Graduate Geothermal training in the European Economic Area

J. A. Newson[1], G. Trullenque[2], C. Bossennec[3], I. Sass[4], S. Šadek[5], B. Gautason[6] and R. M. Greene[1]

[1] Iceland School of Energy, Reykjavik University, Menntavegur 1, 102 Reykjavik, Iceland

[2.] UniLaSalle - Beauvais campus 19, rue Pierre Waguet – BP 30313 60026 BEAUVAIS, France

[3.] Institute of Applied Geosciences, Geothermal Science and Technology, Technische Universität Darmstadt, Schnittspahnstraße 9, 64287 Darmstadt, Germany

[4.] Helmholtz Centre Potsdam-GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany

[5.]University of Zagreb, Faculty of Electrical Engineering and Computing, Unska 3, 10000 Zagreb, Croatia

[6.] Iceland Geosurvey (ÍSOR), Rangárvöllum 2, hús 8, 603 Akureyri, Iceland

julietn@ru.is

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ABSTRACT

Intensive graduate courses in geothermal energy have traditionally been the remit of nations with a long tradition of high temperature geothermal utilization: Iceland, Italy, Japan, and New Zealand. In addition, El Salvador has had a Spanish language Geothermal Diploma Course for Latin America since 2010, courses in Indonesia, taught in Indonesian, and African geothermal training is under development. However, increasing impacts of climate change, geopolitical conflict and related refugee movement has drawn attention to the need for clean, renewable and sustainable energy worldwide. This attention has created interest in geothermal research and utilization in many countries that do not have high temperature, tectonic margin or volcano-related, geothermal systems. This paper discusses the ongoing development of an EU-funded European Erasmus + Strategic Partnership dealing aiming at the construction of a geothermal course curriculum for international students, involving Iceland France, Germany and Croatia.

1. INTRODUCTION

This paper discusses the forerunner intensive course program, called Geo3EN (Geothermal Energy European Education Network), to the development of an Erasmus Mundus Master's degree, which can be funded by the EU. This Master's degree is taught in English by a consortium of higher education institutions (HEIs) from different countries; in this case from Croatia, France, Germany and Iceland.

This paper presents first the European context of geothermal energy in terms of resource utilization, research and teaching funding, and then discusses the implementation of some Geo3EN test courses.

2. EUROPEAN CONTEXT

This section is intended to give context to Geo3EN, the geothermal training programme that is the subject of the paper. The section contains a brief description of geothermal energy in Europe, followed by an outline of the main European research funding programme, Horizon Europe, and the youth training programme, Erasmus+ and how the Geo3EN programme fits into this funding regime.

2.1 Utilization of Geothermal Energy in Europe

Utilization of geothermal energy for electricity in Europe ('Europe' is defined as countries in the EU and EEA) is currently 20,881 GWh/yr. The majority of electrical generation is within three countries of Iceland (6,010 GWh/yr), Italy (6,100 GWh/yr) and Turkey (8,168 GWh/yr) (Huttrer, 2020). These countries have geothermal systems related to volcanic areas. However, Figure 1 (Dalla Longa et al, 2020) shows that there is so far un-utilized geothermal potential all across Europe, for instance at more than 2 km depth in sedimentary basins such as the Pannonian , as well as in fractured basement in rift systems within the Rhine Graben. The producing power plants of Velika 1 in Croatia, Soultz sous Forêts and Rittershofen in France, Insheim in Germany are already-operating examples.

Direct use of geothermal heat in Europe amounts to 264,843 TJ/yr, including use by heat pumps. Sweden, Turkey and Iceland (Lund & Toth, 2020) lead this growth in direct use for space heating. Much of Europe has suitable resources for direct geothermal heat applications in agriculture, industry and the built environment in reservoirs at depths of less than 2 km (Figure 1).

The pandemic slowed geothermal development in Europe, but the energy crisis associated with the 2022 war in Ukraine rushed the European Union to develop renewable heating systems. Half of new geothermal projects have been in heating and cooling (Figure 2). In particular, there is strong growth of geothermal heat pump installation, and 13 new district heating systems have added more than 154 MWth of new capacity. 75% of new growth in district heating came from France, Poland and Iceland (EGEC, 2022).

In European heating and cooling projects there is a decentralized energy system approach, and a large effort with respect to technology, system integration and 'non-technical' issues (i.e. policies, building standards, risk management and social acceptance issues) (EGEC, 2020).

The availability of low temperature geothermal resources, the need for renewable energy sources, and a recent focus on geothermal as part of a local-scale energy system, means that use of shallow, lower temperature geothermal resources will continue to support Europe's energy transition and independence in the future.

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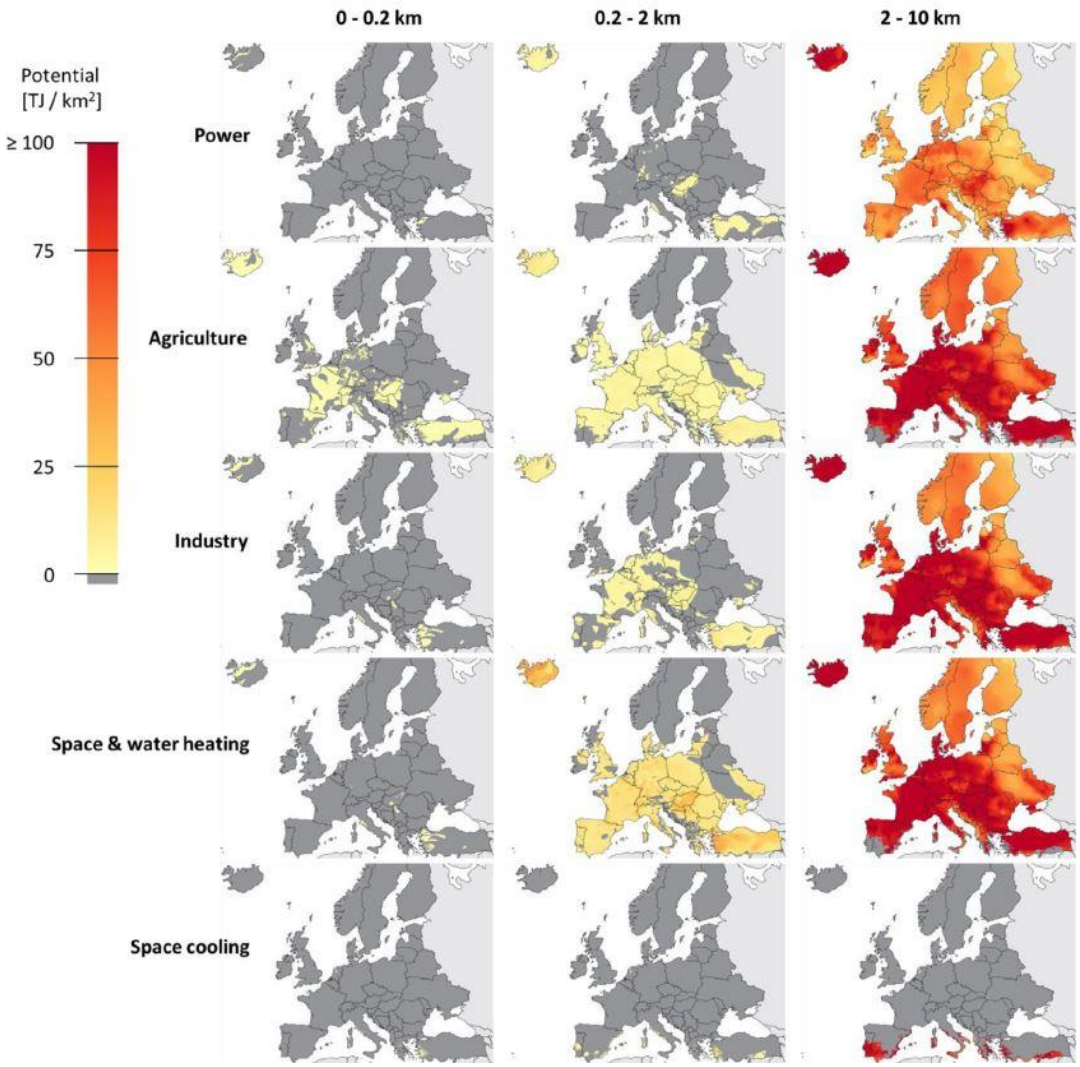

Figure 1: Long-term economic potentials for various geothermal applications in Europe at three different depth ranges. Adapted from Dalla Longa et al, 2020.

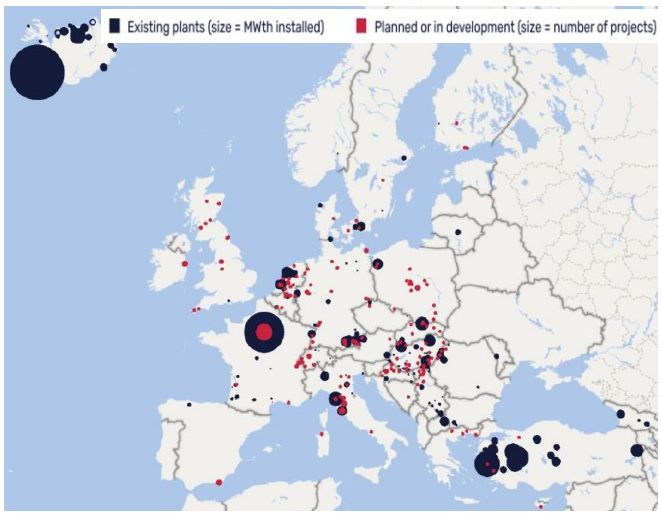

Figure 2. Location of existing and planned geothermal district heating and cooling systems in Europe (from EGEC, 2022).

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2.2 Horizon Europe Funding Programme

Horizon Europe and the Erasmus Programme are the funding sources for the project under discussion in this paper (Geo3EN). Hence a brief description of these programmes is included here.

Horizon 2020 was the EU Research and Innovation funding programme, with a budget of € 80 billion, from 2014 to 2020. This has been followed by the new Horizon Europe (budget € 95.5 billion), running from 2021 to 2027.

2.3 Erasmus+ Funding Programme

Erasmus+ is the EU programme for education, training, youth, and sport. There are 3 Key Actions (KA's):

- KA1 Learning mobility of individuals, promoting student and teacher exchange programmes all over Europe, and (albeit with less opportunities) with the rest of the world. .
- KA2 Cooperation among organizations and institutions. This Programme funded the classes described in this paper.
- KA3: Support to policy development and cooperation.

2.4 KA2 and Geo3EN

The Geothermal Energy European Education Network (Geo3EN) has been funded by the Erasmus+ Programme (KA2) of the EU under the project number 2019-1-FR01-KA203-062936.

The higher education priorities of KA2 are:

1. Tackling skills gaps and mismatches
2. Promoting and rewarding excellence in teaching and skills development
3. Promoting internationalization

The Geo3EN programme aims to remedy the lack of qualified junior graduates in Europe available to master all elements of the geothermal energy value chain. Hence it is most closely related to the first KA2 priority of tackling skills gaps.

Geo3EN originated as academic spin-off of the H2020 research project MEET on Enhanced Geothermal Systems (Trullenque et al. 2018; Dalmais, 2020; Ledésert et al, 2022, Raos et al., 2022). The aim of MEET was to demonstrate the lower cost of small-scale production of electricity and heat in wider areas with various geological environments, in order to support a large increase of geothermal-based production sites in Europe in a near future.

In terms of the future, Geo3EN is intended to be the forerunner to an international multi-site MSc in geothermal science and engineering. This will provide students with competencies in geology, material sciences, mechanical engineering, geothermal project development (above and below ground), power system management, modelling, and energy economics but also project management, entrepreneurship and intercultural awareness to successfully lead and design complex geothermal energy projects. All the Geo3EN and the proposed MSc programme will be entirely taught in English. The proposed degree will be operated under a programme known as the Erasmus Mundus Joint Master.

2.5 Erasmus Mundus Joint Master Degree

The aim of the Geo3EN project is the creation of Erasmus Mundus Joint Master Degree (EMJM). The Erasmus Mundus programme supports high-level integrated transnational Master's study that is taught by a consortium of higher education institutions (HEIs) from different countries worldwide, with specific expertise and interest in the concerned study areas/professional domains. The programme provides a predetermined number of full scholarships for the particular EMJM course and students may apply from anywhere in the world. The students must study at a minimum of two HEIs, and earn either a joint degree or a dual degree, depending on the original agreement between institutions. These agreements between institutions depend on the fundamental degree-granting rules of each institution, and may be the controlling factor in the final designation of the Erasmus Mundus degree.

4. THE GEO3EN PROJECT

4.1 Background

The Geo3EN programme was under development since 2019, with an implementation period over March to July of 2022. This paper describes the background, development and implementation of the course. This period unfortunately was concurrent with the most drastic effects of COVID 19 on the world education system and society, with restricted mobility, online teaching and widespread stress. For a programme built on the concept of mobility this period was a challenge, and ultimately the mobility activity was compressed into the final nine months of the project.

4.2 Need for the Geo3EN Project

The objective of Geo3EN is to contribute to making Europe the leader in geothermal energy education and geothermal energy applications by creating a multi-site European MSc of Excellence in Geothermal Engineering. The need for such a qualification has been expressed by geothermal industry stakeholders (as represented by the 19 associated partners of Geo3EN). Their feedback as players of the European geothermal energy sector (industry, energy agencies, clusters, electricity operators, etc.) makes it clear that they face difficulties in finding suitable profiles for developing their activities.

The employment study of the GEOELEC project (funded by the EU, www.geoelec.eu) evaluated that in 2013 around 3000 jobs were directly related to geothermal electricity in the EU-28. The total number of geothermal power jobs (heat + electricity) between 2013 and 2030 is expected to grow from 10,000 to 100,000. The biggest industry challenges will be (EGEC, 2016):

- Finding the right combination of technical and soft skills, and shortage of people at the feasibility stage
- Development of drilling expertise, energy storage, solutions against scaling, efficient communication, and legal and financial framework
- Finding competencies such as flexibility to adapt to the changing environment and clients' needs, reservoir engineering, project and plant management.

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These are the challenges that Geo3EN begins to address.

Geo3EN is a truly international project since the education of geothermal engineers requires a multidisciplinary set of competencies that are not available in a single university programme. Geo3EN aims to use the knowledge of its consortium partners to provide their students with the required competencies and skill sets, i.e. to be able to understand geology, material science, geothermal energy storage, drilling, reservoir management, energy production and transmission, energy economics, and to have excellent project management and entrepreneurial skills to successfully lead and design complex geothermal energy projects. We note that engineering accreditation will depend on a number of factors; mainly the structure of the agreements between universities, the exact degree path, and the student undergraduate degree.

Similarly, Geo3EN aims at increasing the mobility of its students to benefit from the different competencies of the consortium partners and to test the curriculum of the future MSc programme. Moreover, boosting mobility will help students to be acquainted with different working techniques, pedagogic techniques and working methods, to master different equipment, experience another working environment and study designs.

4.3 Institutions

The lead applicant for the project was Institut Polytechnique UniLaSalle of France. This is a private higher education establishment founded in 1854. UniLaSalle hosts 4050 students on four campuses in Beauvais, Amiens, Rouen and Rennes and has been emerging as one of France's leading knowledge hub in applied sustainable development. UniLaSalle trains generalist engineers to hold high-level executive and top management positions in the following sectors: agriculture, food industry, food and health, geosciences and the environment, and is an accredited Engineering school. The leader of the Geo3EN project application is Dr Ghislain Trullenque.

TU Darmstadt (Technische Universitat Darmstadt), founded in 1877, is a public higher education and research institution. It belongs to the TU9, which is the alliance of leading Universities of Technology in Germany. TU Darmstadt offers 111 degree programmes to 25,840 students. The Geothermal Science and Technology research group is led by Prof Dr Ingo Sass, and is part of the Darmstadt Graduate School of Energy Science and Engineering.

The University of Zagreb (Sveučilište u Zagrebu) is a public university, and the largest university in Croatia. The status of university was formally recognized in 1669. The University of Zagreb offers education programmes in all scientific fields and a wide range of courses at all study levels, from undergraduate to postgraduate for more than 70,000 students. The Technical College, which included engineering, was established in 1918, and today the Faculty of Electrical Engineering and Computing (FER) is the largest technical faculty and R&D institution in the fields of electrical engineering, information and communication technology and computing in the Republic of Croatia. The present research and educational staff comprises more than 190 professors, 202 teaching and research assistants and around 3300 undergraduate and graduate students. Izv. Prof. Dr. Sc. Siniša Šadek, Department of Energy and Power Systems was the FER representative on the Geo3EN programme.

Nýsköpunarmiðstöð Íslands (the Innovation Centre of Iceland) was the original Icelandic institution involved in this grant, however by 2021 this organization was failing, and Reykjavik University (Háskólinn í Reykjavík) was asked to be the Icelandic partner. Reykjavik University is a small private university in Reykjavík, Iceland. The University is ranked 53rd in the Times Higher Education young universities rankings, and has around 3800 students. Reykjavik University teaches Law, Computer Science, Engineering, Business and Sports Science. The Engineering Department hosts the Iceland School of Energy, led by Dr J. Newson, is the school involved in the Geo3EN programme.

4.4 Logistics and the Budget Component of Geo3EN

The project primarily supported academic staff working time dedicated to curriculum construction, financing transnational project meetings plus project management and communication. Funds were available to test some of the proposed lectures and site visits in the form of an intensive study program for two academics and six students per institution, including costs for international travel. There were some events that had to be modified or cancelled due to COVID 19, and thus cost less than budgeted. The nature of these EU funded projects is such that funds are not generally transferrable between categories, so the final total spend of €191,000 was around €60,000 less than the original budget.

The Erasmus Mundus project logistics include coordination of activity times and degree regulations between four universities in four different countries. The complexities of this and of the detailed Erasmus Mundus study plan are not discussed further in this paper, but nonetheless we are aware that timetable, credits and curriculum design management will be an important and time-consuming part of the project.

4.5 Academic component of Geo3EN

4.5.1 Stakeholder Consultations

As already mentioned in section 2.4, Geo3EN originated from the Innovation Action MEET demonstration project during which the lack of young, qualified, multi and interdisciplinary geothermal engineers appeared. From this data, and stakeholder consultations, members of the consortium produced a preliminary version of a competence matrix needed for future engineers. To achieve this, stakeholder consultations were carried out prior to the curriculum development. The stakeholders were first consulted via a questionnaire to be filled online and four Multiplier Events were later organized online due to COVID 19 restrictions in Zagreb, Beauvais, Darmstadt and Reykjavik. From the feedback a competence matrix was designed, in line with the guidelines from both industry, academia and R&D organizations.

The competence requirements are a key feature to determine the exact design and selection of Erasmus Mundus courses, which feed into the mobility tracks to be followed by the students. Geo3EN was the first test of the process of four-way university cooperation on specialist shared courses with a classroom and field component.

4.5.2 Intensive Study Program (ISP)

One of the main challenges when dealing with the Geothermal Masters concept is to enable students from different thematic backgrounds to gain the same level of base competencies in geothermal topics. The tools and methods

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should ensure that students acquire basic knowledge in all fields of geothermal engineering in order to be able to follow classes in unrelated fields. The challenge is in bringing a multi-disciplinary approach to a group of students with diverse academic backgrounds. The students in this cohort were from earth science or engineering background, but that still resulted in significant difference in the type of student foundational knowledge. For instance, there is a large difference in basic professional knowledge between an electrical engineer and a geologist.

In order to test the practicality of bringing together students with different educational backgrounds, ISPs were organized between 23 students and several academic staff. The concept of the program was leading up to a final project which was a geothermal energy utilization feasibility study. Students had to acquire and treat data from a given reservoir, study rock properties in the laboratory, plan surface installations and take into accounts a given investment budget plus energy price. The teaching methods originally included classroom instruction, field and laboratory work. The results were evaluated in the form of group projects, where each group consisted of one student from each university.

The original plan consisted of four classroom-based courses, with one delivered from each university, and one week of site visits to each country. This allowed each university to test their geothermal courses on this diverse student group.

4.5.3 Classroom courses

On-going COVID 19 restrictions and differences in availability between institutions meant that courses were delivered online, and eventually in a very short time period before the project ended, which was an unfortunate restriction; material had to be compressed. The students had two weeks to listen to the online lectures and complete the coursework. The courses from each university are described below.

UniLaSalle: Geodynamics and rock rheology related to reservoir properties

1. 3D outcrop visualization
2. Metamorphism and fluid-rock interaction
3. Large-scale geodynamic processes
4. Rock rheology (stress & strain in geologic materials)
5. Brittle deformation processes
6. Ductile deformation processes

TU Darmstadt: Resource Characterization & Utilization

1. Introduction to petrothermal systems and reservoir characteristics.
2. Geological and geothermal models
3. Resource assessment.
4. Quantification and identification of deep geothermal potentials.
5. Introduction to EGS reservoir utilization assessment.

University of Zagreb: Power engineering

1. Introduction to power engineering
2. Power plant operation
3. Fluid machinery
4. Geothermal power plants
5. Electric machines and transformers
6. Transmission and distribution of electric energy
7. Heat exchangers and heat pumps
8. High voltage technology

Reykjavik University: Economics of geothermal energy

1. Conceptual models of high temperature geothermal systems.
2. Geothermal Power Plant configurations.
3. Energy Financial Assessment.
4. Environmental and resource impact of utilization, extracting maximum value from a project.
5. Economics of geothermal utilization.

4.5.4 Site visits

Each taught course was followed, some weeks later by field-work, site visits and practical laboratory work. These visits were finally able to go ahead after most COVID 19 restrictions were lifted, although visits to some industrial facilities were limited. The resulting trips still encompassed an interesting variety of reservoir analogue sites, active geothermal areas, and power stations, power developments adjacent to protected environments (Thjórsá in Iceland), and the protected historic areas with old mines which now give us valuable information on adjacent basement reservoirs.

The first country visit was to Croatia. The visits were somewhat restricted by COVID 19, but the group had access to Zagreb thermal power plant, the 16.5 MW Velika 1 Geothermal Binary Plant (Figure3), and the Varaždin Hydro Plant on the Drava River.

Figure 3. The Geo3EN class on a study visit to the Velika 1 geothermal binary power station in Croatia.

Visits to geothermal power plants within the Upper Rhine Graben were able to go ahead and consisted of visits to Soultz-sous-Forêts, Rittershoffen, and the Insheim Power Plants.

Several reservoir analogues were visited in the Upper Rhine Graben border massifs, namely in the Black Forest (Teufelsgrund and Schauinsland mines, shown in Figures 4, 5 & 6) and Vosges (Gabe Gottes Mine). The excursion led by UniLaSalle consisted of a transect across the graben and several paleo geothermal reservoir systems containing hydrothermal ore deposits were investigated.

Figure 4. Geological overview presentation to students within the Schauinsland mine.

Figure 5. The Geo3EN class at the Rhine Graben reservoir analogue site – the Teufelsgrund (Devilsground) underground mine.

Figure 6. It was a long descent (~99 m) into the Schauinsland mine.

Field visits in Iceland consisted of Seltún and Reykjanes active thermal areas, the 2021 Fagradalsfjall volcano (Figure 7) and the Hellidsheiði Geothermal Heat and Power Station. In addition, the class visited Thjórsádalur (the valley of the river of bulls) which is the location of Iceland's longest and second most voluminous river. More than half (1035 MW) of Iceland's hydro capacity is in the Thjórsá area, which also hosts extensive fractured basalt flow (geothermal reservoir analogue) outcrops. The overnight trip to the Highlands took the class to Landmannalaugar thermal area on the northern margin of the Torfajökull caldera, the largest silicic volcanic area in Iceland, and a very popular tourist destination and protected geothermal area within the Fjallabak National Park.

Figure 7. Part of the Geo3EN class at the recently active Fagradalsfjall volcano.

The TU Darmstadt section of site visits consisted of petrophysical investigations in the laboratory, and proved very popular with the students. During this week of laboratory work, students had the opportunity to follow the complete process of petrophysical property measurements on representative facies rock samples from the different geothermal reservoirs.

The hydrothermikum platform accessible at the TU Darmstadt provides high-tech analytics and an interdisciplinary laboratory concept for a broad spectrum of investigation options (Figure 8). It consists of a thermophysical laboratory, containing facilities to determine permeability and porosity, and other thermopetrophysical properties of rocks relevant for geothermal reservoir characterization. Participants were also introduced to a thermo-triax facility, which allows an experimental characterization of rock properties in in-situ conditions (high temperature, high pressure, variable pH of brines).

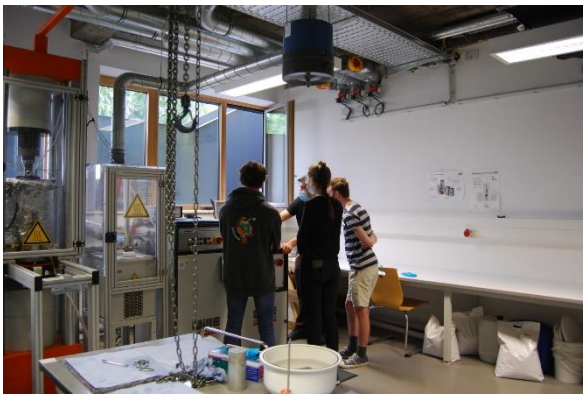

Figure 8. ISP Students performing experiments with mentoring in the Thermo-triax facility necessary for optimal permeabilities for geothermal reservoir rocks samples.

5. RESULTS

This Geo3EN programme was the forerunner to implementation of an Erasmus Mundus Joint Master Degree in Geothermal Engineering. It occurred over the period of the COVID 19 pandemic, and was affected by this, although there were many other important learnings from this project.

The activities demonstrated the production and testing of a geothermal engineering curriculum at international level and reasonable cost with a large variety of students' educational background.

The idea of baseline courses is to develop tools and methodology that will enable students from different

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thematic backgrounds to gain the same level of competencies in geothermal engineering. The tools and methods should ensure that students acquire basic knowledge in all fields of geothermal engineering in order to be able to follow classes in unrelated fields.

The students completed four online courses. Each course was a combination of recorded and live lectures and the evaluation was carried out in several ways:

- discussion and exercises after the lectures,
- quizzes after the lectures,
- group discussions and presentations after the field trips,
- conducting a survey,
- student projects.

Student work on the final group project was the most important evaluation task. It demonstrated the students' ability to apply the acquired knowledge in a methodical way and tested all competencies students obtained during the project. The final comments of the students, but also of the teachers, were positive.

The main lessons, based on student and teacher feedback are:

- When there are four groups of students from four different countries, it is better to have more in-person contact for fruitful discussions.

- The students and teachers felt that the country visits occurred too close together. This was due to the limited time when limited international travel began to open up but in any case, care has been taken to sufficiently separate events of this type in the curriculum

- Students with no initial geological education background have passed on their difficulties working in the field, analyzing outcrops and investigating geological structures. This was expected by the consortium as it is likely related to the short duration of the ISP program. A substantial number of intensive basic geology lectures are planned for students in question here. These lectures are available within a pool of Base Line Courses provided by Reykjavik University, TU Darmstadt and UniLaSalle Beauvais.

- Coordination between different universities with respect to the pre-and co-requisites for courses, the course requirements for the degree; also the semester start and finish times are a challenge. This point will require an intensive and precise planning.

DISCUSSION.

For university staff, Geo3EN demonstrated that people from four universities could work together on a common course. The site visits facilitated observation of the built and natural environment at each university, so staff had a good idea of what the students would experience.

For the students it was a mostly positive experience; socially they appeared to enjoy it, although the intensive travel period was considered too compressed in time. Two weeks was not sufficient time to completely overcome a deficiency in the background of some students.

The Geo3EN program permitted the construction of a solid base for an application to the EMJD program. The current worldwide geopolitical situation and increasing public awareness regarding environmental concerns are factors in favour of the Geo3EN consortium initiative. Multi- and inter-disciplinary engineers able to lead the energy transition process are highly needed and it is expected that the employment market in this field will grow exponentially.

The next steps are the design of a full Erasmus Mundus Joint International Master's degree, considering our Geo3EN experience.

All consortium members are highly motivated in bringing their expertise to this novel and innovative training program.

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