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DELIVERABLE D6.5

Final report on Dissemination and Exploitation including Communication

Lead Beneficiary: CNR

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ABBREVIATIONS AND GLOSSARY OF ACRONYMS

Acronym	Extended definition
CA	Consortium Agreement
D	Deliverable
DCM	Dissemination and Communication Manager
D&C	Dissemination and Communication
EC	European Commission
EM	Exploitation Manager
EP	Exploitation Plan
GA	Grant Agreement
HE	Horizon Europe
IPR	Intellectual Property Rights
M	Month
PC	Project Coordinator
PDEC	Plan for Dissemination and Exploitation including Communication activities
SC	Steering Committee
VRE	Virtual Research Environment
WP	Work Package

EXECUTIVE SUMMARY

This report provides the final overview of the Dissemination, Exploitation and Communication activities carried out throughout the DeepU project. It represents the final and consolidated version of the Plan for Dissemination and Exploitation, including Communication activities (PDEC), a crucial report that Horizon Europe projects are required to submit to the EC. DeepU PDEC is a guide for the project partners on promoting the project and maximising its impact using the promotion tools and dissemination channels. This document also outlines the partners' roles and responsibilities, identifies the audience, and specifies the key messages to be shared.

Building on the strategy and framework outlined in the PDEC document released at the start of the project, this deliverable summarises the actions implemented to M44, assessing their results, impacts, and contributions to the overall project objectives. It provides an integrated overview of the activities aimed at promoting the DeepU concept, disseminating the generated knowledge, and maximising the potential for exploitation of project outcomes.

This document describes the dissemination, communication and exploitation actions performed by the consortium partners, highlighting the most significant achievements and outreach performance.

The deliverable addresses the three key areas of dissemination, exploitation and communication, which are reported separately. It includes an overview of the tools and channels adopted to reach the identified target audiences, the main indicators used to monitor performance, and the strategic measures put in place to ensure visibility and impact beyond the project's lifetime.

The document is structured into five main chapters, following the approach of the previous reports, and is publicly available through the DeepU project website.

Chapter 1, Introduction, contains information about the document's scope and objectives and their links to the DeepU Project objectives.

Chapter 2 (Dissemination Strategy) describes the dissemination measures and activities planned and implemented throughout the project's lifetime. The plan aims to promote the project on European and international stages. Based on the plan, target groups for dissemination are identified, and the subjects and matters of these actions are described. The management, as well as the tools and activities, are defined, and the partner roles are shown. Cost-effective measures have been chosen to achieve maximum publicity for the project and its results, and indicators have been identified to monitor dissemination activities. The lists of events attended are included in Annex 1.

Chapter 3 (Exploitation Strategy) briefly describes the exploitation management. More detailed reports on Exploitation activities and IPR have been prepared in the frame of the Work Package 5 activities dedicated to Exploitation planning and IPR management (deliverable D5.2).

Chapter 4 (Communication Strategy) outlines the communication activities carried out during the DeepU project and the chosen communication channels. The published communication documents are included in Annex 2.

Chapter 5 summarises Dissemination, communication tools, channels, and target groups.

1. INTRODUCTION

1.1 DeepU PROJECT IN A NUTSHELL

DeepU is a European-funded project dedicated to creating a deep (>4 km) closed-loop connection shaped like a U-tube exchanger by developing a fast and effective drilling technology. It has spanned 44 months (March 2022-October 2025) and has involved 7 partners from 4 countries, led by RED, Italy.

The disruptive technology envisioned in the "Deep U-tube heat exchanger breakthrough: combining laser and cryogenics gas for geothermal energy exploitation (DeepU)" Project is expected to revolutionise the deep geothermal energy sector. A laser drill head is combined with special drill strings sustaining the coupled action of laser and cryogenic gas, responsible for melting, vaporising, evaporating and cooling even the hardest rocks. The technical feasibility of DeepU is demonstrated at the laboratory scale, and the specific objectives of the Project have been: (i) select a cryogenic gas able to cool in a controlled manner the rock melted by a laser; (ii) develop an innovative lightweight drill string able to host the gas and the laser at the same time; (iii) develop specific temperature control analysis and innovative laser lenses able to convey the heat and to sustain multilateral drilling, (iv) determine the physical-thermal phenomena affecting different kinds of rocks in order to assess the borehole wall vitrification and integrity. All objectives have been achieved, as described in detail in other deliverables. Numerical simulations calibrated by the laboratory data have provided a basis for defining the DeepU geothermal exploitation potential, including for economic analyses. The legislative aspects and environmental standards related to the proposed solution have also been assessed.

DEEPU Key Words: Laser and cryogenic drilling technology, drilling speed, vitrified/glazed borehole wall, borehole casing, deep heat exchanger, environmental assessment, regulation, numerical simulation.

1.2 CONTENT, SCOPE AND OBJECTIVES OF THIS DELIVERABLE

This Deliverable is the third and final of three deliverables regarding the Dissemination, Exploitation, and Communication Activities of the DeepU project. In the Plan for Dissemination, Exploitation, including Communication Activities (PDEC) presented in D6.3, we laid out and steered the project's approach to disseminating and exploiting its results, as well as communicating the research to various audiences throughout the project lifespan. The PDEC has been progressively updated throughout the project, first on the occasion of the First Interim Report (M12) and then in Deliverable D6.4 (M25). This final document (D6.5, M44) consolidates and concludes the Dissemination, Exploitation and Communication strategy of the DeepU project, integrating the outcomes of the activities carried out within Work Package 5 (WP5) dedicated to Exploitation planning and IPR management.

The dissemination activities are essential to inform project participants and other stakeholders about progress. They should also encourage feedback from interested groups and increase the project's international visibility. The main goal of these activities is to enhance the project's visibility within selected communities and target groups at the national, European, and international levels, supporting the achievement of impacts. Special focus is given to engaging specific stakeholder groups to maximize influence.

This deliverable outlines the DeepU dissemination strategy in terms of identification and description of the dissemination key elements:

a. the objectives of the dissemination (mission, vision),
b. the subjects of dissemination (what will be disseminated),
c. the target audience (to whom it will be disseminated and who would be interested in learning about the project findings),
d. the dissemination channels (how it will be disseminated),
e. the monitoring (how much dissemination works)
f. the timing (when dissemination will take place)
g. the dissemination management and policy (who is responsible for and how dissemination is ruled).

The Consortium valued dissemination. Most partners contributed to this effort and strived to maximise the use of all available dissemination channels, including high-quality papers presenting the main scientific achievements and oral and poster presentations at relevant international and European conferences. In addition, the coordinator and industrial partners participated in workshops, fairs, and showcases where technical achievements and prototypes were presented to stakeholders. Gathering all exploitable outputs developed by DeepU during its lifespan was crucial for defining the concrete use of research results for commercial, societal, and policy purposes. The Exploitation Plan (EP) was designed to multiply the impact of the proposed solutions and to prepare the transition towards industrial and commercial uptake in order to fully achieve the expected impact. The EP described the activities undertaken (how and by whom) to ensure exploitation beyond the project itself. The exploitation strategy was built on a sound analysis of market trends, potential users, and financial sustainability. Target users were identified and analysed according to their specific needs and objectives. Through interaction with stakeholders, valuable feedback from those interested in DeepU's outputs, its exploitable results, and – above all – the potential future market products derived from the developed technology, contributed to the finalisation of the EP.

The communication activities aimed to demonstrate how the DeepU project contributed to research and innovation, broadened the applicability of geothermal installations, and strengthened the European geothermal technology base. The communication strategy of the project was built around the following objectives:

a. Raise awareness about co-creation and design among a broad segment of the public;
b. Support the dissemination and exploitation of the results of DeepU;
c. Provide a solid and common brand for the project, facilitating its recognition;
d. Establish sustainable tools and structures for the project, including the different communication channels, printed materials, website and social media;
e. Ensure the visibility of the project's events, activities and different actions.

The present document is available on the DeepU project website. It should be used by anyone interested in the activities carried out to promote the DeepU project and ensure effective utilization of its results.

2. DISSEMINATION STRATEGY

2.1 OBJECTIVES

The main goal of the Dissemination Strategy within DeepU PDEC was to identify and organize the activities needed to maximize the project's impact and to promote the commercial and other uses of the project results.

The objectives of dissemination activities included:

- To raise public awareness about the project, its expected results and progress within defined target groups using effective dissemination and communication channels and tools (see also Chapter 4);
- To exchange experience with projects and groups working in the field in order to join efforts, minimise duplication and maximise potential;
- To disseminate the fundamental knowledge, the methodologies and technologies developed during the project;
- To pave the way for a successful commercial and non-commercial exploitation of the project outcomes.

2.2 SUBJECTS

The following DeepU general subjects were disseminated:

- interim and final results (reached objectives and achievements)
- techniques and methodologies (in respect of IPR issues)
- environmental, legal and regulatory aspects
- innovation aspects (in an “open innovation” perspective)

The dissemination covered technical aspects such as lab research and modelling on physical phenomena related to rock melting and evaporation using a laser beam, quench cooling with cryogenic gas, material characterization of borehole walls and drilling residues, and modeling of deep heat exchangers. Additionally, environmental and regulatory aspects of the proposed technologies were also included for dissemination and discussion.

2.3 TARGET AUDIENCE

One of the critical part of the DeepU dissemination strategy was pinpointing target areas and audiences.

2.3.1 Internal dissemination (within the DeepU partners)

Ensuring effective internal communication and dissemination among the Consortium partners represented an important success factor for the DeepU Project. Industrial partners acted both as potential users and “influencers” due to their impact on the associated industrial sectors, while academic partners were crucial for technical development.

Adequate knowledge sharing accelerated the achievement of project results and maximised collective efforts. The internal dissemination strategy aimed to keep all partners fully informed about planning, ongoing work, and existing or potential issues.

In addition to the required EC and internal reporting, all partners actively communicated with WP Leaders about technical progress and challenges. WP Leaders, in turn, kept the Project Coordinator (PC) updated on the activities. Furthermore, all partners informed the PC of any administrative or legal issues that arose during project implementation. The PC remained available to partners for any technical or administrative support required.

The Virtual Research Environment (VRE) technologies, described in Section 4.1.3, supported data and information sharing among DeepU partners, facilitating collaborative work and efficient internal communication throughout the project.

2.3.2 Dissemination beyond the DeepU Consortium (External dissemination)

Selecting target groups was crucial for defining the scope and characteristics of the "potential users" that the dissemination activities were designed to reach. Table 1 lists the target groups that were identified for the project. The International Standardization Bodies (ISB), initially identified as a potential audience, were omitted due to the technology's early development stage.

Table 1: DeepU external audience

Type of audience	Definition and Motivation
Scientific and research community	This group targets all research communities interested in the DeepU project's developments, results and innovation, which can benefit their research activities. Scientific contributions of DeepU are particularly interesting for researchers working in the field of Deep Geothermal (e.g. those participating in EERA-JP Geothermal[1]) and those working in developing drilling technologies, laser techniques, material integrity, corrosion, and sub-surface geomechanics.
Industry and innovation community	Representatives of industry associations at regional, national and international levels to address and trigger the active involvement of industrial and user communities. They are expected to provide valuable feedback on the project, introduce challenging requirements to be considered and significantly impact the project's sustainable development.
Other EU projects	The project will also target other EU-funded projects in the same areas.
Policymakers	This comprehensive group encompasses local, regional, national and EU Authorities, Public Administrations and regulators. Representative groups are also included.

[1] European Energy Research Alliance – Joint Programme Geothermal, https://www.eera-geothermal.eu

Technology and Professional Clusters/platforms/associations	This group targets sectorial/industrial international associations like ETIP-DG[2], EGEC[3], IGA[4], EFG[5], IADC[6], IWCF[7], API[8], SPE[9] Professional associations may act as essential influencers.
Civil Society/ Non-Governmental organisations	Including associations, foundations, cooperatives and networks that operate locally, nationally and internationally. They are a significant influencer in the application sought by the project.

DeepU Consortium maintains strong and meaningful connections with European and global initiatives. Some partners are part of international committees, boards, and prominent platforms that have helped share DeepU's results more widely.

2.4 DISSEMINATION CHANNELS

Various DeepU dissemination channels were used, and the tools were tailored to the different target audiences, as described in Table 2.

Table 2: Dissemination tools foreseen in DeepU

Target audience	Tools
DeepU partners	Virtual Research Environment (VRE, see Section 4.1.3 for details)
Scientific and research community	Scientific publications Webinars and workshops Scientific conferences
Industry and innovation community	Webinars and workshops Research and Innovation Events Fairs and exhibitions Articles in national and international geothermal associations' newsletters
Other EU projects	Webinars and workshops Research and Innovation Events
Policymakers	Research and Innovation Events

[2] European Technology & Innovation Platform on Deep Geothermal, https://www.etip-dg.eu
[3] European Geothermal Energy Council, https://www.egec.org
[4] International Geothermal Association, https://www.lovegeothermal.org
[5] European Federation of Geologists, https://eurogeologists.eu
[6] International Assoc. of Drilling Contractors
[7] International Well Control Federation
[8] American Petroleum Institute
[9] Society Petroleum Engineers

	Face-to-face / existing networks
Technology and Professional Clusters/platforms/associations	Webinars and workshops Research and Innovation Events National and international geothermal association's newsletters
Civil Society/ Non-Governmental organisations	Face-to-face / existing networks

Annex 1 provides a list of webinars and technical events organised within DeepU, as well as a list of scientific conferences, fairs, and exhibitions attended.

All publications are being listed in an online document and collected on the VRE.

2.5 EVALUATION OF DISSEMINATION IMPACT

At the start of the project, quantitative indicators were defined to monitor and evaluate the effects of the dissemination activities. Such methods are synthesised in Table 3, which also reports the achieved results.

Monitoring dissemination activities helped identify the potential risk of ineffective dissemination and reassess the dissemination strategy. This updated DeepU PDEC takes tracking data into account.

Table 3 Dissemination activities monitoring tools

Dissemination tools	Monitoring tools	Achieved Results
VRE	Number of shared technical documents	32 shared technical documents, 15 infographic documents
Scientific publications	Number of submitted or published articles Downloads of publications	5 proceeding (World Geothermal Conference, WGC 2023; EGU General Assembly 2024; Stanford Geothermal Workshop 2025; Drilling Turkiye 2025; EGU General Assembly 2025) 15 abstracts in national and international events More than 70 downloads
DeepU Webinars and workshops	Number of registered people	2 DeepU webinars (E*nergy performance of deep heat exchangers (DHE) by numerical simulation* - online, October 23, 2024; *Does deep drilling need a revolution?* - online, April 4, 2025) 63 participants in total

Face-to-face meetings	Number of meetings Number of external participants	None reported by partners, but numerous during the attended events
Scientific conferences, Research and Innovation Events	Number of attended conferences with presentations or posters Number of participants	18 conferences and workshops 8000-10000 participants in total
Articles in national and international geothermal associations' newsletters	Number of articles Associations' members' number	Deepu has been mentioned by: • EERA Geothermal Newsletter, 2023 • EGEC News • ThinkGeoenergy • Greenreport • Perforare Info regarding recipients' number is not available
Fairs and exhibitions	Number of attended fairs or exhibitions Number of visits and distributed brochures and flyers Number of post-event contacts List of contacts	3 fairs (GeoTHERM expo & congress 2024, Offenburg; Fiera Klimahouse 2024; GeoTHERM expo & congress Offenburg 2025) 350 visitors 200 flyers and 300 brochures distributed 50 contacts

All consortium partners have been encouraged, by email and during the project meetings, to share the dissemination material (papers, conference presentations, or the audio file of an interview, for example) on the VRE and to report the results of each dissemination activity immediately after they were presented. The reports include feedback gathered by the respective partner from the target audience (if applicable) and eventually gained contacts to be listed in the contact repository for further dissemination. The dissemination activities were checked at each project progress meeting.

2.6 TIMING

Dissemination activities took place throughout the project, with the most important ones occurring after the final research results were available. The main activity during the project's first two years consisted of communication efforts to promote the project and its objectives, while final results were disseminated at a few strategic events.

The dissemination activities were performed according to the logical schedule foreseen in the original plan (D6.3, M6):

1) Targeted dissemination phase (M6-M24): The consortium attended selected events and presented preliminary project results to the target audiences.

2) Pre-launch phase (M25-M44): this period represents the period closely before the end of the project, during which the DeepU consortium partners prepared their own utilisation and business plans for the industrialisation of the DeepU project outputs. This phase focused on informing the target audience about the exploitable results of DeepU.

Following this logic, a list of dissemination events was defined (see Annex 1), considering the events attended, those organised by the project, and events of potential interest for the project partners based on available information on international conferences.

2.7 DISSEMINATION MANAGEMENT AND POLICY

2.7.1 Responsibilities

According to Annex 5 of the EC-GA, "*The beneficiaries must disseminate their results as soon as feasible, in a publicly available format, subject to any restrictions due to the protection of intellectual property, security rules or legitimate interests*". They are also requested to "*use the EIC Market Place platform to exchange information on results (including preliminary findings)*". In particular, the academic and research partners (CNR, UNIPD, FhG) were expected to publish scientific articles (about 12) in the professional literature (peer-reviewed, congress acts, scientific magazines, etc.). All partners contributed to maximizing the use of all existing dissemination tools, such as high-quality papers showcasing the best scientific achievements and oral and poster presentations at major international and European conferences. Additionally, industrial partners participated in workshops, fairs, and showcases where technical achievements could be debated with stakeholders.

Project partners were also requested to "ensure open access to peer-reviewed scientific publications relating to their results." All partners were responsible for the open access publication of their scientific papers.

Moreover, "*the beneficiaries must provide and regularly update a plan for the exploitation and dissemination of results including communication activities*". In this regard, CNR, which led the WP6 dedicated to Dissemination and Communication, was responsible for providing and updating the Plan, which was discussed at all General Assemblies of the project. All partners were responsible for checking and reviewing the proposed actions.

CNR was responsible for organising webinars and technical events in coordination with the PC and the Consortium.

CNR has also been responsible for ensuring that the open access publications are stored following the rules set in Annex 5 of the GA. CNR reminded to partners:

"- at the latest at the time of publication, a machine-readable electronic copy of the published version or the final peer-reviewed manuscript accepted for publication, is deposited in a trusted repository for scientific publications

- immediate open access is provided to the deposited publication via the repository, under the latest available version of the Creative Commons Attribution International Public Licence (CC BY) or a licence with equivalent rights; for monographs and other long-text formats, the licence may exclude commercial uses and derivative works (e.g. CC BY-NC, CC BY-ND) and

- information is given via the repository about any research output or any other tools and instruments needed to validate the conclusions of the scientific publication.

Metadata of deposited publications must be open under a Creative Common Public Domain Dedication (CC 0) or equivalent, in line with the FAIR principles (in particular machine-actionable) and provide information at least about the following: publication (author(s), title, date of publication, publication venue); Horizon Europe or Euratom funding; grant project name, acronym and number; licensing terms; persistent identifiers for the publication, the authors involved in the action and, if possible, for their organisations and the grant. Where applicable, the metadata must include persistent identifiers for any research output or any other tools and instruments needed to validate the conclusions of the publication".

It was also reminded and checked that the bibliographic metadata followed a standard format and included all of the following:
- the terms "European Union (EU)" and "European Innovation Council";
- the name of the action, acronym and grant number;
- the publication date and length of the embargo period, if applicable, and
- a persistent identifier.

All DeepU partners were responsible for providing CNR with their dissemination products as soon as they are finalised to guarantee proper open access to them and provide all the necessary metadata information.

All partners were responsible for acknowledging EC and EIC funding in their dissemination documents, as stated in Deliverable 7.1. We recap here the general rule.

Acknowledgement

All publications or any other dissemination relating to foreground shall include the following statement to indicate that said foreground was generated with the assistance of financial support from the European Commission (according to GA, Article 17):

This research is funded by the European Union (G.A. 101046937).

Moreover, the following sentence has to be included in all publications:

The views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EISMEA. Neither the European Union nor the granting authority can be held responsible for them.

For infrastructure, equipment and major results, the following sentence has to be included:

"This [infrastructure][equipment][insert type of result] is part of a project that has received funding from the European Union under grant agreement No 101046937".

For any communication document, including posters and presentations, it is compulsory to include the project logo (see Chapter 4), which is part of the branded templates provided to the partners.

The primary contact for Dissemination scopes has been the Dissemination and Communication Manager (DCM), Adele Manzella adele.manzella@igg.cnr.it.

2.7.2 Policy and Rules

We again report the rules established since the beginning of the Project.

Article 17 of the GA and art. 8.4 of CA, signed on February 9, 2022, governs the general dissemination rules. Dissemination activities shall be compatible with protecting intellectual property rights, confidentiality obligations, and the legitimate interests of the owner of the Foreground and/or Background.

The dissemination strategy and activities will follow principles set in Annex 5 of the GA and the best practices successfully tested by the partners in other projects. Dissemination activities in the DeepU project are deeply wedded with intellectual property rights (IPR) protection. It is crucial to set up the dissemination rules and procedures to avoid any potential breach of any partner's IPR and to understand the difference between the interests of academia and industry partners of the DeepU project, the former inclined to publish all information they have at disposal and the latter deciding whether, when and where to publish depending on commercial considerations.

Following Annex 5, "*A beneficiary that intends to disseminate its results must give at least 15 days advance notice to the other beneficiaries (unless agreed otherwise), together with sufficient information on the results it will disseminate. Any other beneficiary may object within (unless agreed otherwise) 15 days of receiving notification, if it can show that its legitimate interests in relation to the results or background would be significantly harmed. In such cases, the results may not be disseminated unless appropriate steps are taken to safeguard those interests".*

- Prior notice to any planned publication shall be given to the other beneficiaries 30 days before the publication, providing a copy of the planned publication. Any objection to the planned publication shall be made in accordance with the Grant Agreement in writing to the Scientific and Technical Coordinator and to any partner concerned within 30 days after the receipt of the planned publication.
- When submitted to a journal, the scientific publication must be sent to all partners, who have 15 days to check and send any objection to the authors, also informing the PC. The authors will be in charge of modifying the document to safeguard other partners' interests.
- A common graphic identity has been defined (see Section 4.1) to allow for better visibility, recognition, and branding of the DeepU project. Therefore, all dissemination products must rely on templates provided by DCM and the instructions detailed in Section 4.1.
- The research will be conducted following sound analysis and scientific practice principles, considering as many policy requirements and needs as possible.
- All consortium members contributing to the project activities will be duly informed about the final outcomes and the implications stemming from project results.
- All public results will be accessible from the project website and usable by all parties who may benefit from them. In addition, sensitive results will be accessible on the VRE by the partners authorised by the PC and the reference WP leader.

3. EXPLOITATION STRATEGY

3.1 Market trends

Geothermal to date meets less than 1% of global energy demand. Its use is concentrated in a few countries with easily accessible and high-quality resources, including the United States, Iceland, Indonesia, Türkiye, Kenya and Italy. But geothermal energy is getting more and more attention worldwide and in Europe. The International Energy Agency predicts huge growth opportunities (reference 'The future of Geothermal Energy' by IEA) driven by technology breakthroughs. One of these breakthroughs is the laser drilling technology developed within the DeepU project up to a technological readiness level of 4. In Europe, the European Parliament voted in January 2024 on a resolution for an EU Geothermal Strategy. The Commissioner for Energy and Housing has responded by confirming the publication of the Geothermal Action Plan of the Commission in the first quarter of 2026. Meanwhile, the German government requested by law that all regions come up with a plan to decarbonize the heating of buildings. As a consequence, several drilling projects for district heating have been launched in Southern and Western Germany. In the rest of the world, Enhanced Geothermal Systems (EGS) are predicted to grow fast, particularly in China, the USA, and India, with capacities reaching 120 GW by 2035 and over 800 GW by 2050. In Europe, EGS technology is getting a lot of opposition from the public and the authorities. Nevertheless, geothermal energy for power production and heating will be growing in the near future. The European Geothermal Energy Council predicts in its market report of 2024 that 230 wells will be drilled in the period 2025 – 2027, or around 80 wells per year, compared to an average of less than 30 wells per year up to now.

3.2 Potential users of DeepU technology

DeepU laser drilling technology can be used in open as well as in closed-loop geothermal systems for electrical power production, heating, or a combination of both. The advantages of this technology over conventional mechanical drilling are best exploited in hard rock formations such as granite and basalt, where drilling cost estimates in deliverable D5.2 indicate significant cost-reduction potential. Therefore, potential users for this technology are utilities looking to decarbonize energy production, oil and gas companies and drillers diversifying in geothermal drilling, geothermal drilling operators, and investors in geothermal energy production systems with or without local authority participation.

Also, mining companies are potential users of DeepU laser drilling technology for surface mining applications. This technology does need a lot less energy, and delivers more accurately drilled holes than the state-of-the-art surface-blast and pre-split drilling methods.

3.3 Financial sustainability

Estimates to date, as part of deliverable D5.2, show moderate cost reductions compared with conventional mechanical drilling. A lot of progress has been made in mechanical drilling recently, thanks to developments in the PDC (Polycrystalline Diamond Compact) drill bits. However, the DeepU laser drilling technology has a high potential for further cost reductions. The technology is very recent and sits at the beginning of a learning curve that each technology goes through from its inception. Next to that fact, vitrification of the borehole wall is one of the most important cost-reduction opportunities as it eliminates at least in part the installation of casing. Casing represents today 40 % of the total drilling cost, but further research is necessary to develop the concept of vitrification of the borehole walls. The feasibility of the concept has already been addressed in literature[10]. Another topic for cost reduction is the cost of nitrogen. As it is used in large quantities, opportunities for cost reductions need to be explored with the suppliers and manufacturers.

3.4 Exploitation plans

3.4.1 Fields of exploitation

Laser drilling of geothermal wells to depths of 1500 – 2000 m in sedimentary formations is limited due to environmental and regulatory concerns, as outlined in deliverable D4.3 of work package 4. With the current state of development, the laser drilling technology of DeepU can move to the field and be developed further. Upon progressing from actual technology readiness levels of 4 to levels of 8-9, geothermal wells for open and closed loop systems can be realized. With lasers of 250 kW, borehole diameters of 20 cm can be achieved based on the extrapolation of the laboratory tests in Hamburg at Fraunhofer-IAPT.

As an intermediate step, the laser drilling technology could also be deployed in surface mining as explained above.

3.4.2 Exploitation pathways

Several exploration pathways have been explored with the consortium partners.

The first and least capital-intensive path in geothermal drilling is to license the know–how of the technology to stakeholders such as drilling operators, multi-utility companies, investors in geothermal energy projects, heat energy suppliers in part supported or owned by local authorities. The technology is protected through existing and future patents as described in deliverable D5.3. The process patents are owned by partner Prevent. The know-how generated within the consortium in DeepU and the know-how to be acquired in further research to reach technology readiness levels of 8 – 9 can be sold under licenses. The sale/leasing of the proprietary drill strings and drill processing heads could be part of this license agreement with the respective stakeholders mentioned above and generate income next to the sale of the know-how to use the technology. The proprietary drill string, developed by partner WUST, will be the subject of two patent requests and provide protection as described in deliverable D5.3. Conditions for use have still to be discussed amongst the consortium partners interested in exploiting this development. The drilling process head, developed by Fraunhofer IAPT, is planned to remain proprietary knowledge and be supplied by the owner/partner as a service to the company exploiting the laser drilling technology.

Another possible path to exploitation is to associate with a drilling machine manufacturer and/or drilling operator in a joint venture approach with partners bringing in, respectively, know-how and capital. Exploratory contacts have been made with, respectively, Herrenknecht Vertical, a German drill rig manufacturer, and Bonasissa Drilling Company, an Italian drilling operator from the oil and gas industry interested in diversifying into geothermal drilling.

Ultimately, a more remote pathway could be to partner with stakeholders such as multi-utilities and investors, realizing and exploiting geothermal energy projects.

[10] A good review is *Exploring the potential of laser technology in oil well drilling: An overview*, by Ahmed Gowida, Hany Gamal, Salaheldin Elkatatny, https://doi.org/10.1016/j.geoen.2023.212278

But before one of these pathways can be followed, further research and funding will be needed, as explained in paragraph 3.4.3.

Meanwhile, another possibility could be to deploy the laser drilling technology in surface mining applications. Given the shallow depths and known formations to be drilled in this application, limited investments in drill strings and drilling machines would be needed. Given the advantages of this technology in this application over the state-of-the-art, as explained above, mining companies may be interested in investing. Some mining companies have already shown interest. This route has two main advantages: (1) a fast pathway to move from lab into the field, increasing the credibility and the confidence in the technology; (2) it provides a revenue stream to further develop the geothermal laser drilling technology to readiness levels 5-6 and ultimately to levels 8-9.

3.4.3 Next steps in the technology development and its funding

The technology readiness level of the DeepU laser drilling technology is estimated at level 4, since feasibility has been demonstrated in the laboratory. The next step is to move into the field and demonstrate the technology in a relevant environment.

An EIC transition project is being considered with two possibilities for field demonstrations:

- drilling in a basalt or granite quarry up to 10 – 20 meters in depth
- drilling in the region of Abano - Montegrotto Terme in Italy, up to 100 meters, where formation conditions are found equivalent to formations at 1000 meters

The Fraunhofer-IAPT laser of 30 kW could be moved to the quarry, or a more powerful laser could be rented from suppliers like IPG. A small drill rig is already available. Participations of Prevent (process patent holder, main exploitation company, and drill string manufacturer), Fraunhofer-IAPT (laser knowledge, drilling process head developed), WUST (drill string design owner and cryogenic gas expert), UNIPD (geological experts) and Geoserv/RED (drilling expertise, project management experience) are under consideration, either as partner or as service supplier.

Within this project proposal, further research to develop instrumentation recognizing formation types is necessary in order to set operating parameters and control the drilling operations (laser power, drilling speed, nitrogen flow, nitrogen pressure,..). Also, solutions to capture drilling residues and clean the nitrogen gas flow at the surface need to be engineered, as well as nitrogen cost reductions.

The disadvantage of this EIC transition proposal is that funds are limited to 2,5 million €, the success rate is very low, and the time to grant agreement is long. With a project submission date in mid–September 2026, the project could start in May 2027.

Therefore, another Company, Laser drilling technology GmbH, has been set up by the process patent holder with the objective to attract 5 million € from private investors and apply already in March 2026 for an EIC Open accelerator project to raise an additional 5 million €. With these funds, a drilling demonstrator up to a depth of 400 meters will be realized next to the above-mentioned research on instrumentation, controls, and surface equipment.

4. COMMUNICATION STRATEGY

Communication aimed to raise awareness of the DeepU project's general scope, coverage, goals, plans to achieve them, and results. CNR has been the lead partner of these activities and coordinated its actions with the PC and all the DeepU partners.

4.1 COMMUNICATION TOOLS

4.1.1 Brand identity

Branding involves creating a unique name and image using a consistent theme to raise awareness about the project activities. It includes a logo for the project, templates for printable reports (Deliverables), and presentations. CNR created all the branding documents, shared them on the VRE, and included them in the Communication KIT, available for free download from the Project Website.

The DeepU LOGO is

It has been used for any (internal or external) deliverable, report and dissemination tool.

The logo was also available in other formats for use across various media and occasions.

For example, another version of the DeepU LOGO was in two colours

4.1.2 Website

The website serves as a hub for all project-related information. To ensure maximum visibility of the DeepU objectives and results, the website has been registered in the "eu" domain and with an intuitive URL to increase hit rates: https://www.deepu.eu

CNR maintains the website, and its Webmaster has regularly updated it based on input from the DCM and partners. The website includes tools to track users, their geographical locations, most-visited pages, and other parameters. All partners have been asked to link to the DeepU website from their own websites to improve Search Engine Optimization.

The website's structure has been defined according to the needs and focus of the projects. Its language is English, and it contains all the planned sections, including:

- a HOME page, which briefly introduces the DeepU project and provides news and relevant information. It also includes links to the digital version of the project leaflet and brochures;

- an ABOUT THE PROJECT page, with project objectives, a short profile of each of the DeepU Partners, and a link to their websites;
- a CONTACT page, which enables people to quickly get in touch with relevant contact people of the project Consortium and to be inserted in the DeepU list of contacts for further communication via the official email address info@deepu.eu;
- a VRE button for direct access to the VRE (see next section for details).
- a PROJECT OUTPUTS page containing public deliverables, open access scientific papers, presentations and posters, eNewsletter and videos, and press releases;
- an EVENTS page with information (calendar) on events organised within DeepU;
- Social Networks buttons for direct access to active social media (LinkedIn, YouTube – see section 4.1.5 for details).

The DeepU website also allowed subscribing to the Newsletter via the subscription form on the home page. Information about the Newsletters' content and structure can be found in paragraph 4.1.6.

The DeepU website also includes a Privacy Policy on cookies, protecting online privacy and enhancing the browsing experience.

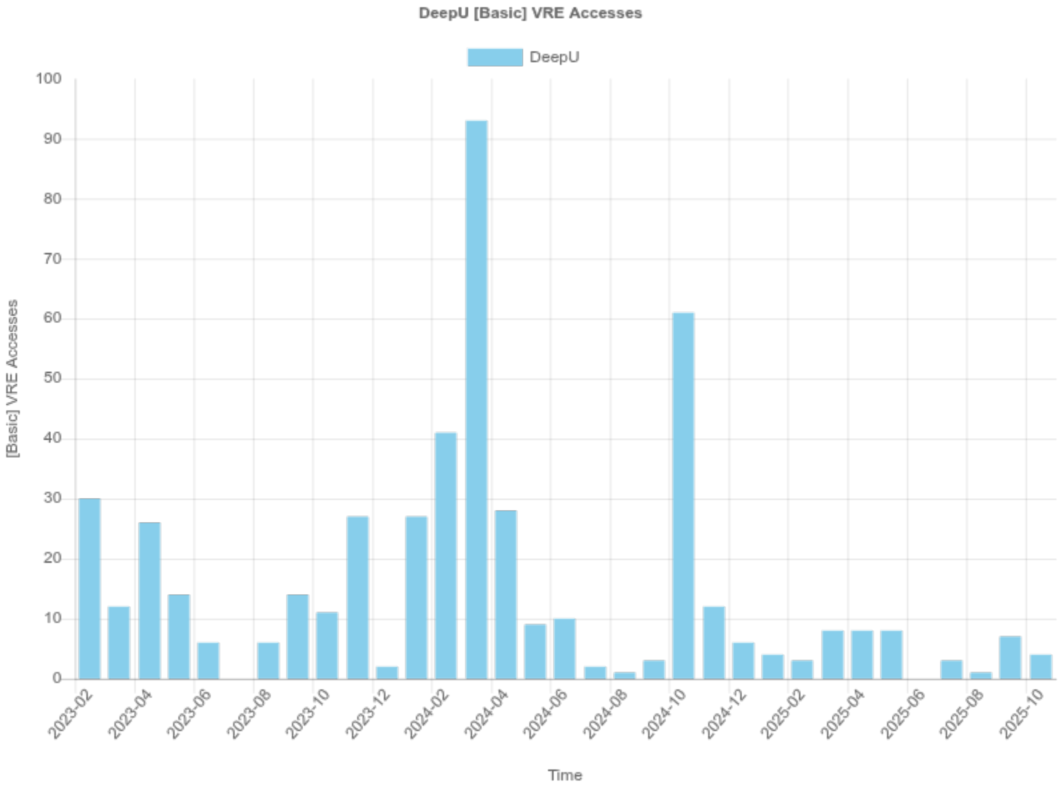
The EU co-funding is duly acknowledged on all website pages.

The website will remain available for at least 2 years after the project's termination, although the content will not be updated. However, all published deliverables, papers, leaflet, and brochures have been uploaded to Zenodo, the public repository chosen for storing the project data.

4.1.3 Private Collaborative Platform, the VRE

The Virtual Research Environment (VRE) technologies, set up early in the project, have guaranteed internal communication among DeepU partners. The VRE is accessible to the registered partners from the project website. Through VRE, DeepU members have leveraged modern collaboration tools, including social networking and a shared workspace. The Shared Workspace acts as a remote, redundant data repository (file system) that stores and organises data in different formats and sizes within a system of folders, shared or not, within the community. The Platform also enables messaging among partners and news (e.g., when a new document is uploaded). VRE has been a tool for both dissemination and communication activities and has served as the basis for data sharing among partners. However, it was not always utilized to its full potential and mainly served as a storage space for documents after meetings. Fig. 1 illustrates the number of accesses and users.

VRE sharing will be stopped upon completion of the project, ensuring that all partners have copies of the documents they want to store.



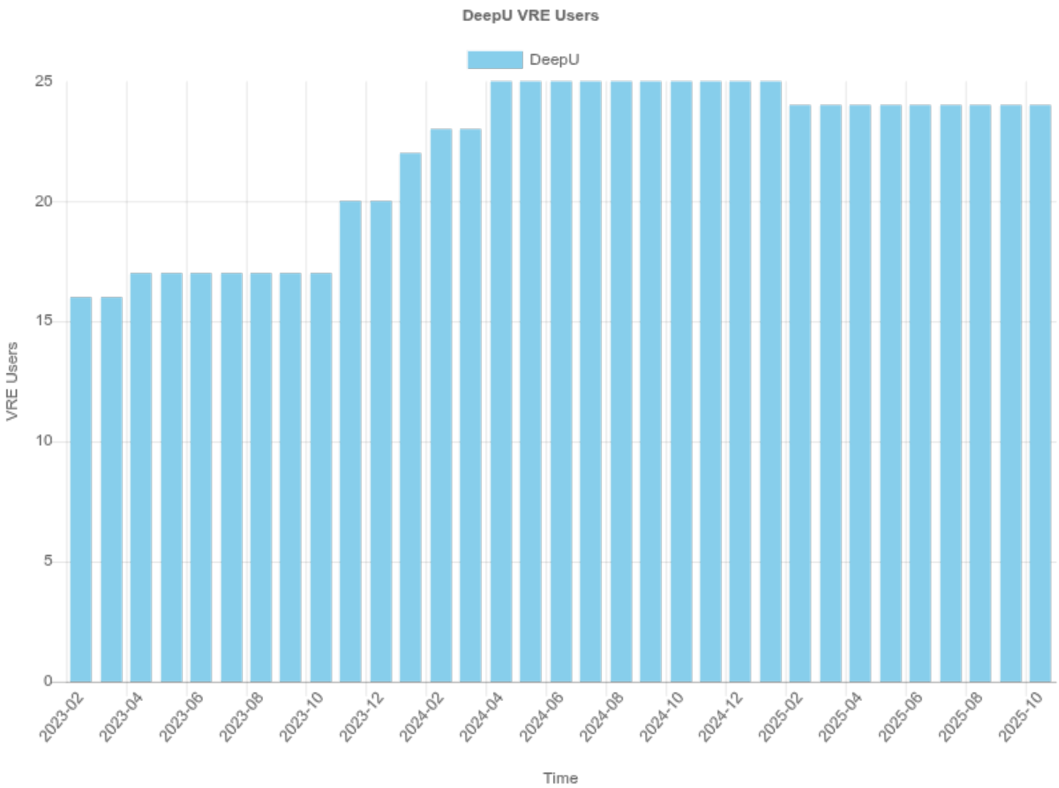


Figure 1 - Number of VRE accesses (top) and users (bottom) throughout the project's duration

4.1.4 Print Media

Several print media are being developed throughout the project.

The main objective of the project leaflet and brochures has been to provide the audience with an attractive, well-written project overview and a summary of the main project objectives and results. The text was designed to inform not only experts but also interested non-specialists. The attractive, professionally prepared documents prepared by CNR are published on the project website to support dissemination efforts. The leaflet and the first brochure presented the project's goals and objectives and included the website address. The documents were updated when a new partner from Poland joined the Consortium. The first brochure broadened the perspective from the leaflet by offering insights into the background context, the innovative concept, and the main expected findings. Furthermore, it provided essential information on the DeepU Consortium. All partners' logos were also displayed. The documents have been translated into Italian, German, and Polish, and edited for national-level communication (e.g., in German for the Offenburg fair), using the master template created and managed by CNR. The various versions are available on the project website and were occasionally printed.

The final version of the brochure has been implemented in the final stage of the project, in September 2025 (M43). This version, described in detail in the deliverable D6.6, contains an overview of the technical results and a new layout to make it more attractive.

The leaflet and brochure have been circulated in print, e.g., at conferences or other events. Their electronic versions (PDF files) were distributed via email or via media networks and downloaded from the project website.

A poster for fairs and large conference booths has been prepared in the first phase of the project and used to catch the audience's attention in large events. CNR took care of its visual design while ensuring its content was clear and easy to understand for the target end users. Concerning the layout and design, the poster showed the project's logo and the colours to emphasise the link to the project´s graphics. From a content point of view, the poster illustrated the project's objectives and included basic information, as well as the Consortium, including all partners' logos.

A business card was created, its electronic version shared with partners and on the website, and 100 copies were printed and distributed to partners. It included the main project information (Coordination, website, contact email address, LinkedIn page, partners' logos and funding). A QR code linking to the project website was also generated for the event and included in all communication documents produced since then.

All the print documents are included in the Communication KIT (described in §4.1.8) and are accessible for download from the DeepU website. A summary of the documents' main details is provided in Table 4.

Table 4 Print media details

Document	Format	Diffusion	Printed copies	Due date
Leaflet	A4, three-fold	Physical events Face-to-face meetings Website Media channels and networks	300 (M9) + (M24)	M3 in its first version, continuously updated till M24
Preliminary Brochure	A3, two-fold	Physical events Face-to-face meetings Website Media channels and networks	200 (M9) + (M24)	M3 in its first version, continuously updated till M24
Final Brochure	A3, four-fold	Final Conference Face-to-face meetings during the European Geothermal Conference 2025 Website Media channels and networks	100	M43
Poster	A0 or larger	Fairs Congress booths	3 (M6, M12, M16)	M6 in its first version, updated when needed
Business card	85x55 mm	Physical events Face-to-face meetings	100 printed in M24	M24

4.1.5 Social Media

To reach a broad target audience while establishing two-way communication channels, the DeepU project's presence on social media has been a key dissemination action. The channels were used to communicate the project's achievements and to present webinars and videos. DeepU has been registered in two standard platforms:

LinkedIn: A LinkedIn group has been created (https://www.linkedin.com/deepu-eu) as one dissemination instrument for reaching stakeholders and industry professionals.

YouTube: To accompany the website and facilitate the publication of project-produced videos, the CNR team has created a dedicated channel on YouTube. The channel, which contains the four videos embedded into the DeepU project's main website, is publicly available at https://www.youtube.com/channel/UCXGZLd6kkpwRm5Wut7kEPIg.

The website provides direct access to these social networks by clicking the icons on the website footer. This makes it easy for every user to participate when visiting the website.

These social media will continue for at least 2 years after the project's end, although the content will not be updated.

4.1.6 News Media

4.1.6.1Electronic Newsletter

DeepU news has been shared via a Newsletter published whenever there was enough material to warrant it. The Newsletter has played a key role in promoting the DeepU project. It focused less on field experts and more on providing a general overview of the technology and its goals. For in-depth and complex project findings, the Newsletter directed readers to deliverables on the website and other sources. It included updates on the project's progress, important dates, details, and comments about conferences, meetings, events, or publications related to the project. Anyone could subscribe to the Newsletter through the active webpage button. The content was designed to be short, non-technical, engaging, set within a real-world context, colorful, enjoyable to read, and easy to view on-screen. The Newsletters were disseminated via:

- links on social media
- direct emails to the DeepU list of contacts
- passive browsing on the Newsletter page of the DeepU website

The original plan was to issue 5 Newsletters, starting in M14 (April 2023) and then twice per year, i.e. at months M19, M25, M31, and M36) to provide project-related news to the various stakeholder groups. Currently, three issues have been published. A final issue is in preparation, with plans to publish and circulate it in a few days.

Newsletter#1 (https://www.deepu.eu/wp-content/uploads/2023/05/Newsletter_n.1.pdf), released in May 2023 (M15), reported insights into various aspects of DeepU's progress and developments. The highlights included:

- DeepU Storyline
- What's New in DeepU
  - A Novel drilling system
  - Drilling tests: how are they working?
  - A review of the legislative and regulatory framework in Europe for DeepU
  - New partner on board

Newsletter#2 (https://www.deepu.eu/wp-content/uploads/2024/02/Newsletter_n.2.pdf), published in February 2024 (M24), continued to elucidate on DeepU's progress, with updates and developments:

- A new important partner and an updated project structure for DeepU
- DeepU storyline
- DeepU seen from a Legislative and Regulatory perspective
- Event snapshot

Newsletter#3 (https://www.deepu.eu/wp-content/uploads/2025/04/Newsletter_n.3.pdf), published in April 2025 (M38), continued to elaborate on DeepU's progress:

- The technological advances of DeepU
- Exploring supercritical nitrogen as a flushing fluid for deep drilling
- Drilling rocks with laser – DeepU's experience
- Preliminary Risk Analysis of the Laser Drill Cryogenic System
- Regulatory, Environmental, and Commercial Perspectives
- DeepU Storyline: Growing Impact and Expanding Outreach
- Event snapshot

The first three Newsletters are included in Annex 2.

4.1.6.2 Press releases

The press releases were designed to reach a broad, non-expert audience, including citizens, students, and local communities. They aimed to inform about the project's milestones and main results and to generate press coverage of the project's activities. They were written in English and translated when needed. Press releases were intentionally issued following major accomplishments. All press releases were archived on the DeepU project website.

After a preliminary press release at the national (Italian) level, released on M2 and published in a local newspaper, four international press releases were issued and circulated to a mailing list which included international (EGEC, ThinkGeoenergy) as well as national (Greenreport, Italian) important geothermal communication agents:

Press release #1, released in May 2023, https://www.deepu.eu/index.php/optimising-access-to-deep-geothermal-resources-with-new-state-of-the-art-drilling-technologies-to-unleash-clean-abundant-energy-from-the-earth/, is titled *Optimising access to deep geothermal resources with new state-of-the-art drilling technologies to unleash clean, abundant energy from the Earth*

Press release #2, released in September 2024, https://www.deepu.eu/index.php/deepu-pioneering-the-future-of-geothermal-drilling-and-deployment/, is titled *DeepU: Pioneering the Future of Geothermal Drilling and Deployment*

Press release #3, released in April 2025, https://www.deepu.eu/index.php/does-deep-geothermal-drilling-need-a-revolution/, is titled *Does Deep Geothermal Drilling need a Revolution?*

Press release #4, released in October 2025, https://www.deepu.eu/wp-content/uploads/2025/10/press-release-DeepU-29.10.2025.pdf, is titled *DeepU Laser Drilling Technology is ready to Enter Field Testing Phase*

The international press releases are included in Annex 2 of this report.

4.1.7 Other Media

4.1.7.1 Video

Four videos have been prepared, promoting the DeepU project goals and developed geothermal technologies. They are available on the project website and on the YouTube project channel (https://www.youtube.com/@DeepU-geothermalenergy). The first video introduced the main concept of the project and focused on the activity conducted by the University of Padua. A second video was created by recording the project webinar titled "Does deep drilling need a revolution?". Additionally, a high-quality movie showcasing the main project results was shot at the end of the project. It was delivered in two versions: a brief one, lasting 3 minutes, showing only the main results, and a longer version of 5,5 minutes that dives into more detail. The longer version of the final video was shown during the DeepU final conference.

4.1.7.2 Outreach

Participation in outreach activities such as the European Night of Researchers was meant to target a broad non-expert audience, such as citizens, students, and local communities, and to inform about the project milestones and main results. All partners were invited to promote and participate in such events in their countries, but only the University of Padua and CNR were active in this regard.

DeepU has been presented on three outreach occasions:

- Poster illustration at Bo Live Event, Padua (M6);
- Poster illustration at an event organised by the Italian geothermal association (UGI) in Pisa (M12)
- Poster illustration at the Centenary of the CNR, Viale dell'Energia Sostenibile, Padua (M16).

4.1.8 Communication KIT

It is available on the DeepU website and has been updated when new documents (brochures, posters) were produced. It contains all branding documents (logo, deliverable template, presentation template), the leaflet, the two brochures, the poster and the business card.

4.2 EVALUATION OF COMMUNICATION IMPACT

Table 5 lists the indicators used for monitoring and evaluation purposes. It contains the monitoring results achieved up to M44.

Table 5 Communication activities monitoring tools

Dissemination tools	Monitoring tools	Achieved Results
Website	Number of visits Most viewed website pages Search terms and search engines leading to the website could also be checked and analysed	2600 users 4278 number of pageviews, 42% homepage (Most viewed pages)
VRE	Individual participant activity monitoring (access, social interaction, posts and replies)	20 partners were active on VRE (uploading and downloading files)
Leaflet and brochures	Number of reprints Downloads from the website	300 brochure and 200 leaflet distributed at events and meetings

		51 leaflet and 50 brochure downloads from deepu.eu
Social media	Media coverage Clicks, likes, new followers	LinkedIn: 1415 impressions; 150 followers; 272 visitors; 39 likes.
Newsletter	Subscription rate Readership rate Download from the website	Subscription: 20 Download newsletter#1: 47 Download newsletter#2: 16 Download newsletter#3: 10
Press releases	Number of articles Download from the website	4 press releases Download press release#1: 3 Download press release#2: 8 Download press release#3: 7 Download press release#4: none at the moment
Videos	Visualisations	4 videos more than 350 views
Outreach	Number of attended outreach occasions at national and international levels	3 events (Bo Live Event in Padua, Event UGI in Pisa, Centenary of CNR in Padua)
Communication KIT	Downloads from the website	10

4.3 COMMUNICATION MANAGEMENT

4.3.1 Responsibilities

CNR has been responsible for managing the website, VRE, social media, and eNewsletters and preparing branding and print materials, press releases, and videos. CNR coordinated with the PC to plan and monitor communication activities.

WP leaders have been responsible for organising articles for the eNewsletters and press releases.

The primary contact for Communication scopes was the DCM Adele Manzella adele.manzella@igg.cnr.it.

5. OVERVIEW OF DISSEMINATION AND COMMUNICATION TOOLS AND TARGET AUDIENCE

Table 6 summarises how the different tools are distributed on the mentioned channels and the main stakeholder groups targeted by the D&C activities, as established in the original PDEC (D6.3).

Table 6 DeepU dissemination tools, channels and target audience

Tools	Online/Digital	Media	Network	External Events	Target audience
Brand identity	x	x	x	x	Scientific community Industry&SME Public at large
Website	x	x	x		Scientific community Industry&SME Public at large
Print media (brochure, leaflet, poster)	x	x	x	x	Scientific community Industry&SME Public at large
eNews	x	x	x		Scientific community Industry&SME Public at large
Press releases	x	x			Industry&SME Public at large
Videos	x	x	x		Scientific community Industry&SME Public at large
Outreach				x	Public at large
DeepU Webinar, conferences	x		x		Scientific community Industry&SME
Scientific publications	x		x	x	Scientific community Industry&SME
General audience articles	x	x	x		Industry&SME Public at large
Participation in fairs, technical exhibitions				x	Industry&SME

6. ANALYSIS OF DISSEMINATION AND COMMUNICATION RESULTS

Communication products were mainly aligned with the original plan, except for the number and type of organized events and the newsletter's frequency. The WP6 leader found it difficult to draw partners' attention to this activity, as they were more focused on continuing research and innovation and did not see the benefit of organizing such documents and events. The webinars were reduced in number, but still covered all project aspects. Given the small audience for the non-contact drilling topic, the two webinars and the final conference were well attended, attracting about 20 people outside the project consortium.

Most likely, many face-to-face meetings took place during the project, but partners did not record or report them. There are few scientific papers because most products are sensitive. However, all presentations at scientific events attracted audiences and facilitated in-depth discussions. Most major international sector events in Europe and abroad have been utilized to communicate the project's aims and outcomes.

Overall, dissemination and communication efforts can be considered successful, given the niche nature of the topic and the difficulty of communicating about products that are still in development and sensitive. However, the topic is becoming increasingly interesting, as shown by the growing number of references to deep drilling and the project. For example, a recent article has showcased the importance of deep drilling in UK and mentioned DeepU results (https://www.ingenia.org.uk/articles/deep-geothermal-energy-a-renewable-option-for-the-uk/). A thorough demonstration in the field will probably be more effective in capturing the interest of decision makers and the general public.

ANNEX 1

LIST OF EVENTS

List of events organised by DeepU

Event	Location & Date	Type of event	Activities
Energy performance of deep heat exchangers (DHE) by numerical simulation	online, October 2024	International webinar	Presentation of DeepU concept and results, consultation with target groups. Included presentations from other EU projects and research teams
Does deep drilling need a revolution?	online, April 2025	International webinar	Presentation of DeepU concept and results, consultation with target groups
DeepU Final Conference	Zurich, 6 October 2025	Conference	Presentation of all project results to stakeholders

List of external events with DeepU participation

Event	Location & Date	Type of event	DeepU contribution
National event organised but the Italian Geothermal Association (UGI)	Pisa, Italy, March 2023	Workshop	Abstract and Poster
ETIP Geothermal Webinar on drilling technologies	Online, April 2023	Webinar	Presentation of project concept and results
World Geothermal Congress 2023	Beijing, China, September 2023	Conference	Abstract, Proceeding, presentation

The Geoscience paradigm: resources, risk and future perspectives	Potenza, Italy, September 2023	Conference	Presentation of project concept and results
Geofluid	Piacenza, Italy, September 2023	Conference	Presentation of project concept and results
Energy trends 2023	Roma, Italy, November 2023	Conference	Abstract and presentation
GeoTHERM - expo & congress in Offenburg	Offenburg, Germany, February 2024	Trade fair	One-to-one meetings and distribution of print documents (brochure and leaflet)
ETIP Geothermal annual conference	Pisa, Italy, November 2023	Conference	Presentation
Fiera Klimahouse 2024	Bolzano, Italy, February 2024	Trade fair	Distribution of print documents (brochure and leaflet)
EGU General Assembly 2024	Vienna, Austria, April 2024	Conference	Abstract, Proceeding, presentation
ETIP: Updates on drilling for geothermal	Online, April 2024	Webinar	Presentation of project concept and results
UK Geothermal Symposium	London, UK, November 2024	Conference	Abstract and Poster
ETIP Geothermmal Innovation Days 2024	Munich Germany, November 2024	Stakeholder networking meeting	Presentation of project concept and results
Stanford Geothermal workshop 2025	Stanford, US, February 2025	Workshop	Abstract, Proceeding, presentation
GeoTHERM - expo & congress in Offenburg	Offenburg, Germany, February 2025	Trade fair	Distribution of print documents (brochure and leaflet)
EGU General Assembly 2025	Vienna, Austria, April 2025	Conference	Abstract, Proceeding, Poster
International Drilling Congress and Exhibition of Türkiye 2025	Ankara, Türkiye, May 2025	Conference	Abstract, Proceeding, Presentation
Cryogenic Engineering Conference (CEC)	Reno, US, May 2025	Conference	Presentation of project concept and results
Congresso congiunto SIMP-SGI 2025	Padova, Italy, September 2025	Conference	Presentation of project concept and results

Congresso congiunto SIMP-SGI 2025	Padova, Italy, September 2025	Conference	Presentation of project concept and results
National Geothermal Energy Summit Events	Ireland, October 2025	Conference	Project dissemination and networking
European Geothermal Congress 2025	Zurich, Switzerland, October 2025	Conference	Abstract, Proceeding, Presentation

ANNEX 2

NEWSLETTERS AND PRESS RELEASES

NEWSLETTER #1

May 2023

Come to hear about DeepU

15-17 September 2023 — **World Geothermal Conference,** Beijing, China

19-21 September 2023 — **The Geoscience paradigma: resources, risk and future perspectives,** Potenza, Italy

Welcome to the first issue of the DeepU Project Newsletter

You will read the central concept behind DeepU and its main objectives and goals here. DeepU is a fantastic opportunity for designing and developing disruptive drilling technology to overcome the main obstacles to producing energy from deep closed-loop heat exchangers.

By developing a fast, effective and efficient drilling technology, DeepU will be a powerful engine for distributed geothermal production and economic growth. The main advantages of geothermal energy are decarbonisation, stable, base-load, but also flexible production, and will be affordable everywhere, advancing in the European Green Deal actions toward energy security and the fight against the climate crisis.

We have completed the first year of activities. The project started in March 2022 by meeting and sharing competencies, detailed planning, and adopting a multidisciplinary approach. This first year has seen different analyses for investigating various materials, ideas, and designs. A preparatory year: the project is approaching its focus now, and we will be ready to inform you of the interim and final results.
From now on, we will publish the Newsletter twice a year, and you will find all published issues on our website.

Stay tuned and happy reading!

Eloisa Di Sipio, University of Padua, Italy
DeepU Project Coordinator

Funded by the European Union
(G.A. 101046937)

DeepU storyline

Once upon a time, the traditional deep geothermal drilling methods strongly constrained the economic viability of deep underground heat exchangers, as 55% of the total project costs were spent on well drilling and completion.

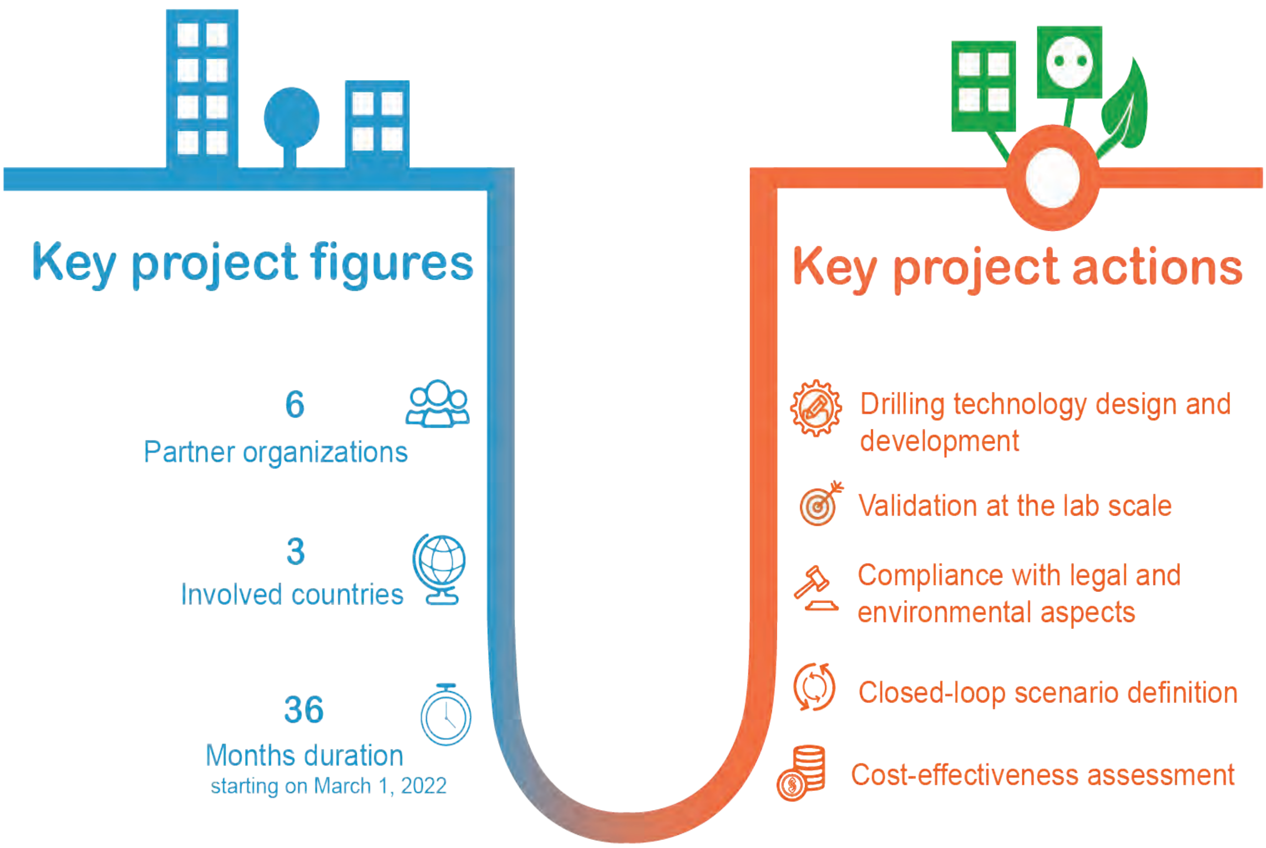
Nowadays, new, ground-breaking technologies are in development to overcome these limitations.

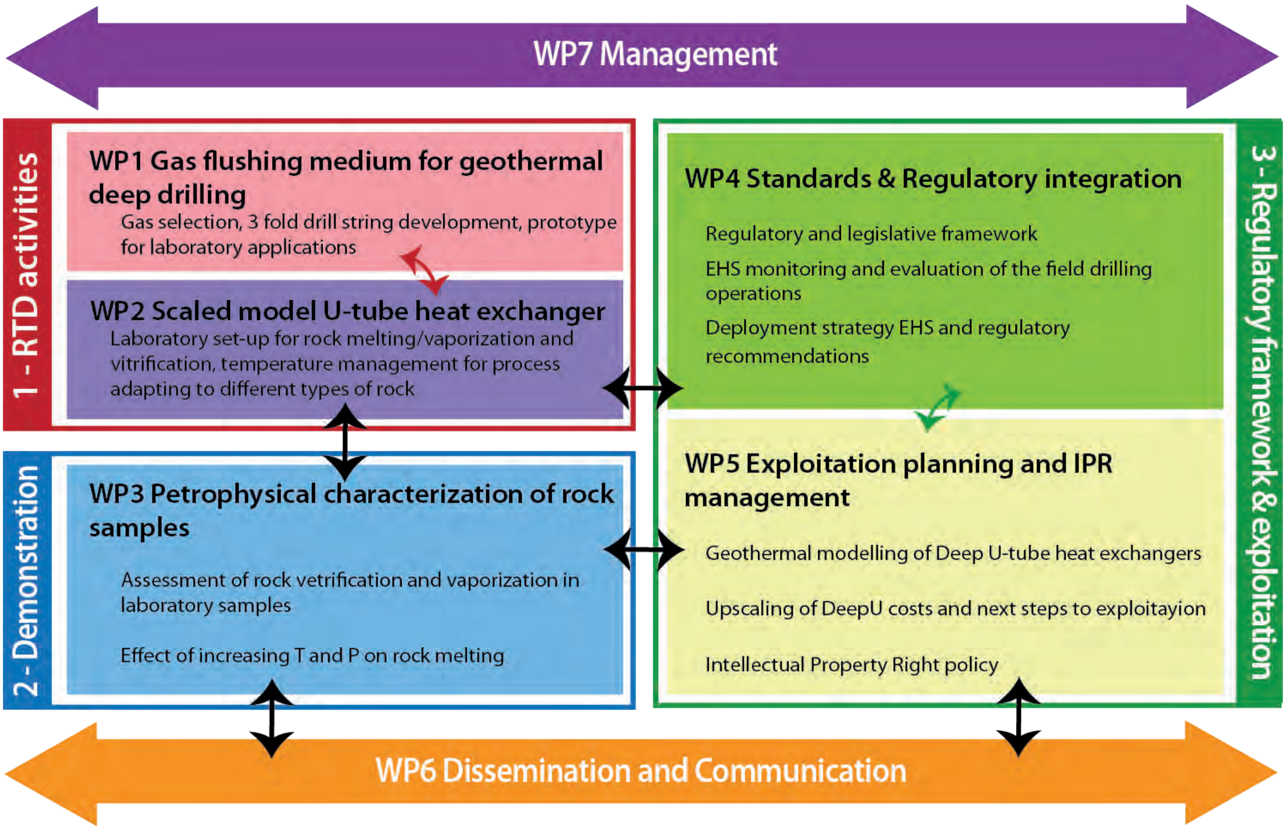
Funded with around 3 million euros by the European Union and European Innovation Council as part of Horizon Europe and launched last year by the University of Padua - in collaboration with Prevent, Fraunhofer IAPT, GeoServ, RED and CNR-IGG - the DeepU project aims to drill efficiently and rapidly, obtaining deep (>4 km) U-shaped geothermal heat exchangers. The project will run until February 2025.

The unique technology developed and tested in a dedicated lab involves a laser propulsion drilling method with cryogenic gaseous flushing for cooling the laser drill head.

As a result, well drilling costs will be reduced due to the higher drilling speed and reduced need for casing since - if vitrification of the borehole walls is achieved - the systems will be physically isolated from the surrounding rocks and ready to be put into production immediately after drilling or with minimal casing activities.

The new technology proposed in DeepU is a game-changer for the geothermal energy sector.





We have divided our work for DeepU into 7 Work Packages (WP), where we explore the road toward the implementation, from the technological development to the demonstration, with a view to the economic and regulatory aspects of the application.

The Research and Technological Development (RTD) activities are for developing the drilling technology prototype (**WP1**) and prepare and carry out laboratory drilling experiments (**WP2**).

To demonstrate the efficacy of the RTD (**WP3**), we will analyse the lithological-thermo-mechanical phenomena affecting different rocks and assess the borehole wall vitrification and integrity.

The laboratory results will be crucial for optimising RTD activities and evaluating the regulatory and exploitation framework.

Intending to achieve regulator acceptance and commercialisation, we are analysing the Health and Safety aspects related to site development, drilling operations and completion, as well as environmental aspects of the DeepU technology uptake (**WP4**).

Using numerical simulations of DeepU systems calibrated by laboratory results, two virtual case studies, in Italy and Ireland, will assist our analysis of the exploitation potential and economics of the developed drilling technology (**WP5**).

Finally, dissemination and Communication (**WP6**) and Management activities (**WP7**) support the entire chain of actions, directing it toward implementation upscaling.

DeepU's First 15 months

In the first year, three consortium meetings have been held to discuss all the details for defining the cryogenic gas selection criteria, implementing the new drilling design and examining the thermal effects of the combined action of laser and cryogenic gas on different types of rocks. They were essential for tuning the various activities and contributed to the delivery of ten reports and a Press Release, available on the Project Output page of the website.

We presented the DeepU concepts on some national or international occasions (e.g. at the "Updates on Drilling for Geothermal" Webinar organised by ETIP Geothermal on 21st April 2023: look at our presentation here).

We also took advantage of some main European events (European Geothermal Congress in Berlin, Germany, on October 2022, and at the GeothermExpo in Offenburg, Germany, on February 2023) to distribute our preliminary leaflets and brochures…

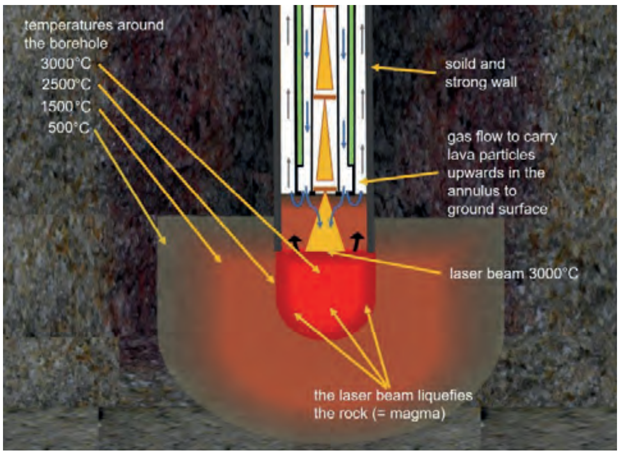
By the way! These leaflets and brochures are available on the project website in three different languages: English, German and Italian: look for them on the project Home Page! We plan to have many more occasions for disseminating the project results in the coming years, and we will provide a list of events on the first page of the Newsletter.

Continue to read: we are so pleased to share the latest developments on DeepU geothermal drilling project.

What is new in DeepU

1. A novel drilling system

The laser drilling process to produce a scaled model of a heat exchanger for deep geothermal energy exploitation involves melting rock with a high-power laser assisted by cryogenic gaseous flushing to cool the laser drill head and carry the melted rock out of the borehole. When the processing head advances through the melted rock, it should create precise and symmetrical holes around the drill string, producing an annular free space through which the melted rock particles can escape and be pushed to the surface with the help of gas.



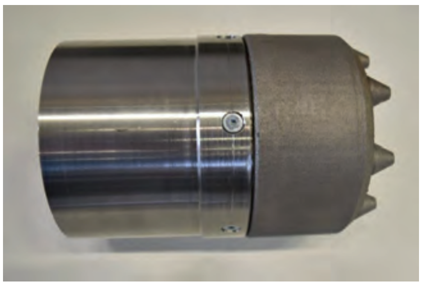
Funded by the European Union (G.A. 101046937)

During our first year of DeepU activities, Prevent and Fraunhofer IAPT designed new concepts for the drill string and drilling platform. The novel drill string guides the laser beam through the inner drill string and also transports the cryogenic gas down to the drill head.
The choice of cryogenic gas has been a crucial activity: we need a gas that remains in a liquid state for a very long distance and in a wide range of temperature and pressure conditions to reach the base of the well during drilling. After a series of analyses and tests, Prevent chose the most suitable cryogenic gas based on the required qualities, i.e., availability, low price, and thermodynamic properties.

In the meantime, Fraunhofer IAPT designed a novel lightweight laser and gas processing drill head. The processing head is the final, bottom part of the drill string. Utilising a small area in the centre of the drill string, this unique processing head enables the high-power laser beam to reach the rock melting point at the end of the borehole and directs the gas stream through nozzles onto the melted rock.

We now have our first, 3D-printed prototype! It is made of titanium alloy, which is suitable in terms of mechanical strength and temperature resistance. Indeed, 3D printing technology offers the advantage of rapid prototyping and the simplicity of printing the gas channels directly into the component.
The processing head can also be equipped with diverging lens to expand the laser beam and enlarge the bore diameter.

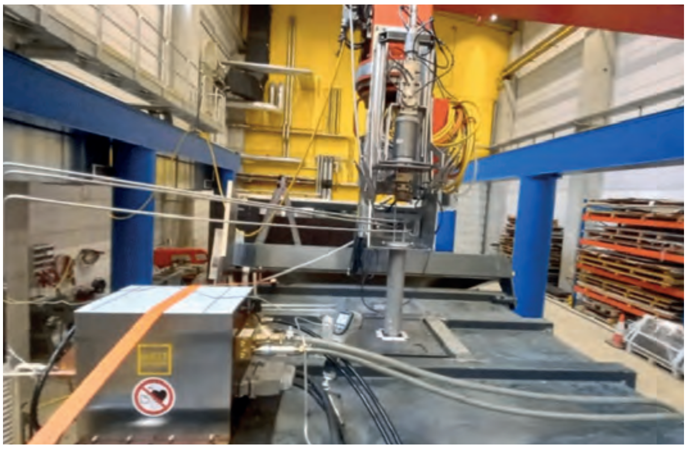
The preliminary drilling results obtained with this innovative drill head have already proved exciting. Read the news in the following article!



2. Drilling tests: how are they working?

First, we set up a laboratory for the experimental development and testing of the new laser drilling method. The facility was designed and provided by Fraunhofer IAPT in Germany. It is equipped with a 30-kW laser system, processing optics specially designed for such a laser, a drill string equipped with our unique 3D printed drill head, and a cryogenic gas feeding system.

Our experiments take place inside a press container acting as a safety enclosure to resist the high pressures and temperature of the experiments. Rock material is piled up inside the press container, which can also be used to compact loose soil formations.



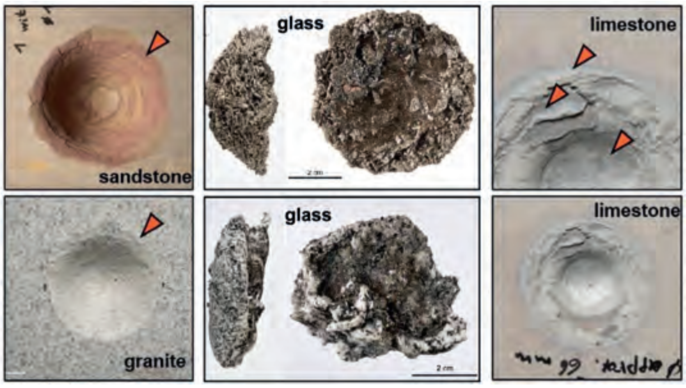
During the drilling process, the drill string is manoeuvred robotically.

Optics, drill string and drill head, mounted one above the other at the robot, are guided through an opening in the cover plate of the press container where the hosted rock material is drilled. The cryogenic gas is supplied from a tank.

In preliminary drilling tests, using our 3D-printed laser processing head but only the laser beam without the cryogenic gas, we achieved constant rates of penetration upwards of 20m/hr, with relatively low energy inputs and no component wear of the kind that would be associated with mechanical engaging drilling methods. We obtained precise and symmetrical holes in samples representing the hardest rocks to drill at depth, i.e., granite, and the most common geothermal reservoir rocks, i.e., sandstone and limestone.

For the moment, we are analysing the post-drilling rock samples to characterise the impact of the laser beam and cryogenic gas and the vitrification, cracking, and bulging effects. For each lithology, we collected three samples with dimensions of 500 x 350 x 150 mm: one from fresh, unaltered rocks from the quarry and two undergoing the DeepU laser drilling process under variable external conditions (e.g. confining pressure).

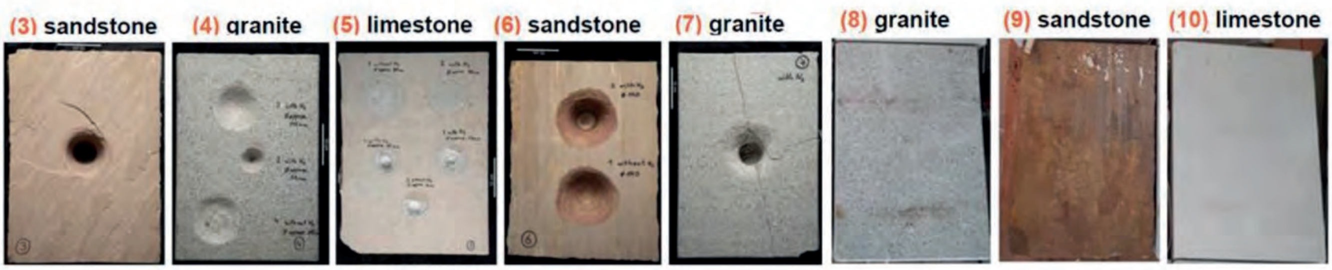
The petrophysical laboratory set up at the University of Padua allows a series of sample analyses by various techniques, including optical microscopy (OM) for petrographic description, Raman spectroscopy for mineral identification, electron microscopy (SEM, EMP) for chemical characterisation, X-ray diffraction (XRD) and X-ray fluorescence (XRF) for mineral phase recognition and chemical analysis of powders, and ultrasound and thermal optical scanner measurements for determining mechanical and thermal parameters of the rocks.



The observations are preliminary but already very intriguing. For example, we observed that an annular thermal alteration is more evident in sandstone and limestone than in granite. Moreover, at the bottom of the boreholes, we found glass entrapping volatiles in granite and spalled flakes in the sandstone, suggesting different melting effects that will be interesting to rule out.

The laboratory experiments will ultimately provide information for optimising the DeepU laser drilling process and for geothermal reservoir characterisation and modelling in virtual case studies in Italy and Ireland. Waiting for the simulation and its findings, the exploitation strategy is already in progress, although qualitative, because the concept behind the drilling process is evident.

However, any technology uptake and commercialisation should achieve regulator acceptance, right? So, let's read how we are already working on this aspect.

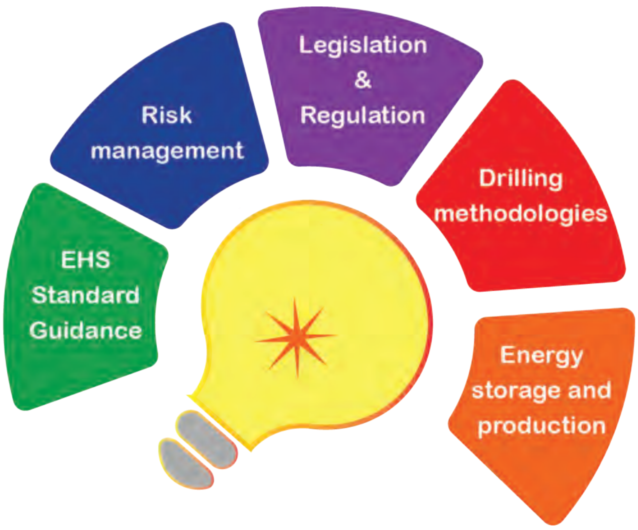


3. A review of the legislative and regulatory framework in Europe for DeepU

What are the current regulatory challenges of DeepU drilling technology, and how to gain compliance with the current deep drilling market? It is a question that we must ask ourselves since the beginning to identify the potential barriers to the development of the DeepU technology, but also the opportunities that such a new drilling method may bring in the context of reduced environmental and health and safety (EHS) conditions associated with the drilling and completion of deep geothermal wells compared to the existing drilling and completion methodologies currently used.

In essence, we want a clear idea of instances where regulatory expectations based on standard processes may require a different approach for DeepU technologies.

With this in mind, we started to review existing legislation and regulations that govern the health and safety of drilling equipment and drill site operations and the utilisation of industrial scale lasers, and the assessment of environmental impact as well as the requirements for mitigation measures applicable in the development of deep drilling projects in Europe.



Admittedly, they differ slightly in terms of national or even regional or municipal implementation. Albeit they are broadly aligned as they derive from common EU Directives.

To integrate the novel technologies into an approved drilling operation, we had to identify the fundamental EHS aspects potentially unique or novel about DeepU from the perspective of a regulator and the requirements and potential consequences of deploying a DeepU system with respect to using existing drilling and completion methodologies. GeoServ, which led this analysis and related review, selected jurisdictions for which identifying the types of governing legislation, nature of the licencing system and application processes for geothermal Projects. Other than Ireland and Italy, our virtual case studies in the DeepU project, France, Germany, and The Netherlands were selected, given the active nature of the geothermal sector in those countries.

A list of recommendations has already been drafted. Some of them are of immediate use for DeepU partners for optimising the technology to mitigate risks through design. Others provide the basis for implementing recommendations to allow the DeepU drilling method to achieve regulator acceptance and commercialisation. Moreover, the review supports undertaking an Environmental Health and Safety risk assessment of the technology with a focus on the virtual case study sites.

The news does not end here: the DeepU team is expanding!

4. New partner on board

Politechnika Wroclawska has recently joined the project and will contribute to assessing the minimal space requirements and technological feasibility of the cryogenic gas supply for the laser drilling system. We look forward to meeting our colleagues and starting the cooperation to speed up the optimisation and set-up of DeepU laser technology.

DeepU is online

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NEWSLETTER #2

February 2024

Come to hear about DeepU

29-1
Feb.-March2024

GeoTHERM Expo 2024
Offenburg, Germany

14-19
April 2024

EGU General Assembly 2024
Vienna, Austria

Welcome to the second issue of the DeepU Project Newsletter!

The last period has seen important changes in the DeepU organisation and structure. First of all, in coordination. Eloisa Di Sipio, who led the Consortium till last summer, enthusiastically follows a new channel of work. We thank her for the wonderful job she did for us, and we wish her all the success she deserves. For this reason, I stepped in, changing my status from partner to Project Coordinator. Moreover, as anticipated in the previous issue, the DeepU Team has enlarged, and a new partner is on board; we are so pleased to announce it officially! This collaboration reshapes and deploys the structure of the DeepU Project, and we can't wait to share the details with you.

Our goal with this Newsletter remains to keep you engaged, informed, and inspired. Whether you are an expert industry professional or a curious enthusiast, there is something for everyone in this edition!

Get ready to read our latest updates, insightful analyses and a sneak peek into the future of DeepU geothermal drilling.

Happy reading!

Luc Pockelé, RED Srl, Padua (Italy)
DeepU Project Coordinator

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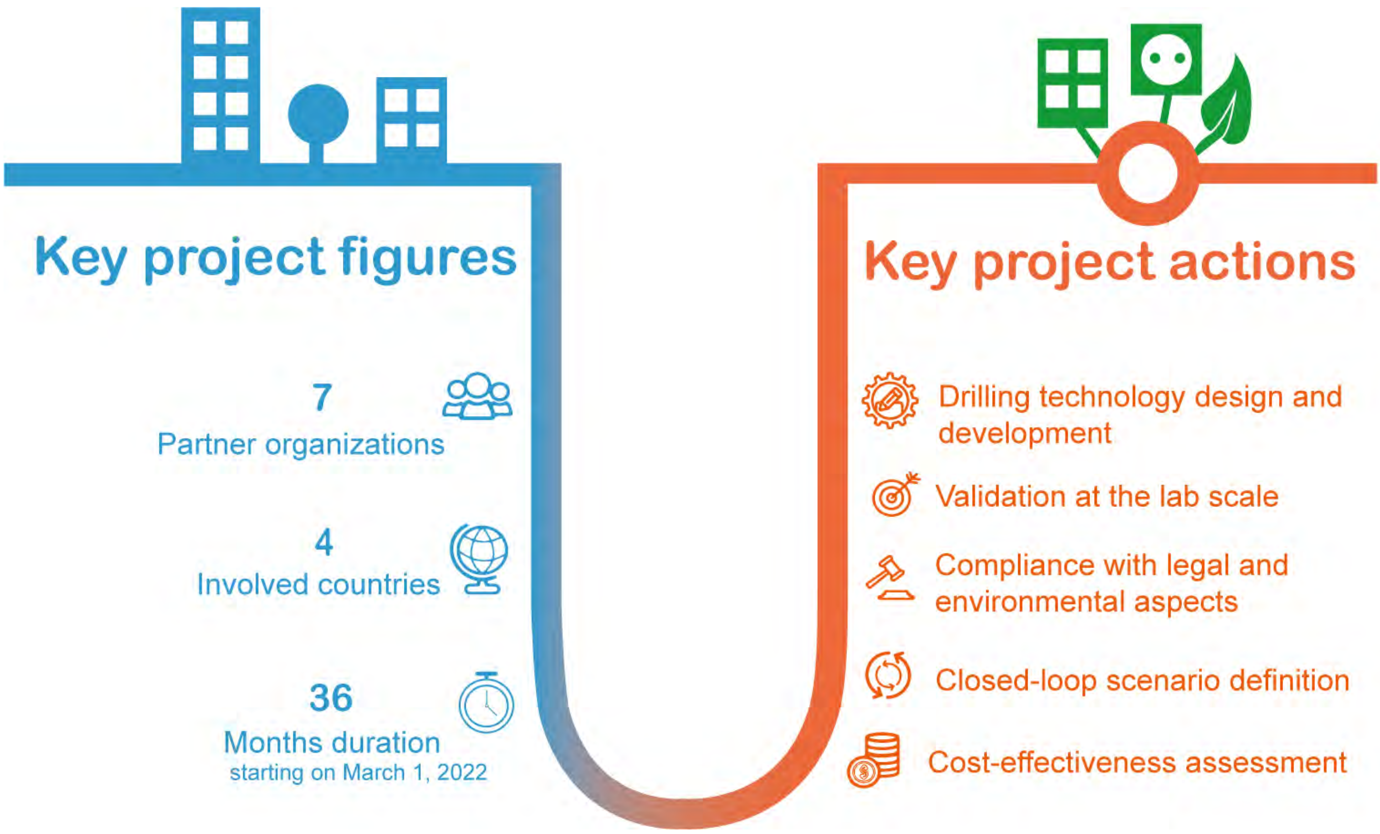


A new important partner and an updated project structure for DeepU

Established in 1945, the Wrocław University of Science and Technology (WUST) has evolved into one of Poland's leading technical universities, boasting a legacy built on resilience and academic excellence. Rooted in the cryogenic traditions of two prominent Polish scientists, Karol Olszewski and Zygmunt Wróblewski, who first managed to liquefy the so-called "permanent gases" in Kraków in 1883, WUST has cultivated unparalleled expertise in cryogenic technology, notably WUST's work has led to Poland being the only country in Europe to liquefy helium.

Their prowess extends to the development, design, production supervision and commissioning of complex cryogenic distribution systems supplying liquid cryogens superconducting accelerators, free electron lasers, thermonuclear reactors and other Big Science machines. Notably, their exemplary cryogenic distribution system (**fig. 1**) currently provides superfluid helium to the European Spallation Source accelerator in Lund, Sweden.

Figure 1. *Cryogenic Distribution System designed by WUST, now under commissioning at ESS, Lund, Sweden.*

In the context of the DeepU project and its visionary breakthrough — merging laser technology and cryogenics for geothermal energy exploitation, WUST's participation is strategic and a major boost to the project.

The DeepU project originally envisaged the use of commercially available cryogenic transfer lines to be integrated into the drill string. However, the informative exchange with potential suppliers in the first half year of the project has shown that the provided technical solutions either offer insufficient thermal insulation or take up too much installation space within the drill string. In addition, the standard cryogenic gas lines are usually made of stainless steel, and their weight would be too high in deep drilling applications. This means that the new laser and gas drilling technology requires a new design of the cryogenic gas supply system. It is here that WUST steps in, to assess the minimal space requirements and technological feasibility of the cryogenic gas supply for the laser drilling system.

WUST has already commenced the analysis of potential novel solutions for gas supply down the bore and removal of the material drilled by the laser beam.

Focusing on this topic, the DeepU work program added a specific work package led by the WUST team and the DeepU Project structure is now in place.

WUST's objectives span a comprehensive list:

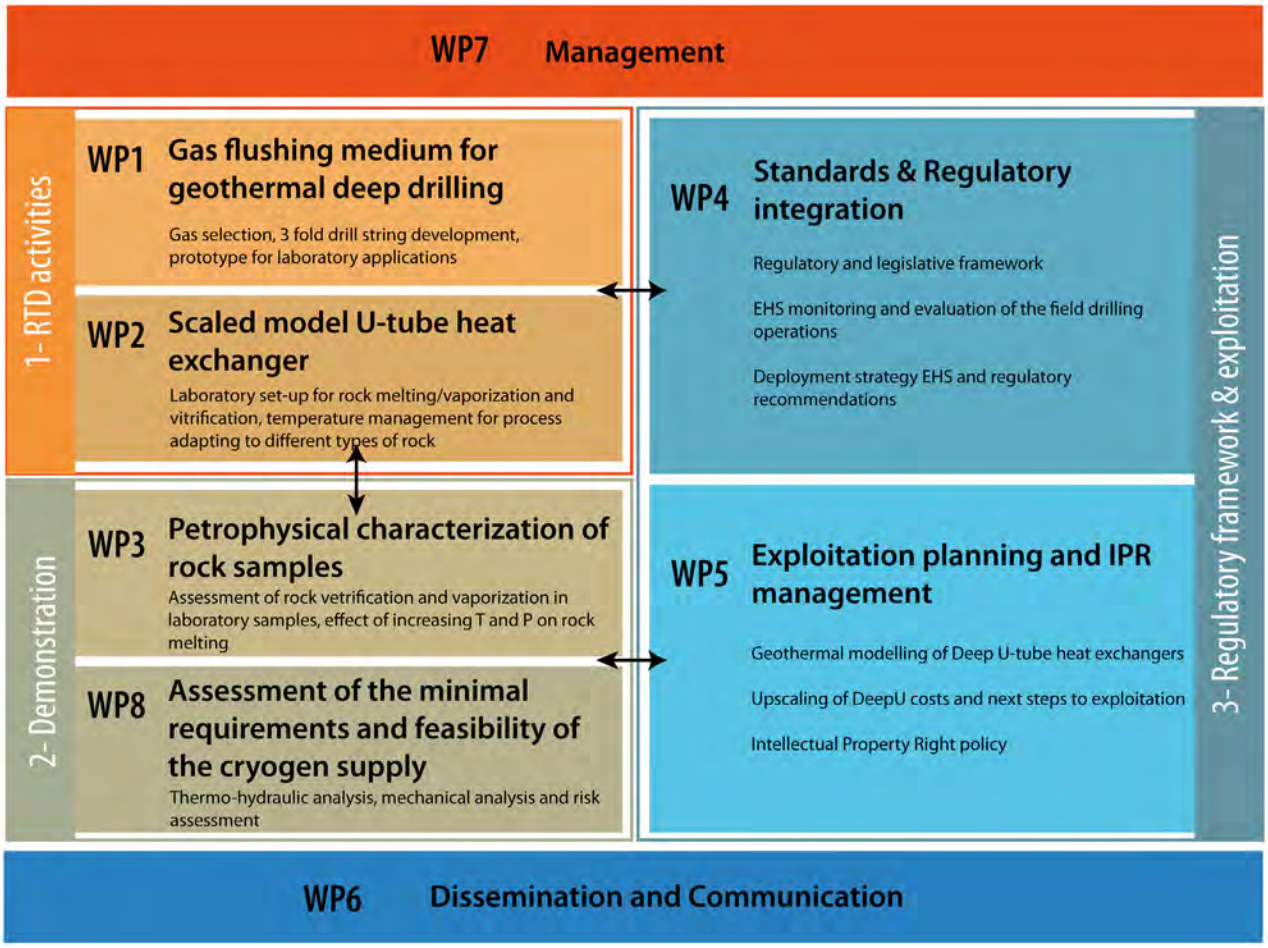
- determining the cryogenic gas flow needed to ensure melted rock adequate cooling and dispersed rock pneumatic transport to the surface;
- identifying the thermodynamic transition along the wellbore and the possible negative flow-related issues;
- investigating the thermal insulation concepts needed to guarantee the desired thermodynamic parameters at the drill outlet;
- assessing the mechanical and thermal requirements of the laser drill system elements, taking into account the thermal expansion compensation requirements of the material;
- assessing the laser drill cryogenic system risk analysis.

Prof. Chorowski, our WUST team leader, highlights that *"The project is a real challenge. To combine cryogenics with drilling is a new concept and requires an innovative approach. The WUST team is young and very motivated. If the task is feasible, we will do it."* This determined perspective underscores the team's motivation and determination to pioneer this innovative concept.

The team's approach, driven by this ambitious goal, is multidisciplinary and forward-thinking. Key members, including DSc Zbigniew Rogala leading the modelling task, Dr Katarzyna Strzelecka, Dr Michał Stanclik heading the design task, alongside Dr Agnieszka Piotrowska, Dr Wojciech Gizicki, Dr Tomasz Banaszkiewicz, and Jakub Kielar, exemplify this diverse expertise.

Fuelled by the passion and enthusiasm of its young team, WUST aims to achieve the fusion of cryogenics and drilling, driving innovation and setting new benchmarks in the field.

The DeepU Project structure modified to embed the new contribution provided by WUST.



The reorganized WPs structure

DeepU storyline

While we take pride in this new collaboration, it is equally essential to highlight the ongoing Research and Technological Development (RTD) activities and our successful communication initiatives.

In these recent months, our DeepU team has been immersed in a flurry of activity, marked by meticulous petrophysical analyses, strategic planning, and the exploration of diverse materials and designs. Our commitment has extended beyond borders, with active participation and impactful communication at both European and global levels. Notably, our presence at the World Geothermal Congress in Beijing allowed us to showcase our advancements and engage with experts on an international stage.

We also presented DeepU at key events in Italy, including Geofluid in Piacenza, Energy Trends 2023 in Rome, The Geoscience Paradigm: resources, risk and future perspectives in Potenza and ETIP Geothermal Annual Conference in Pisa. These experiences facilitate knowledge exchange and strengthen our collaborative networks within the global geothermal community.

The endeavours of the **IAPT** and **Prevent** partners align with our implementation objectives and also serve as the bedrock for the next phases of the project. Currently, our laboratory demonstration partners, **University of Padua**, **CNR-IGG** and **WUST**, and regulatory and framework exploitation collaborators, **Geoserv** and **RED**, are now transitioning into a crucial concentration phase, symbolising a pivotal point in our project.

Let us recap what we are doing, with a novel graphic summarising the concept.

The core concept of DeepU (Deep U-tube heat exchanger) is the novel drilling technology, which is poised to revolutionise the boundaries of geothermal development and use.

We are working to create a deep (>4 km) closed-loop connection in the shape of a U-tube exchanger by developing a fast and effective laser drilling technology and increasing the accessibility of deep geothermal resources for low-carbon heating and possible power generation.

The drill-head prototype has been realised, combining the laser system with a novel drill strings design that can sustain the coupled action of laser and cryogenic gas (**fig. 2**). This image encapsulates a glimpse into the future of geothermal drilling: the laser, with the power to cut through the toughest materials, is enhanced by the cryogenic gas, strategically optimising the drilling process.

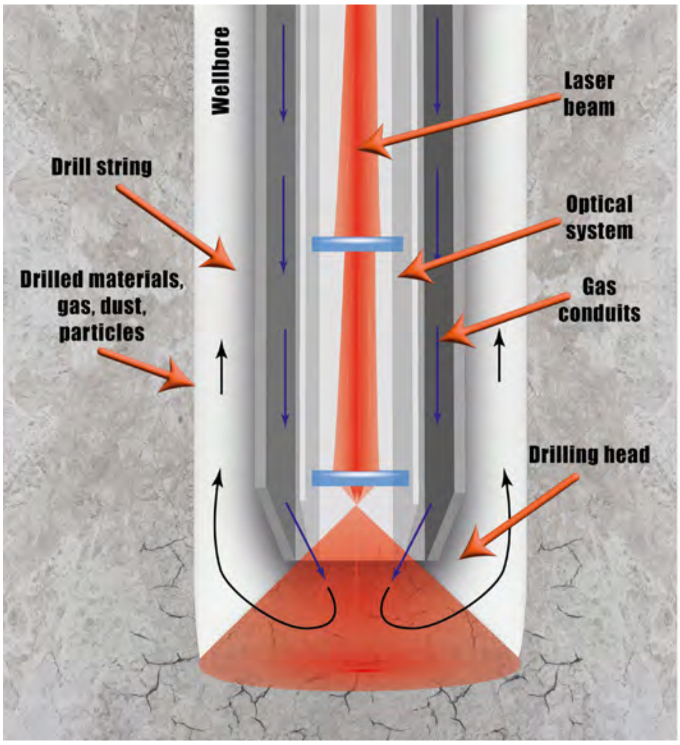


***Figure 2.** Drill head designed by the DeepU project*

The research team in Hamburg at Fraunhofer IAPT during experimental activities

Unravelling the secrets of DeepU

How does laser-cryogenic gas drilling take place?

At the heart of the drilling emerges a powerful laser beam, which heats up the surface of the drilling target. The fine particles of the rock begin to yield to the overwhelming heat, initiating the spallation journey supplemented by melting and evaporation. The rock undergoes extreme temperatures that generate stress forces affecting the rock. As the laser's influence persists, layer by layer, portions of the rock are broken out in a violent process of spallation. The strain energy accumulated on the surface is released, and the surface portion of the rock is removed. That allows to progressively heat subsequent portions of rock and sustain the drilling process. With a current laser setup, spallation is the most efficient process for rock penetration, while melting and evaporation are the secondary processes. The spallation is supported by the flow of N2 that efficiently removes spalled particles. The fine particles of drilled rocks are ejected to the surface in the gas stream via the borehole annulus.

The laser's influence has penetrated the rock and left its indelible mark.

Our expert team monitors the process with unwavering attention using an optical camera and a thermo-camera, investigating the borehole to unravel the secrets of the drilling process as it progresses.

The meticulous optimisation of laser parameters and experimental setups, coupled with microscopic examinations of drilled rocks, has revealed macro- and micro-scale phenomena that contribute to the successful development of this innovative drilling method. DeepU study not only delves into the geothermal potential of rocks but also paves the way for the sustainable exploitation of geothermal energy from depths below 4 km.

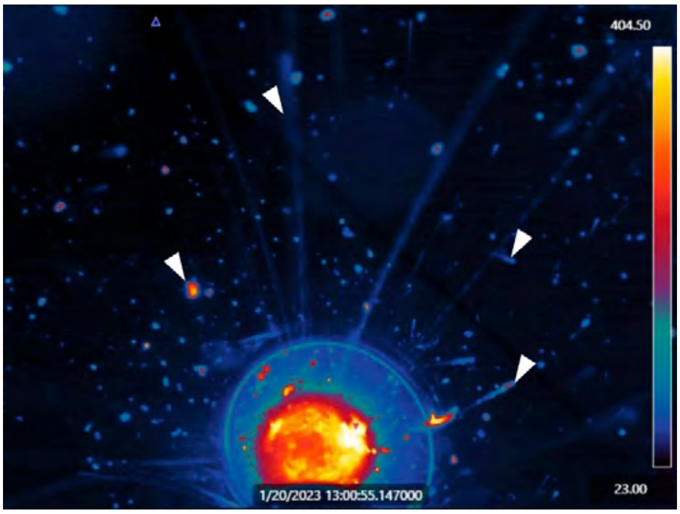


Figure 3. *Thermal image of laser-drilled wet sandstone. High temperature region represents laser beam spot size (5cmØ) i.e., borehole. White arrows show spalled particles. Temperature scale is expressed in °C.*

DeepU seen from a Legislative and Regulatory perspective

Let's delve into the intricate landscape of legislative and regulatory frameworks in Europe as they pertain to DeepU drilling technology.

As we navigate the new state-of-the-art drilling technologies of DeepU, understanding and aligning with regulatory expectations becomes paramount.

Our ongoing commitment to environmental, health, and safety (EHS) standards remains a keystone in paving the way for the successful integration and commercialisation of DeepU technology. GeoServ, at the forefront of this regulatory exploration, has meticulously examined the legislative landscape and licensing systems for geothermal projects.

Based on this, Geoserv has looked at how the laser and cryogenic gas will operate in a real drilling operation, which includes surface equipment and

DeepU
Funded by the European Union (G.A. 101046937)

the downhole environment. There are many novel aspects to consider to guarantee that the system will succeed commercially and meet all health, safety and environmental requirements. Using conventional oil and gas and deep geothermal technologies as a benchmark, a report was compiled on the risks that may arise with the laser/cryogenic gas technology and its corresponding mitigation strategy. Not least, the concerns around the high temperatures generated downhole and how lithologies encountered will behave. The work undertaken by UniPD and Fraunhofer is essential in gaining a better understanding of these particular aspects.

Complementing this, a Failure Mode and Effects Analysis (FMEA) was carried out, whereby each process was analysed as to how and when it may fail, and the effect such failures would have on the overall drilling/operational process. The FMEA also ranks the risks and combines a step-by-step understanding of how risks can be detected, minimised and accounted for. This is a powerful tool in any process-driven operation.

Looking ahead, future work includes the development of a technology roadmap and a fully integrated Environment, Health and Safety (EHS) plan. This plan is designed not only to meet but exceed current legislation and protocols, ensuring that DeepU remains at the forefront of technological innovation while upholding the highest standards of EHS.

Event Snapshots

World Geothermal Congress 2023, Beijing (China)

Energy trends 2023, Rome (Italy)

ETIP Geothermal Annual Conference, 2023, Pisa (Italy)

Let's come to hear about DeepU in these upcoming events:

1. **GeoTHERM Expo & Congress 2024** - Offenburg, Germany
   - **Date**: February 29 - March 1, 2024
2. **EGU General Assembly 2024** - Vienna, Austria
   - **Date**: April 14-19, 2024

We look forward to meeting you there!

DeepU is online

Follow us and stay up to date!

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RED Renewable Energy Development
Institute of Geosciences and Earth Resources – Consiglio Nazionale delle Ricerche – igg
Prevent CO_2
Fraunhofer IAPT
Wrocław University of Science and Technology
Geoserv

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NEWSLETTER #3

April 2025

Come to hear about DeepU

30 April 2025 — **EGU General Assembly 2025,** Vienna, Austria

8-9 May 2025 — **Drilling Türkiye 2025 –** Ankara, Türkiye

21 May 2025 — **Cryogenic Engineering Conference 2025,** Reno, Nevada (USA)

Welcome to the third issue of the DeepU Project Newsletter!

Since our last update in February 2024, the DeepU Project has continued to push the boundaries of innovation in geothermal drilling. A key milestone during this period is the extension of the project until October 2025, which allows us to further refine our technology, conduct additional testing, and enhance our impact in the field of sustainable energy.

The DeepU project represents a groundbreaking advancement in geothermal energy, providing an opportunity to overcome technical and economic challenges of current drilling technologies. DeepU introduces an innovative approach that combines high-power laser technology with cryogenic gas injection. This revolutionary technique enables the creation of deep (>4 km) geothermal systems, offering a more efficient, cost-effective, and sustainable method of harnessing geothermal energy.

In this issue, we bring you the latest updates from the DeepU project, including key insights from risk analysis and environmental assessments, recent advancements in drill string technology, and results from laser drilling experiments. We also highlight DeepU's presence at major international conferences and examine the scalability and economic potential of our innovative laser-based drilling system.

As always, our goal with this newsletter is to keep you engaged, informed, and inspired. Whether you are an industry expert, a researcher, or simply curious about the future of geothermal energy, there is something for everyone in this edition.

Get ready to discover our latest findings and the path forward for DeepU.

Happy reading!

Luc Pockelé, RED Srl, Padua (Italy)
DeepU Project Coordinator

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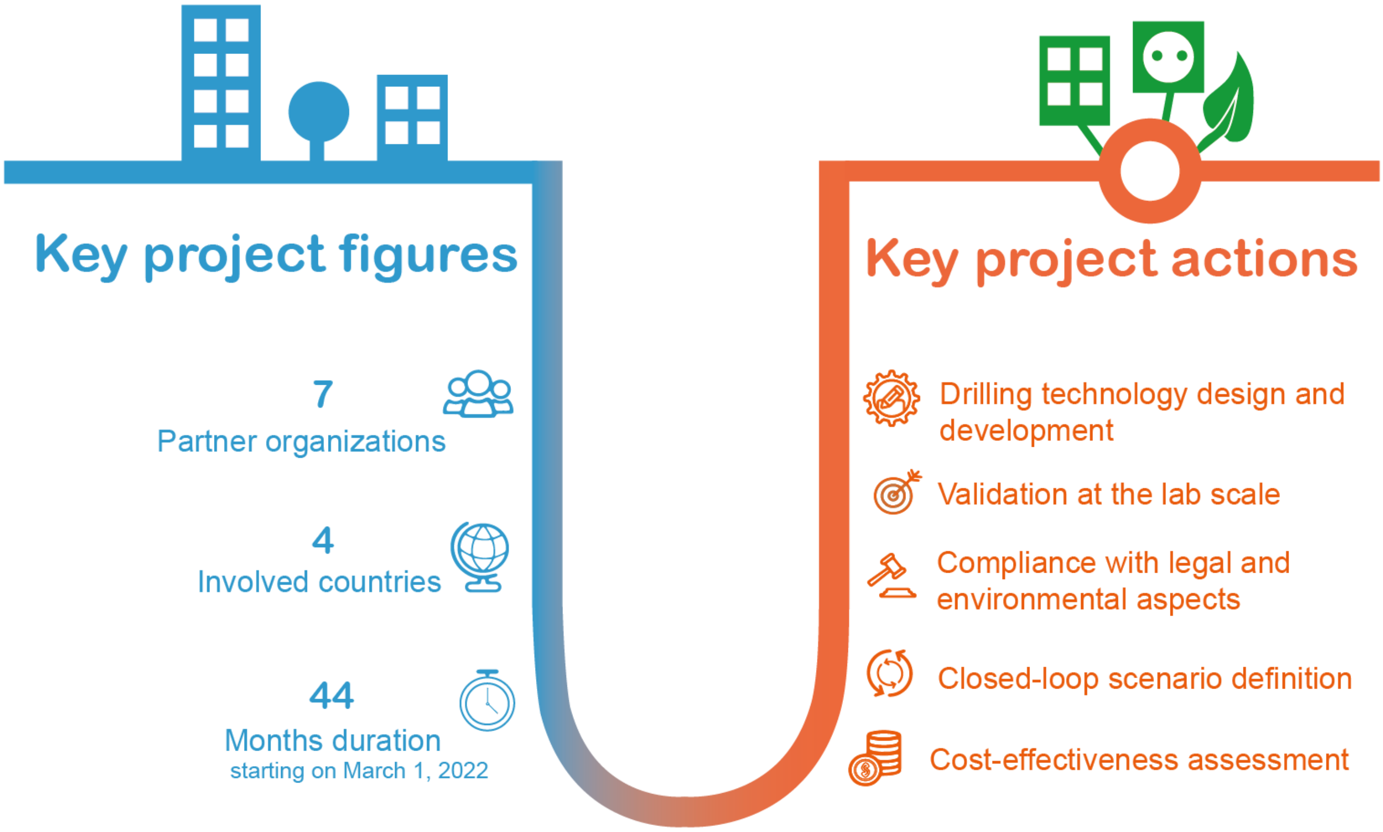

The technological advances of DeepU

Over the past year, the DeepU project has made remarkable progress, especially in advancing the drill string technology. A primary focus has been on developing a lightweight drill string, an essential component created by **Prevent** (WP1) and **Wroclaw University of Science and Technology** (WP8) to effectively transport cryogenic gas while maintaining the integrity of the laser beam used for drilling.

Our engineering team has taken the lead in designing an innovative drill string system that advances the efficiency and sustainability of deep drilling applications by utilising a laser beam as an energy source. They have integrated cutting-edge materials and novel design concepts to enable the safe and stable transport of cryogenic fluids while ensuring precise laser beam guidance – two critical challenges in this non-contact drilling approach.

Through multiple design iterations, the DeepU project tackled key engineering challenges, including thermal expansion, material compatibility, and the operational constraints of connecting individual drill string segments. The final design showcases a robust three-pipe system that offers optimal thermal insulation, mechanical stability, and high-pressure resistance, ensuring performance under extreme subsurface conditions. Laboratory tests and simulations have confirmed its feasibility and reliability, marking a significant step toward the next phases of technology development.

Furthermore, innovative alternatives to traditional materials were examined, concentrating on lightweight yet highly durable solutions like carbon fiber composites. These materials provide significant benefits, including reduced weight, enhanced corrosion resistance, and increased operational flexibility – paving the way for additional advancements in sustainable geothermal drilling.

Exploring supercritical nitrogen as a flushing fluid for deep drilling

While designing the drill string marked a significant leap forward, the DeepU team continued their efforts. Simultaneously, they have explored ways to enhance the overall efficiency of the system by testing an unexpected ally in deep drilling: supercritical nitrogen.

The pursuit of enhanced efficiency led the team to investigate supercritical nitrogen, motivated by its favorable thermodynamic properties and proven effectiveness in removing drilling debris (cuttings). A numerical model was developed to determine the required pressure and flow rates for various borehole depths and was validated through tests on a dedicated rig. The proposed system includes storing liquid nitrogen, compressing it up to 350 bar, and transporting it down the borehole through a specially designed vacuum-insulated channel.

The Wroclaw University of Science and Technology team is encountering significant technical challenges, such as material selection for cryogenic temperatures, thermal load management, and mechanical stability. To support this effort, a prototype coupling system is being developed to test the mechanical and cryogenic aspects of the design, ensuring its feasibility and reliability under extreme operating conditions.

These advances establish the foundation for integrating supercritical nitrogen into DeepU's laser-based drilling system, representing another progress in developing safe, efficient, and sustainable geothermal drilling technology (abstract CEC/ICMC 2025).

Drilling rocks with laser – DeepU's experience

After developing the innovative system that delivers laser and cryogenic gas deep underground, the next question is: what happens when they encounter the rock? That's exactly what our researchers are investigating...

As part of DeepU's ongoing research into non-contact drilling technologies, **Fraunhofer IAPT** (WP2) has continued refining the drill head and advancing experimental tests in controlled laboratory environment. These investigations focus on assessing how the laser beam and cryogenic gas interact with different rock types, particularly regarding drilling feasibility, energy efficiency, and the vitrification process of the borehole walls. Understanding these thermal and physical effects is crucial for optimising the laser drilling process and ensuring its effectiveness across various geological formations.

Complementing these efforts, the **University of Padua** (WP3) has co-designed and monitored the different laboratory test campaigns. In addition, the University of Padua conducted extensive laboratory analyses using state-of-art instruments to characterize the drilled craters, boreholes and residues produced by the laser. The experiments were focused on granite, sandstone, and limestone exploring occurrence of thermal spallation, melting, and vaporisation – phenomena that vary based on rock properties, power density, and irradiation time (abstract EGU25-19025). Among these, thermal spallation has emerged as the most promising process for achieving usable well diameters, with recorded drilling rates between 5 and 15 meters per hour.

A detailed characterisation of the lasing products i.e., vitrified rock was thoroughly performed regarding its mineralogical and chemical composition, shedding new light on its formation process. Profound understanding of the vitrification

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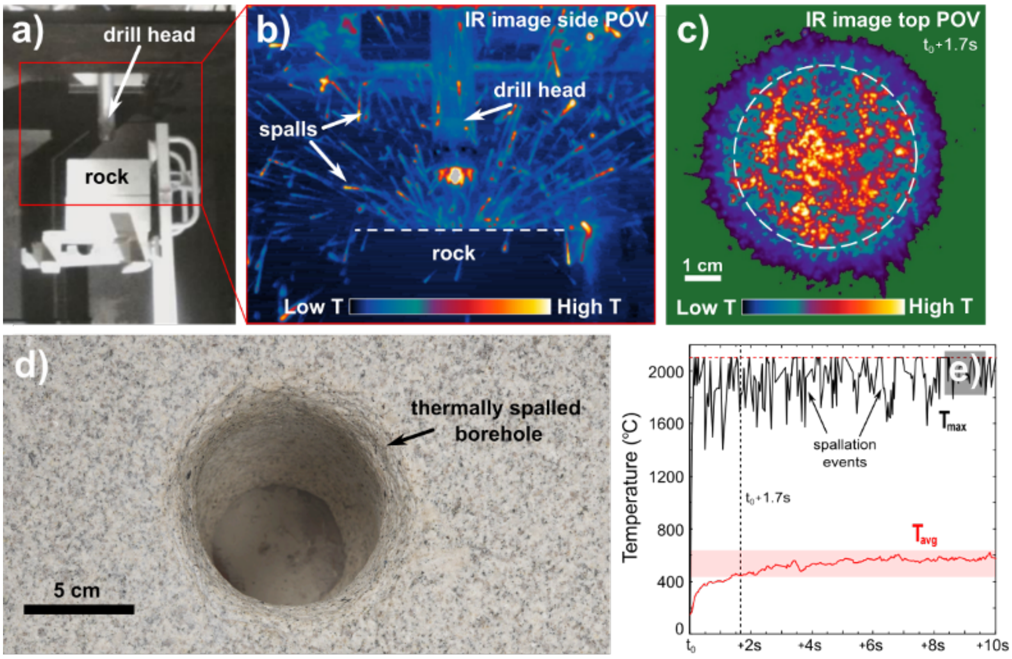


Photograph of the experimental setup (a) used to test DeepU drilling head, IR images of the thermal spallation drilling, side point of view (b), and top point of view (c). Photograph of the thermally spalled borehole, depth 150 mm, diameter ~80 mm (d). The temporal temperature of laser drilling, Tmax – the maximum recorded temperature at a single point, Tavg – the average temperature in beam spot area (e).

(temperature of laser-induced melting, melt viscosity, glass transition temperature) will allow to predict and control (by adjusting laser parameters) thickness of vitrified layer that might be used as alternative for traditional casing. Notably, laser drilling tests resulted in in-situ vitrification along the borehole walls and the formation of strong glassy layer with thickness of 10 mm.

These findings highlight the capability of laser technology to address significant limitations of mechanical drilling, especially in hard rocks at great depth often found in potential deep geothermal reservoirs.

Preliminary Risk Analysis of the Laser Drill Cryogenic System

Due to its exceptionally low-temperature operation, a preliminary risk assessment was conducted on the laser drill's cryogenic system, which is vital for transporting and lifting wellbore debris using cryogenic nitrogen, given the unique safety and operational challenges it presents.

The analysis identified and assessed failure modes related to both cryogenic and mechanical components of the drill string, focusing on risks associated with pressure, temperature, and energy. The objective is twofold: to highlight hazards that cannot be fully eliminated during the design stage and to anticipate how potential failures might develop, providing mitigation strategies from the design phase through operation.

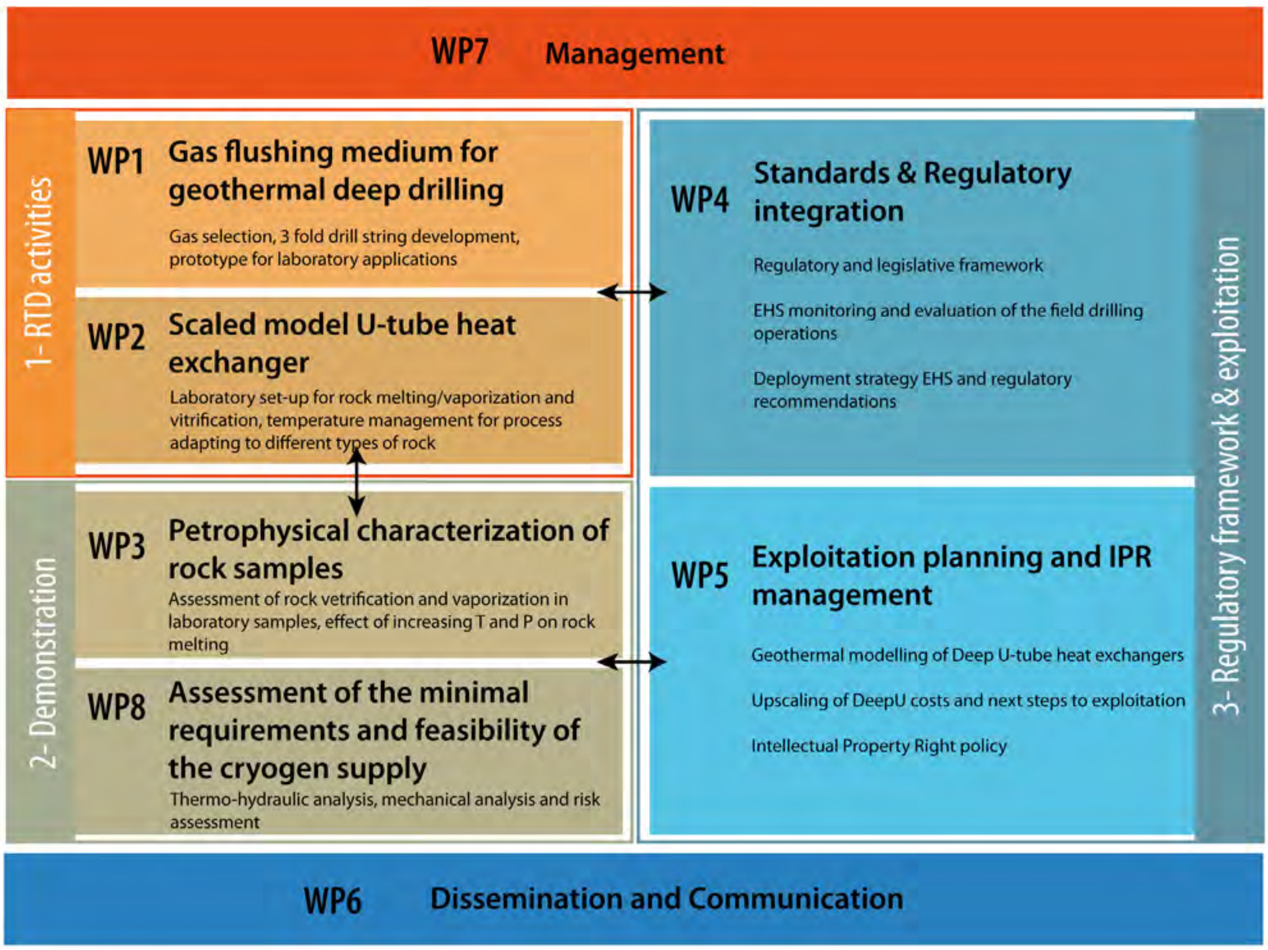
Within the scope of the assessed scenarios, two were identified as critical concerns: first, cryogenic nitrogen leaking into the vacuum insulation. Second, laser energy striking the inner pipe wall. These failure modes display a high probability of occurrence and pose significant threats to system performance, potentially triggering damaging chain reactions across multiple modules.

These failures are highly likely to occur and could significantly impact system performance, possibly triggering chain reactions across multiple modules. The study confirms that deeply understanding process parameters is crucial for minimising/eliminating risks and ensuring the safe, stable operation of the system, thus contributing to the overall reliability of the DeepU drilling concept.

Regulatory, Environmental, and Commercial Perspectives

As technology advances, it's equally important to understand the context in which it operates. That's why DeepU focuses not only on innovation but also on evaluating the regulatory landscape, environmental implications, and market potential of this new drilling approach.

GeoServ (WP4) has conducted an evaluation of the regulatory framework based on different European countries as case studies, to assess the Environmental, Health and Safety (EHS) implications associated for the DeepU drilling



system. Unlike conventional rotary drilling - which relies on a rotating drill string, the use of drilling mud, or compressed air - DeepU introduces a non-mechanical process based on the use of commercial lasers and cryogenic fluids. This leap in technology introduces new operational health, safety and environmental challenges that must be addressed as part of the technology development to gain acceptance from regulators and to facilitate commercialization of the technology in the future.

The complexity of DeepU lies not only in its technical ambition for deep geothermal drilling but also in ensuring compatibility with existing infrastructure and regulations. With the technology currently at TRL 3 and components being tested in controlled laboratory settings, establishing a solid EHS strategy is critical before any field deployment.

To support this, GeoServ utilised two complementary methodologies:

- Failure Mode and Effects Analysis (FMEA) to identify potential failure points in key systems, such as lasers, cryogenic fluids, and drill string components, while proposing targeted mitigation actions;

- An Environmental, Health, and Safety Risk Assessment, in line with EU Directive 2014/52/EU, to compare DeepU's occupational and environmental safety aspects with those of traditional drilling.

Many EHS concerns, such as fluid release, pressure risks, operator safety and training requirements, as well as noise or visual impact, are common in conventional drilling. However, the novel nature of DeepU demands tailored risk management strategies. Crucially, safety must be integrated into the design phase, backed by robust process safety systems and stakeholder coordination as core components.

These early assessments not only help mitigate operational risks but also lay the groundwork for DeepU's integration into actual drilling environments, ensuring that innovation aligns with safety, responsibility, and long-term sustainability.

In addition to these safety and regulatory assessments, the commercial viability of DeepU is also being studied. **RED** (WP5) has initiated feasibility analyses to explore the potential for large-scale deployment of the system, evaluating key parameters such as penetration rate, energy consumption, cost-effectiveness, and environmental footprint compared to current state-of-the-art drilling technologies. Preliminary findings suggest that DeepU could offer a more cost-effective and versatile approach at higher depths to well construction, with high precision and adaptability across a range of geological conditions, potentially supporting the broader development of geothermal energy. Future efforts will focus on optimising system components, sensors and monitoring systems, improving efficiency, studying further vitrification and testing the system in real-world environments, laying the groundwork for commercialisation and industry-wide adoption.

These advancements signify an important stage in DeepU's journey, bringing the vision of laser and cryogenic-based drilling nearer to reality.

DeepU Storyline: Growing Impact and Expanding Outreach

The experimental work represents only one facet of DeepU; clear communication, stakeholder engagement, and effective project coordination are equally vital for transforming innovation into real-world impact.

Beyond laboratory activities, DeepU has also established a strong presence outside of research by enhancing its involvement in the European and International Geothermal Community and participating in key events in the sector. The **National Research Council** (WP6), responsible for the project's communication efforts, has supported DeepU on this journey, contributing to the dissemination of its results. In early 2024, the project took centre stage at Klimahouse in Bolzano, where the role of geothermal energy in sustainable construction was discussed. Over the following months, it presented its latest developments to the European scientific community at the EGU in Vienna and continued the dialogue with experts and professionals at events like the UK Geothermal Symposium in London, the Geothermal Innovation Days in Munich, GeoTHERM in Offenburg, and the Stanford Geothermal Workshop in the United States. All these meetings provided valuable opportunities to discuss the project's progress, exchange ideas, and foster new collaborations regarding the future of geothermal energy.

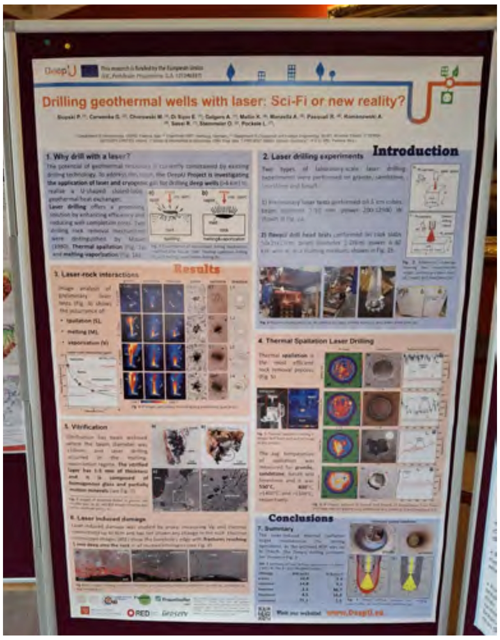
In addition to these participations, DeepU has taken a proactive role in knowledge dissemination by organising two dedicated webinars. The first, "Energy Performance of Deep Heat Exchangers (DHE) by Numerical Simulation," held on 23rd October 2024, delved into the advancements and challenges of DHE systems for deep geothermal energy extraction. Through a round table format, the event featured the participation of the DeepU Team and European experts, who engaged in technical discussions on closed-loop DHE modeling, optimisation strategies, and the repurposing of depleted oil and gas fields.

The second webinar, "Does deep drilling need a revolution?", held on April 4, 2025, showcased the latest technological advancements in deep drilling and fostered a dynamic discussion about the future of the field. Five presentations from DeepU project partners detailed the potential and challenges of innovative drilling methods. Key topics included the future of non-mechanical drilling, significant progress in laser drilling as demonstrated by the University of Padua, novel applications of supercritical nitrogen flushing presented by Wrocław University of Science and Technology, and GEOSERV's analysis of industrial integration and environmental considerations. The event underscored the critical role of technological innovation in driving the future of geothermal energy extraction.

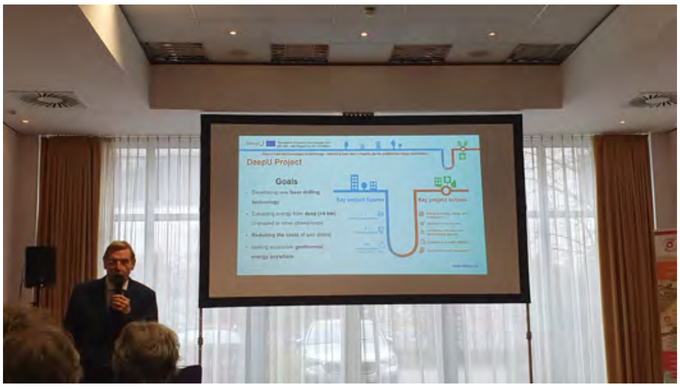
To conclude, we are thrilled to announce that the final conference will take place as a side event at the European Geothermal Congress (EGC) in Zurich, offering a unique opportunity to share our final findings and future perspectives on deep drilling.

Event Snapshots

EGU 2024, Vienna (Austria)



Geothermal Symposium 2024, London (UK)



Geothermal Innovation Days 2024, Munich (Germany)

Let's come to hear about DeepU in these upcoming events:

1. **EGU General Assembly 2025** - Vienna (Austria)
   - **Date**: April 27-May 3, 2025
2. **Drilling Türkiye 2025** - Ankara (Türkiye)
   - **Date**: May 8-9, 2025
3. **Cryogenic Engineering Conference (CEC) 2025** - Reno, Nevada (USA)
   - **Date**: May 18-22, 2025

We look forward to meeting you there!

DeepU is online

Follow us and stay up to date!

Contact us:
info@deepu.eu

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Optimising access to deep geothermal resources with new state-of-the-art drilling technologies to unleash clean, abundant energy from the Earth

A new dawn is opening up for drilling deep U-tube heat exchangers, combining laser and cryogenic gas

May 9, 2023

In 2022, the University of Padua announced the launch of the DeepU project aimed at developing an innovative drilling technology to overcome many geothermal energy production limits.

The project's name reflects the DeepU primary goal of drilling more efficiently with reduced Non-Productive Time, resulting in deep (>4 km) U-shaped closed-loop geothermal heat exchangers. The new technology proposed in DeepU will revolutionise the geothermal energy sector, increasing the accessibility of deep geothermal resources for low-carbon heating and power generation.

The unique technology developed and tested involves a laser propulsion drilling method with cryogenic gaseous flushing for cooling the laser drill head. In case a glazed layer is formed on the borehole walls, the obtained systems are physically isolated from the surrounding rocks and ready to be developed immediately after drilling. The increased drilling speed and the lack of casing and production liner in the reservoir section will substantially reduce well drilling costs.

So, let's recap the results of the first year of activities.

The most suitable cryogenic gas has been selected based on the required qualities: availability, low price, and thermodynamic properties that allow the gas to remain in a liquid state over long distances to reach the base of the well during drilling.

New concepts for drill string and drilling platform design are in development. The novel drill string guides the laser beam down inside the inner drill string while transporting the liquid cryogenic gas downward to the drill head. The drilling tower and platform house the laser and the rotary drilling systems, the liquid cryogenic gas tank and the ash extraction plant with the gas separator and recycling system.

A press container has been set to perform the first laboratory tests with the novel lightweight laser and gas processing drill head and was equipped with monitoring devices. In a preliminary drilling test, a 3D-printed titanium laser processing head created precise and symmetrical holes in granite, limestone and sandstone samples. In addition, constant rates of penetration upwards of 20m/hr have been achieved, with relatively low energy inputs and no component wear that would be associated with mechanical engaging drilling methods.

Health and Safety aspects related to site development, drilling operations and completion, as well as environmental and economic aspects of the DeepU technology uptake are under analysis to achieve regulator acceptance and commercialisation.

DeepU has been funded under the EIC Pathfinder programme (G.A. 101046937) by the European Commission as part of Horizon Europe. Dr Eloisa Di Sipio coordinates the project from the University of Padua in collaboration with partners - Prevent, Fraunhofer IAPT, GeoServ, Red, and CNR-IGG – from 3 different countries. It will run until February 2025.

For further information, check the official website www.deepu.eu and don't hesitate to get in touch with the DeepU team at info@deepu.eu

DeepU: Pioneering the Future of Geothermal Drilling and Deployment

Major technology companies like Meta (Facebook) and Google's interest in geothermal energy underscores the pivotal role of novel geothermal technologies in achieving a low-carbon future. The DeepU project is at the forefront of geothermal innovation and points to advancing laser-based deep geothermal drilling technologies.

September 16, 2024

Since the launch of the DeepU project (Deep U-tube closed loop heat exchanger), the novel drilling technology poised to revolutionise the geothermal sector and push the boundaries of geothermal utilisation, government policies, investments and interests from global players have changed. Recently, two technology giants, Meta and Google, have announced their investment in innovative geothermal projects. The Tech firms' decision was triggered by an urgent need for extensive and continuous electricity provision for the booming data centres, fed by the growing interest in artificial intelligence tools. These data centres forecast to double their consumption in a few years. As for them, advanced geothermal technologies have the potential to play a crucial role in the future of energy sustainability by providing low-carbon, renewable, widely distributed and continuous generation of energy.

The advanced laser drilling technology developed and demonstrated in DeepU aims to increase the accessibility of deep geothermal resources. Its approach involves drilling long U-tubes to a deep depth (>4 km) to create viable closed-loop exchangers for low-carbon natural heat extraction and its power conversion. DeepU's innovative design exploits the synergetic effects of laser and cryogenic gas to optimise the drilling process and reduce drilling costs, increasing the penetration rates and avoiding wear of the drilling head as it is a non-contact method.

The project has already achieved a significant milestone: a prototype drill head which combines a powerful laser system with a new drill string design. The performed tests successfully demonstrated the effectiveness of the method and the drilling assembly at the laboratory scale. The project team is now developing the combination of non-contact laser drilling with cryogenic gas to cool and remove the cuttings while advancing the knowledge of petrological and physical drilling effects and of deep heat exchanger performance, costs and implications.

"The renewed interest in geothermal energy from global players such as Meta and Google confirms our commitment to bringing innovation and concrete solutions to this field," says Luc Pockelé, DeepU Project Coordinator. "We continue to focus on developing drilling technologies that make geothermal energy a more accessible, environmentally friendly and competitive energy source."

DeepU has been funded by the European Commission under the EIC Pathfinder programme (G.A. 101046937) as part of Horizon Europe. Eng. Luc Pockelé coordinates the project from the RED srl in collaboration with partners from four countries: the University of Padua (IT), Prevent GmbH (DE), Fraunhofer IAPT (DE), GeoServ (IRL), The Wroclaw University of Science and Technology (PL), and the Consiglio Nazionale delle Ricerche IGG (IT). The project will run until February 2025.

For further information, check the official website, www.deepu.eu and do not hesitate to get in touch with the DeepU team at info@deepu.eu

Funded by the European Union (G.A. 101046937)

Does deep geothermal drilling need a revolution?

The Earth's depths may hold the key to a sustainable energy future. However, what are the ways to access them more quickly, deeply, and cost-effectively? This daring question forms the basis of the DeepU webinar held on April 4, 2025 – an event that highlights one of the key challenges in the energy transition: exploring new geothermal frontiers through innovative and unconventional drilling methods.

April 7, 2025

Geothermal energy is known for its ability to produce significant amounts of renewable, carbon-free energy with continuity. To boost this contribution, it is crucial to access the underground at increasingly larger depths, but the costs associated with deep drilling present a considerable challenge to developing geothermal technologies and energy production.

The webinar titled "Does deep drilling need a revolution?" united experts and stakeholders to explore a new vision for the future of geothermal energy. Held online as part of the European Project DeepU (G.A. 101046937), the event examined the current state of deep drilling technologies while initiating a discussion on the breakthroughs necessary to access ultra-deep geothermal resources. Central to the conversation was the pioneering technology proposed by DeepU – its approach combines high-power lasers and cryogenic gas to penetrate the most challenging rock formations.

The project partners showcased cutting-edge, innovative drilling technologies while emphasizing the advantages of non-mechanical drilling. They shared significant findings from the DeepU project that demonstrate, on a laboratory level, the potential of laser drilling technology to address the limitations of conventional methods. The research investigates how lasers interact with rock, revealing that thermal spallation, melting, and vaporization occur simultaneously, albeit with varying intensities based on rock type, power density, and irradiation duration. Notably, thermal spallation is the most promising to produce usable diameter wells, with drilling rates ranging from 5 to 15 meters per hour. The team has selected supercritical nitrogen as the flushing medium for deep borehole drilling due to its thermodynamic properties and effectiveness in removing cuttings. They developed a numerical model to determine the necessary pressure and flow rates for different borehole depths, which is being validated through a dedicated test rig. The proposed system involves storing liquid nitrogen, compressing it to high pressures (up to 350 bars), and delivering it down the borehole through a specially designed channel with vacuum insulation. Among the challenges discussed regarding the technology is the need for integration with existing drilling equipment and practices. The presentations and the recording of the webinar are available on the project website https://www.deepu.eu/index.php/events/

Innovation in geothermal drilling may signal a shift in producing carbon-free and renewable energy, aiding the energy transition and utilizing local energy resources. Once the technological challenges are addressed, geothermal energy could transform the global energy landscape and become the most competitive alternative to fossil fuels.

DeepU has been funded by the European Commission under the EIC Pathfinder Programme (G.A. 101046937) as part of Horizon Europe. Eng. Luc Pockelé coordinates the project from the RED srl in collaboration with partners from four countries: the University of Padua (Italy), Prevent GmbH (Germany), Fraunhofer IAPT (Germany), GeoServ (Ireland), The Wroclaw University of Science and Technology (Poland), and the Consiglio Nazionale delle Ricerche IGG (Italy). The project will run until October 2025.

For further information, check the official website, www.deepu.eu and do not hesitate to get in touch with the DeepU team at info@deepu.eu

DeepU Laser Drilling Technology is ready to Enter Field Testing Phase

European innovation aims to make geothermal energy cleaner, cheaper, and accessible anywhere

October 29, 2025

The **DeepU project** has announced that its groundbreaking **laser drilling technology** is now ready for field testing, marking a major milestone in the quest to unlock affordable and sustainable geothermal energy.

After 44 months of intensive research, laboratory experiments, and computer simulations, the DeepU consortium has produced its **first operational prototype** — a system that uses a **laser beam and a supercritical nitrogen stream** to drill through rock without physical contact. The approach promises to cut costs, improve efficiency, and significantly reduce the environmental footprint of deep drilling operations.

Funded by the **European Innovation Council (EIC) Pathfinder programme** under **Horizon Europe (Grant Agreement No. 101046937)**, DeepU has been coordinated by the **University of Padua** and then **RED SRL**, in collaboration with **Prevent GmbH**, **Fraunhofer IAPT**, **Geoserv Ltd**, the **University of Wroclaw**, and **Consiglio Nazionale delle Ricerche-IGG**, representing four European countries.

The newly developed prototype combines three essential functions in a single drill string and a drilling head:

- **Directing the laser beam** to drill rock with precision
- **Channeling the nitrogen flow** to remove particles and cool the borehole walls
- **Providing a robust structure** for the drilling operation

Beyond its technical achievements, the project identified optimal laser settings for different rock types, evaluated environmental and safety standards to ensure responsible deployment, and explored potential markets for large-scale technical applications.

“Reaching the field-testing stage is a key step toward making geothermal energy a reliable, cost-effective source available anytime, anywhere in the world,” said Luc Pockelé, Project Coordinator at RED SRL. “With DeepU, we can tap into the Earth’s heat in a cleaner, smarter way.”

By advancing to real-world testing, DeepU moves closer to its goal of **turning the planet’s natural heat into a practical, sustainable energy source** — helping Europe move towards a resilient, low-carbon future.

About DeepU

DeepU is a European research and innovation project funded by the **European Innovation Council (EIC)** under the **Horizon Europe** programme (G.A. **101046937)**. The project develops an advanced laser drilling system designed to reduce the cost and environmental impact of accessing deep geothermal energy.

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