents how the final products are embedded in EGDI using regional/national scales

Beyond state of art (Excellent)
Deliverables D2.4 and D2.5 explain how the project uses advanced 3D basin modelling and basin history analysis techniques that are state of art in the E&P industry. Applying such methods in a transnational model area is certainly beyond the current state of art
Pan-European assessment of Gas Hydrates is advanced. The application of techniques for offshore unconventional resource assessments at transnational scale is considered state-of-art in this field of research. The project builds on prior experiences and results from the EOUGA project and in-house expertise

Project-2-Project:
GARAH exchanged model data with the 3DGEU-EU project (in GeoEnergy)

Has the project as a whole achieved the objectives and expected impact of the theme?

☐ 5 - **Overachiever** (the project has achieved greater impact on project theme and/or other themes than expected)

☒ 4 - **Excellent progress** (the project has fully achieved its objectives and goals towards the theme as expected)

☐ 3 - **Good progress** (the project has achieved most of its impact towards the theme for the period with relatively minor deviations)

☐ 2 - **Acceptable progress** (the project has minor impact)

☐ 1 - **Unsatisfactory progress** (the project has failed to achieve critical objectives and/or has no impact on the theme)

Comments / deviations / recommendations:

The project shows the added value of valorizing data, knowledge and methodologies from the E&P industry. This is an important asset for most geoenergy assessment and a key recommendation for CSA Geological Services for Europe.

4 LEVEL 4 – GEOERA PROGRESS EVALUATION

In this section the project is reviewed on the Review meetings, where projects present their overall progress and achievements. This section relates to particular project, broader impact of GeoERA as a whole on policies will be covered at the Final Review meeting with questionnaire and interview with Evaluator.

Based on technical review summaries provided by Sections 1 – 3 of this report, and project presentation on the (Final) Review meeting:

Has the project as a whole been making satisfactory progress according to your own understanding and expectations of the GeoERA project?

☐ 5 - **Overachiever** (the project has exceeded expectations)
☒ 4 - **Excellent progress** (as expected)
☐ 3 - **Good progress** (minor recommendations given below)
☐ 2 - **Acceptable progress** (below expectations)
☐ 1 - **Unsatisfactory progress** (the project did not meet expectations)

Overall comments for the project (overall recommendations, modifications, corrective actions, or re-tuning the objectives to optimize the impact or keep up with the State of the Art, re-focusing, or a simple praise).

Stakeholder one review:

The very topical and comprehensive GARAH project has achieved impressive results. Key geoscientific subsurface data was delivered to stakeholders via a user-friendly, web-based information platform. It helps member states to continue the transition of lowering carbon energy sources, to contribute to climate commitments and allow for planning of secure sources of affordable energy.

The transfer of petroleum systems and gas hydrate assessment data plays a key role in the common European Geological Data Infrastructure (EGDI) database of harmonized oil and gas data. Furthermore, the Pan-European gas hydrate assessment in the European continental margins and related risks improves the European model of the gas hydrate stability zone, related hazards and the potential for geological storage of CO_2. Analytical data for a hydrate-related GIS were successfully transferred to the EGDI database.

The project developed a catalogue evaluating the multiple-use of hydrocarbon (HC)-reservoirs for alternative/integral use of the subsurface for CO_2-, H_2-, underground natural gas storage, geothermal energy, and continued exploitation of energy. Since the industries of building material and cement and of oil and gas are obliged to

compensate emissions by buying CO_2 certificates, CO_2-storage will certainly play an important role in a future "net-zero" scenario.

The GARAH project outcomes identify new potential areas for HC exploration to secure energy HC sources by systematical assessments and feed into planning and policy. The results highlight knowledge gaps in commercial exploration strategies, and form the basis for academic research and exploration programmes by states. Moreover, potential risks of closing mature fields and areas with a potential for multiple use of subsurface development were identified, and guidance for appropriate legislation is given.

The project presents hands-on strategies on burning issues in the energy exploration, development, production and closure, as well as the after-use of fields.

The database and the reports provide a comprehensive overview of HC production, sustainable (geothermal) use, near shore H_2-storage and of geo-hazard areas; the results practically feed into planning and policy, licensing, and legislation. The compiled maps contribute to marine spatial planning, try to resolve conflicts between deep HC resources, gas storage, fishing activities, deep sea habitats, and nature security issues.

The outcomes should not only address the oil and gas exploiting industry, but also government institutions, such as mining authorities and energy agencies, academia, and other stakeholders, among others serving as information base for the decommissioning of well fields.

To make this project sustainable, it should be continued and maintained on a day–to-day basis beyond the length of the project, capturing information from old data.
Overall, a very convincing and successful project, laying a solid foundation for further development, with a lot of data usage potential. Congratulations to the project team for their excellent achievements and deliverables. The project has fully achieved its objectives and goals towards the theme as expected.

Stakeholder two review:
The Project aims for a harmonized analysis of conventional and unconventional resources of Europe with emphasis on (i) North Sea potential and (ii) the hydrate potential of the European continental margins. The objectives included support for a transition to a low-carbon future.

The project deliverables provide insights into crucial issues such as infrastructure abandonment when technology shifts happen, such as coal to natural gas. The project outcomes will assist planning and policy formulation and in academic research. Harmonization of data across country boundaries and multiple uses of the sub-surface are significant issues addressed by the Project. As with other conventional and

unconventional resources, using hydrates could be possible through an integrated net-zero approach. The Project provides the essential information for creating a comprehensive awareness of methane.

The Project faced challenges in synthesizing data maintained under different standards such as PRMS, local standards, UNFC etc. The Project also looked into the availability of the potential for CCUS, which is essential for the transition to a low-carbon future.

The Project has performed well in providing all the deliverables in time and overcoming data availability challenges in a uniform standard. As supporting the transition to a low-carbon future is one of the Project's main objectives, a question may be asked on how this Project can contribute to the same. It may have to keep in mind that a low-carbon or a carbon-neutral project need not mean the use of hydrocarbons. It may be that a net-zero future could be envisaged with hydrocarbon use coupled with CCUS. The integrated used hydrocarbons and renewable energy such as offshore wind and marine energy such as wave and tidal power could be necessary for the future. In such a scenario, the increased use of hydrocarbons could be possible as long as a net-zero carbon model could be maintained.

Marine hydrate source presents an economic opportunity while potentially mitigating huge climate risk. Even though workable solutions are not very obvious, this area will have to be given more attention in the future as ocean temperatures, acidity etc., increase. A careful assessment and valuable baseline data are necessary for thinking about possible innovative solutions.

Therefore, the data and information generated by the Project could facilitate assimilation across energy potential of the continental shelf of Europe such as conventional and unconventional hydrocarbons, renewable energies such as offshore wind, tidal, wave energy etc., and the hydrate potential. This approach also could highlight the integration of deep-sea mining, which is also is an essential element in sourcing critical raw materials required for the green transition.

Current industry standards in use for assessing resources may not be suitable for an integrated framework, where a synthesis, as suggested above, may be easily achieved. Multiple-use of the subsurface requires innovative approaches, which this Project has addressed. The technical information can be used for multi-resource assessments and for finding solutions for the energy transition. The reuse of offshore fields for alternate uses such as renewable energy provides opportunities for abandonments that could be addressed better. The 3D models and characterization of uncertainties developed by the Project will be valuable for multi-resource assessments.

In the face of the rapid energy transition, net-zero carbon frameworks are essential, wherein the role of hydrocarbons is central to the equation. The communication strategy of the Project may be rethought in this direction.

I congratulate the Project team for their excellent achievements.

Annex 1: Review meeting list of participants

Name	Role	Organisation
Joop Hasselman	GeoERA coordinator	Netherlands Organisation for Applied Scientific Research
Harikrishnan Tulsidas	GeoERA Stakeholder	UN Economic Commission for Europe
Christoph Gauert	GeoERA Stakeholder	State Office for Geology and Mining Saxony-Anhalt
Barbara Simić	Monitoring and Reporting Officer	Geological Survey of Slovenia
Aleksandra Trenchovska	Monitoring and Reporting Officer	Geological Survey of Slovenia
Jasna Šinigoj	Scientific Reviewer	Geological Survey of Slovenia
Miloš Markič	Scientific Reviewer	Geological Survey of Slovenia
Matija Krivic	Scientific Reviewer	Geological Survey of Slovenia
Serge van Gessel	GeoEnergy Theme coordinator	Netherlands Organisation for Applied Scientific Research
Niels Hemmingsen Schovsbo	Project manager	Geological Survey of Denmark and Greenland
Margaret Stewart	GARAH Project member	British Geological Survey
Susanne Nelskamp	GARAH Project member	Netherlands Organisation for Applied Scientific Research
Rüdiger Lutz	GARAH Project member	Federal Institute for Geosciences and Natural Resources, Germany
Ricardo León Buendia	GARAH Project member	Geological Survey of Spain
Andre Burnol	GARAH Project member	Bureau de Recherches Gélologiques et Minières
Stefan Ladage	GARAH Project member	Federal Institute for Geosciences and Natural Resources, Germany
Uffe Larsen	GARAH Project member	Geological Survey of Denmark and Greenland