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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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Key project figures

7
Partner organizations

4
Involved countries

44
Months duration
starting on March 1, 2022

Key project actions

- Drilling technology design and development
- Validation at the lab scale
- Compliance with legal and environmental aspects
- Closed-loop scenario definition
- Cost-effectiveness assessment

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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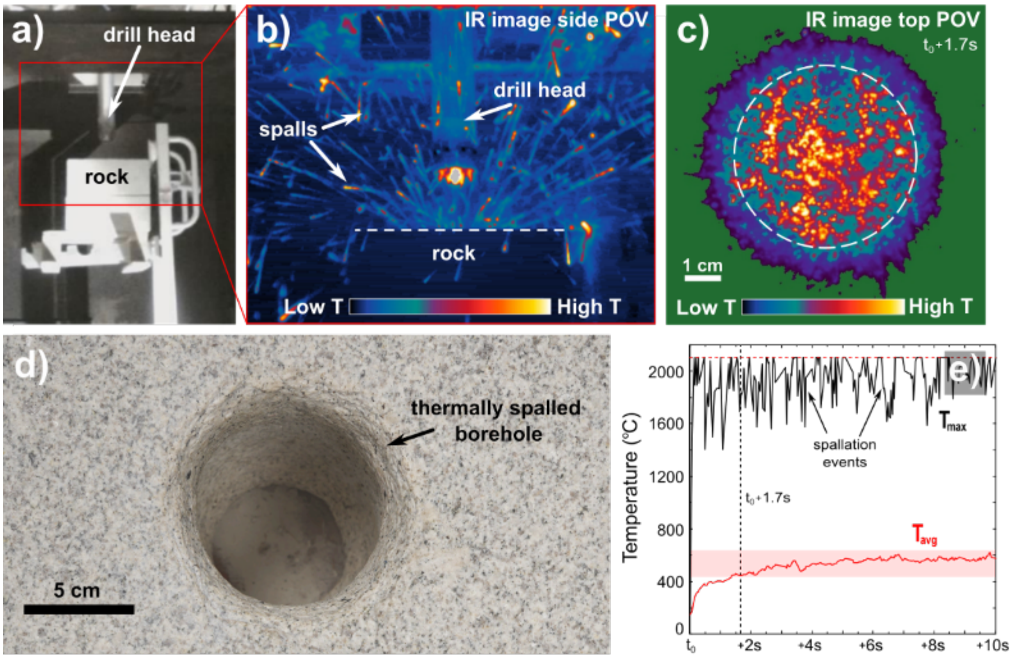

Photograph of the experimental setup (a) used to test DeepU drilling head, IR images of the thermal spallation drilling, side point of view (b), and top point of view (c). Photograph of the thermally spalled borehole, depth 150 mm, diameter ~80 mm (d). The temporal temperature of laser drilling, Tmax – 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.

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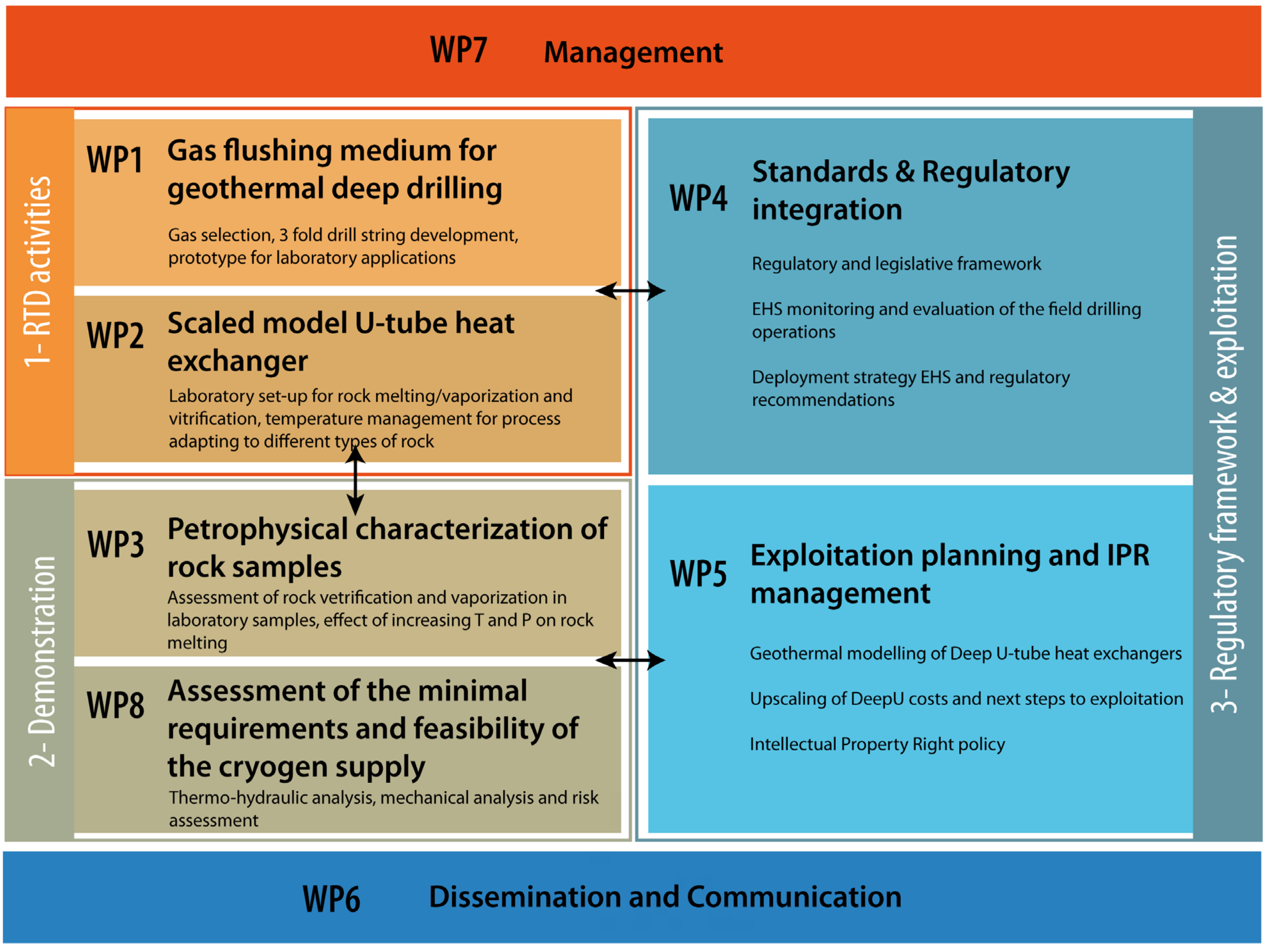
Within the scope of the assessed scenarios, two were identified as critical concerns: first, cryogenic nitrogen leaking into the vacuum insulation. Second, laser energy striking the inner pipe wall. These failure modes display a high probability of occurrence and pose significant threats to system performance,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

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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.

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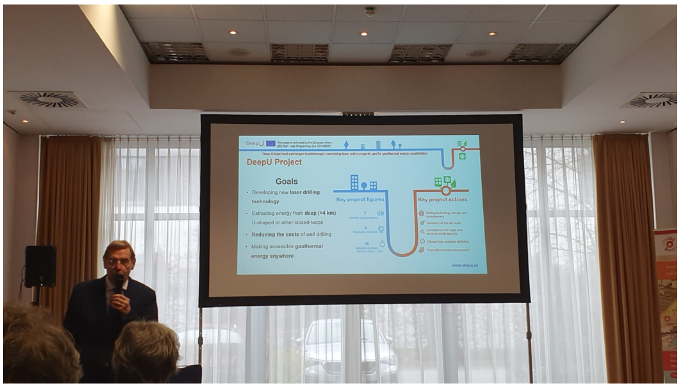
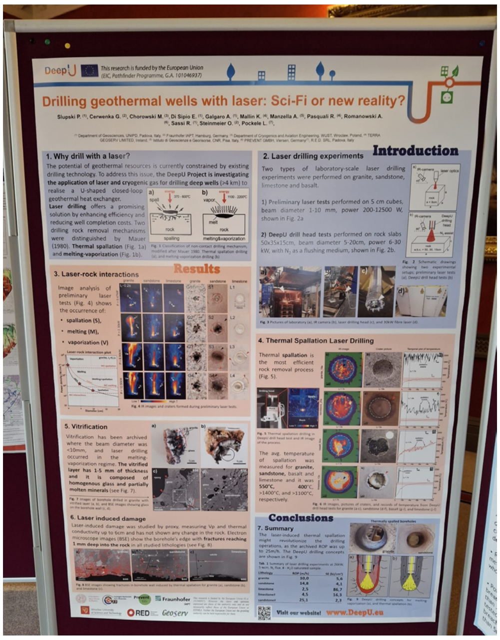
Event Snapshots

EGU 2024, Vienna (Austria)



Geothermal Innovation Days 2024, Munich (Germany)



Geothermal Symposium 2024, London (UK)

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:
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