GEOTHERMAL DHC
Towards Decarbonized Heating and Cooling!

D10 General educational concept for training related to the inclusion of geothermal technologies in heating and cooling grids

Version June 2024

Date of publishing: 28/06/2024

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EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

This publication is based upon work from COST Action **Geothermal-DHC**, supported by COST (European Cooperation in Science and Technology).

List of Content

1 INTRODUCTION

1.1 Description and scope of the deliverable

1.1.1 Description according to the MoU

General educational concept for trainings related to the inclusion of geothermal technologies in heating and cooling grids based on the experiences gained in the Action.

1.1.2 Scope of the deliverable

This deliverable addresses a general academic educational plan **focusing on the integration of geothermal energy into heating and cooling networks of different generation and temperature levels**. In such networks, the subsurface may contribute to the network as a heating and/or cooling source (geothermal energy) or a heat storage (underground thermal energy storage).

The educational plan follows a multidisciplinary approach connecting research findings from geosciences, engineering and social science including legal aspects, tackling the entire process chain . The concept was tested and evaluated in training schools, summer schools, student conferences and webinars organized in the framework of CA18219 Geothermal-DHC.

1.2 Context

The educational concepts is related to the below mentioned Action objectives:

- SO6: Identify and characterize **successful solutions** for the integration of geothermal technologies in monovalent as well as multivalent heating and cooling grids.
- SO11: **Collaborating with already existing European and international organizations** as well as EU institutions dealing with geothermal energy, heating and cooling supply and energy and climate mitigation policies. (applies for TS1)
- SO12: **Collaborating with research groups** in the previously mentioned thematic fields and interlinking research groups of different disciplines to cover all relevant themes. (applies for TS1)
- **SO14: Promoting interdisciplinary education and supporting young careers in the field of geothermally supported heating and cooling grids.** This includes access to data from case studies, short term staff exchange programs, technical workshops and scientific missions linked to academic theses as well as joint field trips, student conferences and training schools (applies for TS1).
- SO15: **Transferring knowledge from leading- to follow-up countries** with regard to geothermal application and heating grids by supporting knowledge transfer workshops, scientific events linked to the covered sites, short-term staff exchange and joint scientific missions.
- SO17: **Promote young scientists**, who will be in charge to realize our concepts in the future and to involve partners from ITC countries, where the need for a decarbonisation of decarbonized heating and cooling grids is very high.
- SO16: To ensure **gender balance** in all planned activities (average share of at least 40% of each gender. (applies for TS1)

Suggested target indicators related to key educational activity as we tested them within the Action:

- Number of trainees: At least 15, of which at least 5 ITC trainees (and not more than 30)
- Average share of at least 40% of each gender
- Trainers and/or trainees from at least 3 backgrounds (e.g. geologists, machine engineers, civil engineers, energy engineers, environmental specialists, social sciences)
- At least 2 trainers from other than the hosting country

1.3 Management structure regarding the elaboration and monitoring of the educational concept

This chapter describes the organizational structure (Ad Hoc WG, scientific committee) for elaborating, testing and implementing the educational concept during the lifetime of the Action. A list of trainers are cited in the Annex of this document.

The Ad-Hoc WG "Educational concept" has around 30 members, most of whom are from Academia, with an experience in developing educational concepts; they are aware of the importance of well-defined learning outcomes as well as tools needed to evaluate their achievement. Also, they are accustomed to planning student workload, which is beneficial in designing educational activities. The overall concept strives towards the balance between different teaching styles, including standard lectures, cooperative learning and problem-based learning.

The Ad-Hoc WG was led by Dr. Kolenković Močilac from University of Zagreb, who is well experienced in both teaching at an academic level and collaborating with researchers in international research networks (e.g., CO2GeoNet, Energ).

2 GENERAL EDUCATIONAL GOALS AND CONTENTS

In this chapter, we will describe the overarching educational aims, contents and a module-based structure. Furthermore, we also define the target group of trainees addressed.

2.1 Premises

Accessibility

- Activities are suggested to be mainly organized as in-person events, but dedicated hybrid sessions or hybrid attendance have also been possible in case required due to special circumstances;
- All training materials have been shared to the participants during the event and were accessible for all registered CA members at the web portal of CA18219 Geothermal-DHC (www.geothermal-dhc.eu).

Certificates

- Students received a certificate of attendance at the end of the training.

2.2 Target group

The focus of COST educational activities were primarily on young experts, most often Master-, PhD students and Postdocs, but all events were open for engineers and young employees outside the academic sector. However, English language skills have been required to follow the training activities offered by CA18219.

2.3 Educational goals

Geothermal-DHC aimed at developing knowledge of young professionals in the area of: i) **shallow geothermal energy (SGE),** including the basic concept and architecture of the SGE systems as well as their limitations and advantages; , ii) **medium depth geothermal energy (MGE)**, (e.g. heat exchangers in abandoned hydrocarbon wells); iii) **deep geothermal energy** (**DGE**) both hydrothermal and petrothermal systems, **underground thermal energy storage**, conventional high temperature **heating grids** (2G to 3G DH) and low temperature heating and/or cooling grids (4G to 5G DH), and combination of geothermal **heat, power and mineral production**.

The Trainings aimed at offering deeper insights into geological, technical, cultural, and historical aspects of the hosting location. Different experiences/stories that reflect the human side behind geothermal technologies are a valuable asset for understanding how progress in geothermal can be made in the long-term. Such stories provide a hopeful vision to participants coming from areas with conflict and should be based on realistic examples seen during the field trips and other activities, where a positive change is indeed possible.

2.4 Educational topics

The following list served as a list of content when organizing a training.

Introductory concepts

- Renewable energy sources and geothermal energy;
- Basics of hydrogeology and fluid dynamics;
- Basics of thermodynamics, heat transfer, mass and energy balance;
- Building heating and cooling and climate change;
- Heating and cooling networks – planning and construction;
- The European heating and cooling sector – energy economics;
- Interdisciplinarity in the geothermal sector and the related workforce requirements towards geologists, geophysicists, hydrogeologists, drillers, petrophysicists, energy engineers etc.;
- Public perception and targeted communication;

- Dissemination in general.

Exploration and Utilization

- Classification of geothermal resources and plays;
- Exploration methodologies (3D geological mapping, geophysics, drilling, pumping tests, thermal response tests, heat transfer measurements, geochemistry...);
- Measurement of thermal properties of soils and rocks in laboratory and in the field;
- Uncertainty quantification related to geoscientific data models;
- Data management & monitoring;
- Dimensioning and optimization of the geothermal energy use;
- Sustainable use of resources and environmental impacts;
- Recovery methods (subsurface heat transfer), reservoir engineering (including numerical modeling);
- Operational issues (scaling & corrosion, gases, seismicity etc.)
- Lifetime management and decommissioning.

Technologies

- Technologies for production and storage
    - Shallow geothermal energy (GHP, closed loop, open loop, geoenergy structures)
    - Direct use of thermal water
    - Subsurface energy storage
    - Cogeneration of heat, power and minerals
    - Hybrid systems and sector coupling
- Energy conversion
- Energy efficiency & loads and comparison analysis
- Maintenance and safety
- Buildings stock & heat loads
- Topologies of district heating and cooling networks including control systems;
- Integration of geothermal energy into heating and cooling networks.

Policies

- Legal framework (policy, regulation and legislation) at international, European and national levels;
- Policy making processes;
- Spatial planning;
- Limitations of use and environmental impact assessment;
- Geothermal project development;
- Data accessibility and management.

Finances

- Risk assessment and risk mitigation schemes related to different categories of geothermal energy use (from low to deep geothermal systems);
- Insurance and risk mitigation schemes;
- Business models for developing of geothermal energy use and energy contracting;
- Funding schemes;

- Sustainable finances.

Engagement

- Public perception;
- Communication;
- Social acceptance;
- Industrial acceptance;
- Raising awareness of stakeholders.

2.5 Training modules

Main trainings: During CA18219 Geothermal-DHC, each in-person training (training school / summer school) had a slightly different thematic focus to cover the main technological concepts of using geothermal energy in heating and cooling networks. Duration of training was varying between 3 days and 5 days. Each training was organized as an independent educational unit.

We aimed to incorporate several types of learning methods during our trainings:

- Lectures with hands-on exercises (use open-source software tools, if possible);
- Field trips to pilot sites including field exercises (geoscientific data surveys);
- Student presentations;
- Joint project related teamwork including final presentations.

3 OVERALL EDUCATIONAL PLAN

The experience from training schools held from 2021 to 2023 (in Slovenia and Croatia on July 2021, in Cyprus on September 2021, in Delft in July 2022 as well as in Slovenia on July 2023) gave valuable insights and enabled the formulation of learning outcomes for the programs intended for PhD students. Although the opinions on interesting topics differed between the groups, trainers had the opportunity to better assess the background knowledge, but also to define the type of projects the students were engaged in, which enabled the members of Ad-Hoc working group on the Educational Concept to formulate the learning outcomes.

Mandatory Learning Outcomes of the Educational Activities for future geothermal specialists:

- Understand the main elements of geothermal heating/cooling concepts and the related advantages as well as disadvantages of each concepts;
- Define SWOT analysis of geothermal energy use for district heating and cooling (DHC) scenarios
- Understand the mechanisms of groundwater flow and heat transfer through the porous and fissured media;
- Apply methods to appraise subsurface conditions (groundwater flow, heat flow and thermal rock properties) with limitations due to scale and uncertainties;
- Understand key engineering concepts to integrate geothermal energy into heating and cooling networks at different temperature and capacity level;
- Know main national and EU regulations regarding exploration and use of geothermal resources;
- Understand the potential of geothermal energy in the climate change mitigation and energy transition in Europe as well as on a national basis;

- Understand challenges and technical as well as societal hurdles towards the wider use of geothermal energy in terms of geological settings, regulations, financial models and public acceptance;
- Understand the different development phases of geothermal projects for heating and cooling networks;
- Understand the options for combining geothermal energy with other energy carriers in multivalent heating and cooling networks including underground thermal energy storage systems (UTES);
- Understand and address concerns that investors and the general public have towards geothermal energy use (financial risk, economic viability, environmental impact).

Mandatory learning outcomes are defined in a way that enables their testing through the project work in pairs or in groups.

Desirable Learning Outcomes of the Educational Activities:

- Classify geothermal reservoirs (shallow, medium, and deep) based on their geological settings as well as geothermal fluids regarding their chemical composition, assume possible operational issues and their mitigation possibilities;
- Understand the concept of geothermal heat pump (GHP) and list the GHP technologies and types;
- Understand the different options in network design for geothermal DHC systems and define their applicability;
- Understand the challenges of the introduction of geothermal energy sources into the DHC distribution networks in the context of the building sector;
- Understand the concept of artificial (e.g. enhanced geothermal reservoirs, i.e. Hot Dry Rock (HDR)) geothermal reservoirs) and other novel technologies;
- Design underground thermal energy storage sites for different geothermal concepts;
- Understand economic factors influencing viability of geothermal DHC projects;
- Perform techno-economic analyses of geothermal DHC projects and present a business case;
- Perform life cycle analyses (LCA) regarding life-cycle costs and environmental impact for different geothermal heat supply and storage concepts;
- Consult investors about best development strategies and needed sequence and time

4 IN PERSON TRAININGS AND SUMMER SCHOOLS PERFORMED IN CA18219

4.1 Training School Cyprus 2021

4.1.1 Title

Design and operation of shallow geothermal energy systems for heating and cooling

4.1.2 Date and location

Five days, September 20th – 24th, 2021, in Limassol, Cyprus.

4.1.3 Organizer and trainers

The training school was co-organized together with the Faculty of Engineering and Technology of the Cyprus University of Technology, Limassol, Cyprus.

Main organizers and trainers:

Paul Christodoulides (paul.christodoulides@cut.ac.cy)

Georgios Florides (georgios.florides@cut.ac.cy)

Additional trainers:

Soteris Kalogirou (renewable energy systems)

Gregor Goetzl (communication and geothermal energy in heating and cooling networks)

Rao Martand Singh (shallow geothermal energy – basic engineering and planning)

Giuseppe Mandrone (integration of geothermal energy in low temperature heating and cooling networks)

Vasiliki Gemeni (communication and dissemination)

Saqib Javed (low temperature heating and cooling networks)

Lazaros Aresti (renewable energy systems)

Soren Andersen (low temperature heating and cooling networks – social-economic aspects)

Konstantinos Tsagarakis (legal and business models related to shallow geothermal energy systems)

4.1.4 Attendants

The training school was attended by 21 students of which 16 attendants. Of these, 11 were physically present while 5 were present online. Five trainees were from Cyprus.

The attendants were engineers, geophysicists, geologists, hydrogeologists and social scientists, The academic level of trainees was equivalent to the MSc level (all possessing at least a BSc degree).

4.1.5 Program

The duration of the school was five days. This includes a 1-day student conference, a 3-day intensive training school separated into lectures, workshop and laboratory work, and a 1-day field trip covering 2 site-visits.

The documentation of the training school can be downloaded **here**.

4.1.6 Feedback from the attendants

To attain the feedback for quality control and to examine the main topics of interest, feedback forms were distributed to attendants.

The themes that students found most interesting were :

- Fundamentals of low-temperature heating and high-temperature cooling
- Heat pumps and geothermal heat pumps
- Thermal properties of soils and rocks
- Implementation of shallow geothermal energy in 5GDHC
- Performance of 5GDHC
- Integration of the ground and the building in system planning
- Technical limits of heat pumps

The themes that students found least interesting were:

- Use of Geothermal Response Test results and technical suggestions
- Results and major outcomes of a field study on energy structures
- Development and testing of a concept for a science cafe linked to CA18219 Geothermal-DHC
- Basic principles of economic evaluation and sensitivity analysis
- European Legal Framework on Renewable Energy Systems and Renewable Energy Directive

- Performing a SWOT analysis

The students were overall satisfied with the Training School, giving it an average 4 out of 5 marks. In particular they were really content with:

- Communication with organizers
- Application procedure (easy and fast)
- Meeting interesting people
- Meet and greet with local shallow geothermal energy planners and/or drillers and experts
- Information about training school (programme, venue)

However, the students expressed that there was room for improvement regarding a stricter organization of content before the training school in order to avoid repetitions. Also, they suggested that the schedule and the time management could be improved with more time allocated for discussion and questions from the audience.

Additionally, some of the attendants were more interested in deep geothermal energy systems and thought that this sector could have been better covered. Others were interested in more specific topics such as in-depth technical planning of district heating networks and different ground heat exchangers, numerical modelling , borehole installations, numerical and semi-analytical modeling of heat transfer in borehole , funding the lectures too general

The trainers were overall very content with the level of interest and the commitment of the students. Both the students and the trainers were happy with the side events with the visit to the Municipal Library Geothermal System Archaeological Site

4.2 Summer school #1 – Slovenia & Croatia (July 2021)

4.2.1 Title

Coupling Technologies to use low and medium depth hydro-geothermal energy

4.2.2 Date and location

The summer school lasted for 8 days and took place from 12th – 19th July 2021. The lectures were given at the Department of Geology, Faculty of Natural Sciences and Engineering, University of Ljubljana, Aškerčeva cesta 12, SI-1000 Ljubljana, Slovenia; https://www.ntf.uni-lj.si/og/en/.

Laboratory activities and part of the field work were performed at the Geological Survey of Slovenia (GeoZS, Dimičeva ulica 14, SI-1000 Ljubljana, Slovenia; https://www.geo-zs.si/index.php/en/), while the other field work at several sites within the field trip in SE Slovenia and N Croatia.

The training consisted of: i) 2 days of field trip; ii) 1 day student conference; iii) 3.5 days of lectures; iv) 1 day for student projects and v) 0.5 day for exam.

The booklet with agenda, student conference abstracts and filed assignments is available at https://www.geo-zs.si/PDF/Projekti/Geothermal-DHC/COST_guidebook.pdf

4.2.3 Organizer and trainers

The training was co-organized by five projects/organizations: COST project CA18219 Geothermal-DHC, Geological Survey of Slovenia (GeoZS, Dimičeva ulica 14, SI-1000 Ljubljana, Slovenia), Faculty of Natural Sciences and Engineering (NTF UL), University of Ljubljana, Slovenia, Faculty of Mining, Geology and Petroleum Engineering (RGN, Pierottijeva 6., p.p. 390, 10 000 Zagreb, Croatia), and Croatian Geological Survey (HGI-CGS, Milana Sachsa 2, 10 000 Zagreb, Croatia).

Main organizers and trainers:

Mihael Brenčič,(Faculty of Natural Sciences and Engineering of University of Ljubljana, Geological Survey of Slovenia,mihael.brencic@geo.ntf.uni-lj.si); Nina Rman (Geological Survey of Slovenia, nina.rman@geo-zs.si); Iva Kolenković Močilac (Faculty of Mining, Geology and Petroleum Engineering of University of Zagreb);Tomislav Kurevija (Faculty of Mining, Geology and Petroleum Engineering of University of Zagreb); Staša Borović (Croatian Geological Survey)

Other trainers:

Tine Compernolle (University of Antwerp, Royal Belgian Institute of Natural Sciences – Geological Survey of Belgium)

Hrvoje Dorotić (Faculty of Mechanical Engineering and Naval Architecture of University of Zagreb)

Philippe Dumas (European Geothermal Energy Council)

Gregor Goetzl (MSc, Geological Survey of Austria)

Marija Macenić (Faculty of Mining, Geology and Petroleum Engineering of University of Zagreb)

Rao Martand Singh (Department of Civil and Environmental Engineering, Norwegian University of Science and Technology, Trondheim, Norway)

Maja Turnšek (Faculty of Tourism of University of Maribor)

Phil Vardon (Faculty of Civil Engineering and Geosciences, TU Delft)

4.2.4 Attendants

There were 19 trainees from 12 countries attending, 7 female and 12 males. One was an MSc student, 13 PhD students, 2 early career investigators and 2 young professionals. Five were from Slovenia, two from Croatia, the rest from other countries.

4.2.5 The feedback from the attendants

For attendants successfully passing the exam and presenting the student projects, 3 ECTS were granted by a Thermogeology course at the MSc programme level at NTF, University of Ljubljana.

Extensive questionnaires were distributed to attendants to attain the feedback for quality control, but also to get unambiguous feedback on main topics of interest. The main results are shown in Figures 1 and 2.

From the results of the questionnaire on relevancy of topics presented, as shown in Figure 1, it is obvious that most of the topics presented to the students were well received. The attendants found basic concept of heat transport and transfer to be among the most relevant topics and that was rather unexpected, since it could be characterized as common knowledge for PhD students engaged in geothermal PhD projects. On the other hand, the information concerning fossil fuels, although only marginally presented, was considered the least relevant . This was expected, considering the attendants' interests in renewable energy . However, knowledge gained in decades of research in O&G sector bears some relevance for geothermal energy systems and that was recognized by attendants.

The attendants proposed to offer well-recognized trainers and more scholarships as well as to link trainings to ECTS credits. In addition, they proposed to organize social-thematic side events. Among other considerations a ttendants said that:

- t he lectures should not be longer than 90 minutes, allowing for 15 to 20 minutes of discussion at the end;

- it would be useful to have more personal lectures than hybrid;
- Introductory events (team building, student conference, field trip) should be soon in the beginning to allow for better acquaintance and easier team work later;
- it would be interesting to have more practical (business) examples and real price data;
- If a field trip is planned to special environment (e.g. caves, shafts etc.) attendees should be properly informed in advance if they have any issues with it.

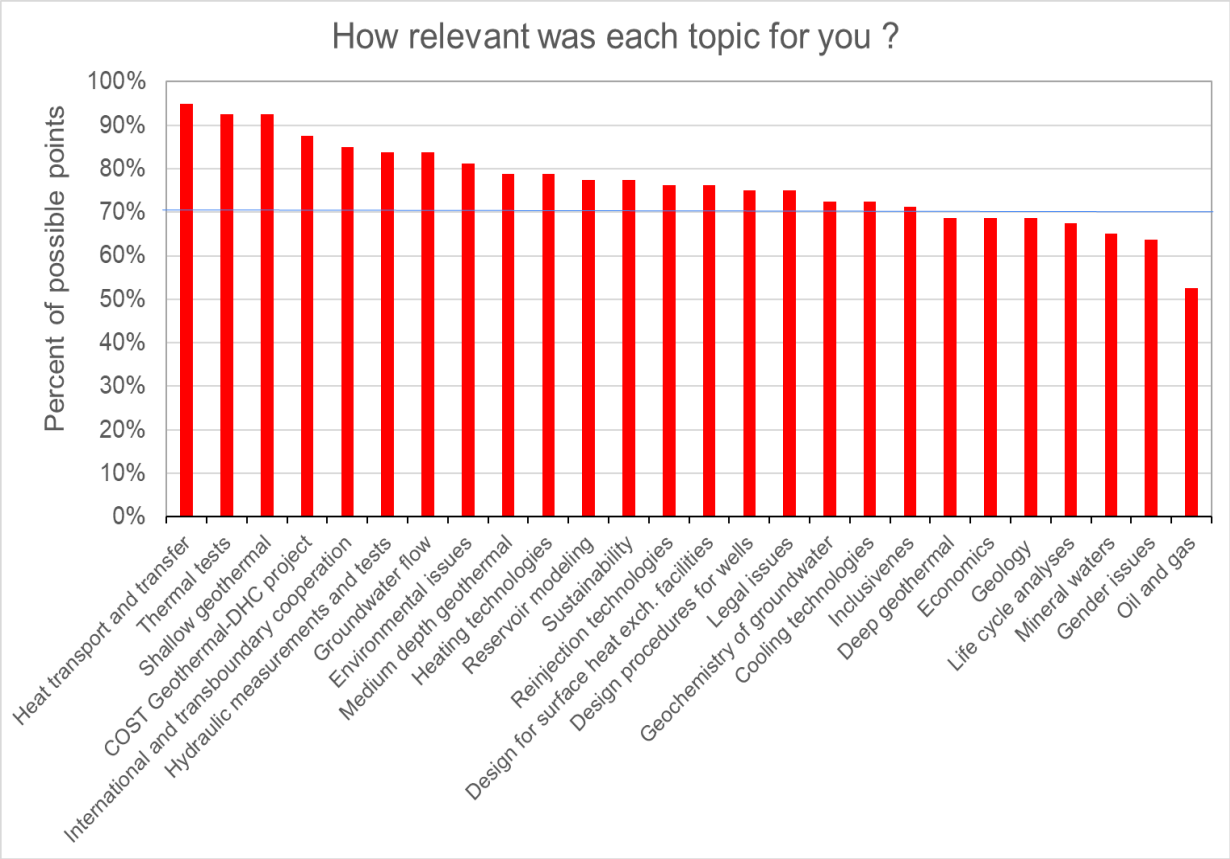

Figure 1: Relevancy of topics presented to students during the Summer School in Slovenia and Croatia in 2021

Attendants were also asked about their interest in different types of activities organized within the Geothermal DHC COST Action. The results are presented on the graph in figure 2 which shows that all attendants found physical workshops interesting, with large majority showing great interest in Summer schools and trainings as well as Short term scientific Missions, while they showed least interest for online events.

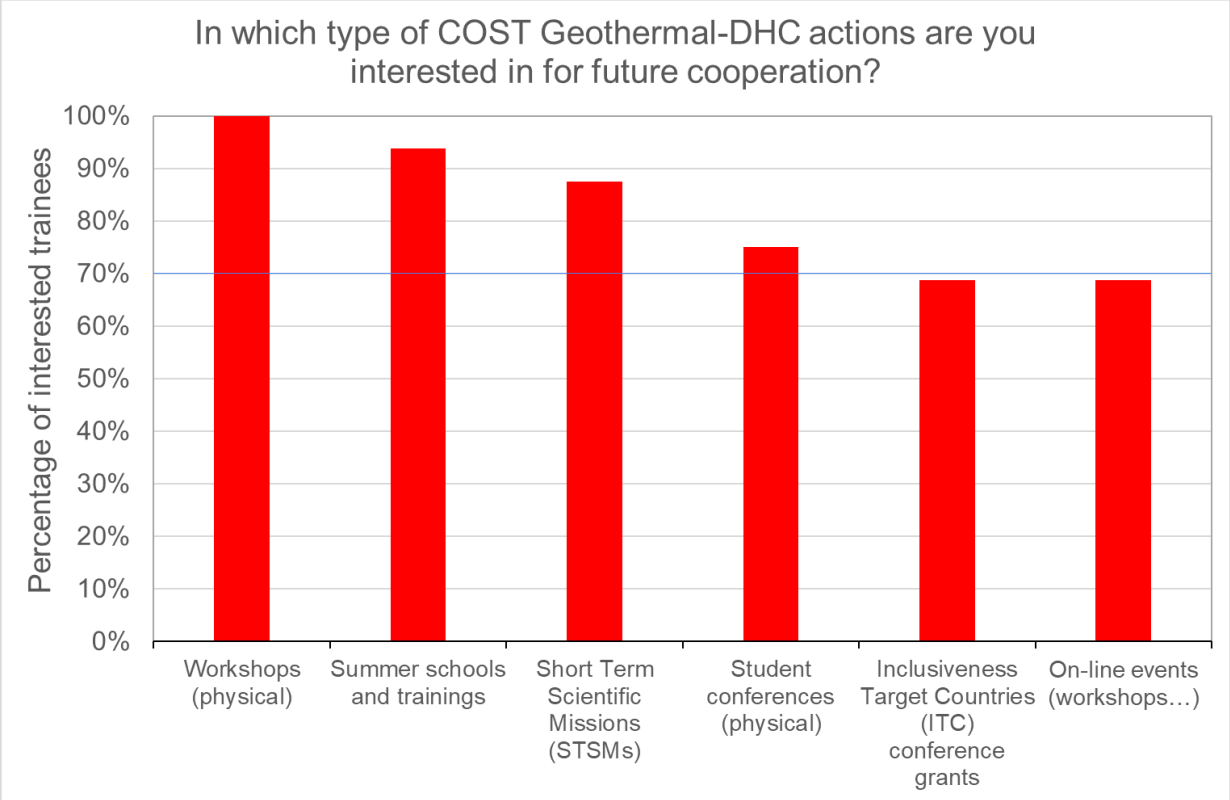

Figure 2: Relevancy of tools offered by the COST program.

Overall impression of the Summer School was very positive. Students emphasized that the different school activities offered deeper insights into technical, cultural, and historical aspects of all the places that were visited.

4.3 Summer School in Delft in 2022

4.3.1 Title

Geothermal District Heating and Cooling - Renewable district heating and cooling systems, using geothermal resources

4.3.2 Date and location

The summer school lasted for 5 days and was held from 11th till 15th of July 2022 at TU Delft, the Netherlands.

4.3.3 Program outline

Day1 started with team building and assessment of the attendants' background. The attendants gave presentations on their own work. The second day was dedicated to lectures on Geothermal heat direct use & other sources of renewable heat, 5th generation of District Heating Networks, Mine + tank + pit thermal energy storage, Aquifer Thermal Energy Storage (ATES) Systems (technical and legal framework across Europe, Chemical composition and Water Quality issues. The attendants started the work on project assignments. These assignments were focused on designing the renewable heating/cooling system including heat storage components based on real cases from practice provided by industry partners. The day ended with the off-campus field trip at a nearby geothermal installation for agricultural use.

On the third day lectures on Heat pumps, BHE, Geo energy structures, Legal aspects of geothermal energy use in district heating and cooling and Reservoir thermal energy storage were given and attendants continued their work on project assignment (sizing of components, modes of operation). Fourth day included an industry workshop about business case development with financial analysis. Also, work on assignment was conducted with experts' help on financial aspects. Another off-campus field trip was organized to Rijswijk Well Research Centre.

Last day was dedicated to finalizing the work on project assignment and ended with Final presentation session.

The documentation of the Summer School can be downloaded **here**.

4.3.4 Organizers and trainers

Delft University of Technology is one of the oldest universities of the Netherlands and ranks among the best universities in the world. Geothermal team within the Delft University of Technology has the expertise covering all aspects of the heat transition. The Summer school was organized by the COST Action Geothermal DHC and geothermal theme coordinators of the TU Delft:

Phil Vardon, David Bruhn, Alexandros Daniilidis and Martin Bloemendal.

Additional trainers were:

Gregor Goetzl, Geological Survey of Austria, Austria

Nina Rman, Geological Survey of Slovenia, Slovenia

Søren Erbs Poulsen, VIA University College, Denmark

Guus van Geldere, GroenHolland, the Netherlands

Erick Burns, United States Geological Survey, USA

Rao Martand Singh, Norwegian University of Science and Technology, Norway

Jessica Maria Chicco, University of Turin, Italy

Rogier Duijff, DWA, the Netherlands

4.3.5 Attendants

Summer school was attended by 25 attendants (PhD students) from 12 countries. Most of the attendants were from Europe (Germany, Italy Greece, Austria, Croatia, Poland, UK), but also from USA, Pakistan, Indonesia and Ivory Coast. 32% of attendants were female, information that clearly reflects the underrepresentation of women in geothermal energy exploration and production.

4.3.6 The feedback from the attendants

At the end of the school the attendants were asked to share their vision of geothermal energy. Many of the attendants emphasized the great potential of geothermal energy in a wide range of applications and expressed their eagerness to take part in harnessing that great potential. They also expressed understanding about underlying issues in exploration and exploitation of geothermal energy.

4.4 Summer School in Slovenia 2023

4.4.1 Title

Advances in developing geothermal resources for heating, cooling and electricity production

4.4.2 Date and location

The summer school lasted for 6 days and took place from 3rd to 8th of July 2023 in the Faculty of Natural Sciences and Engineering in Ljubljana, Slovenija.

4.4.3 *Program overview*

First the basic explanations on heat transfer were given along with the overview of thermal tests and then lectures moved to advances in exploration and exploitation. Lectures included presentations on energy piles, shallow geothermal energy systems, thermal water and geothermal electricity: settings, technologies, operation, grids, power market and project development. Half-day student conference was held (abstract book can be found at: https://www.geo-zs.si/index.php/en/?option=com_content&view=article&id=1120 and https://www.geo-zs.si/PDF/Projekti/INFO-Geothermal/DT_4_1_1%20Geothermal%20summer%20school_abstract%20book.pdf).

Also, a 1-day field trip with user-site visits in NE Slovenia at the beginning of the course took place demonstrating heat pump production, drilling geothermal wells, cascade use of thermal water, as well as demo of geothermal power plant from abandoned gas well. Half-day field work and laboratory measurements were conducted at the Geological Survey of Slovenia (GeoZS) and Environment Agency (ARSO). Summer school ended with 1-day of work on student projects and final exam.

4.4.4 *Organizers and trainers*

The summer school was organized by EEA Grants project INFO-GEOTHERMAL, COST action project CA18219 Geothermal-DHC, Geological Survey of Slovenia (GeoZS), Iceland School of Energy (ISE) and Faculty of Natural Sciences and Engineering in Ljubljana (NTF UL).

It is worth mentioning that the EEA Grants project INFO-GEOTHERMAL provided 5 trainers and 5 trainees from Eastern and South Eastern Europe and covered most of the organizational costs, while COST action CA18219 Geothermal-DHC provided 4 trainers and 11 trainees.

The organizers and trainers were:

Mihael Brenčič, Slovenia

Nina Rman, Slovenia

And additional trainers were:

Jeff Birkby, USA

Alexandros Daniilidis, the Netherlands

Hrvoje Dorotić, Croatia

Nicholas Fry, Canada

María Sigríður Guðjónsdóttir, Iceland

Juliet Newson, Iceland

Bjarni Palsson, Iceland

Rao Martand Singh, Norway

4.4.5 *Attendants*

24 attendants from 13 countries participated the Summer school, while one of them participated online due to problems with late visa approval. From the 24 attendants who physically attended all the lectures and completed all the practical exercises as well as field work, 6 were professionals working in the industry, 10 were PhD students, 7 were graduate students and 1 was undergraduate student. There were 11 female students (46%) and 14 students from ITC countries (58%). Most of the students were geoscientists. The attendants' resident countries were: Austria, Canada, Croatia, Egypt, France, Hungary, Iceland, Italy, Lithuania, The Netherlands, Poland, Slovenia, Sweden.

4.4.6 The feedback from the attendants

For attendants successfully passing the exam and presenting the student project, 3 ECTS was granted for a Thermogeology course at the MSc programme level at NTF, University of Ljubljana.

The attendants showed rather high interest in to presented topics, which is evident from the graph in the Figure 3, with Shallow geothermal resources and design being the most relevant topic, as well as Heat transport and transfer. The least interesting topics included presented information from Oil and Gas exploration and exploitation, as well as balneological topics.

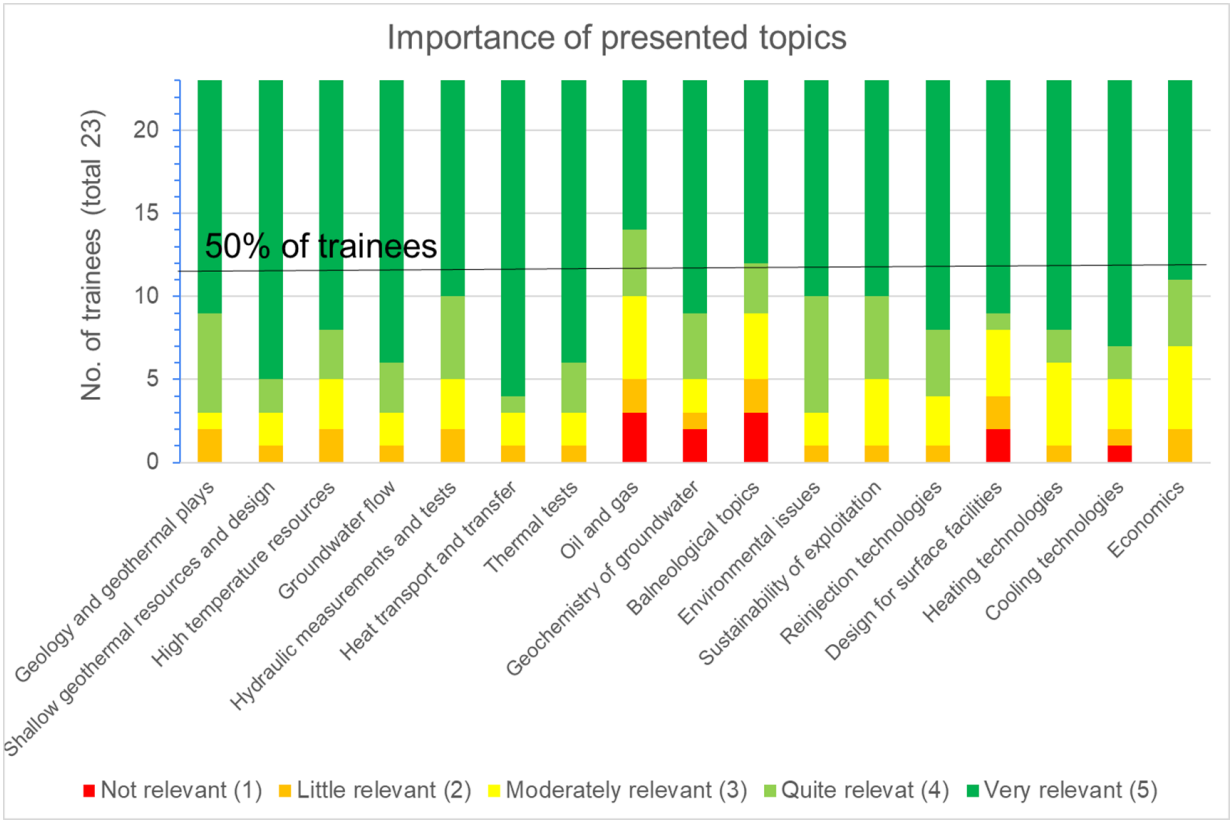

Figure 3: Assessment of the importance of the topics presented at the Summer School in Ljubljana 2023.

Overall impression about the Summer School was very positive, as can be seen from graph in Figure 4. Attendants praised the relevance of the lectures' content, the field trip and meeting interesting young people, and they were satisfied with most of the other aspects of the Summer School.

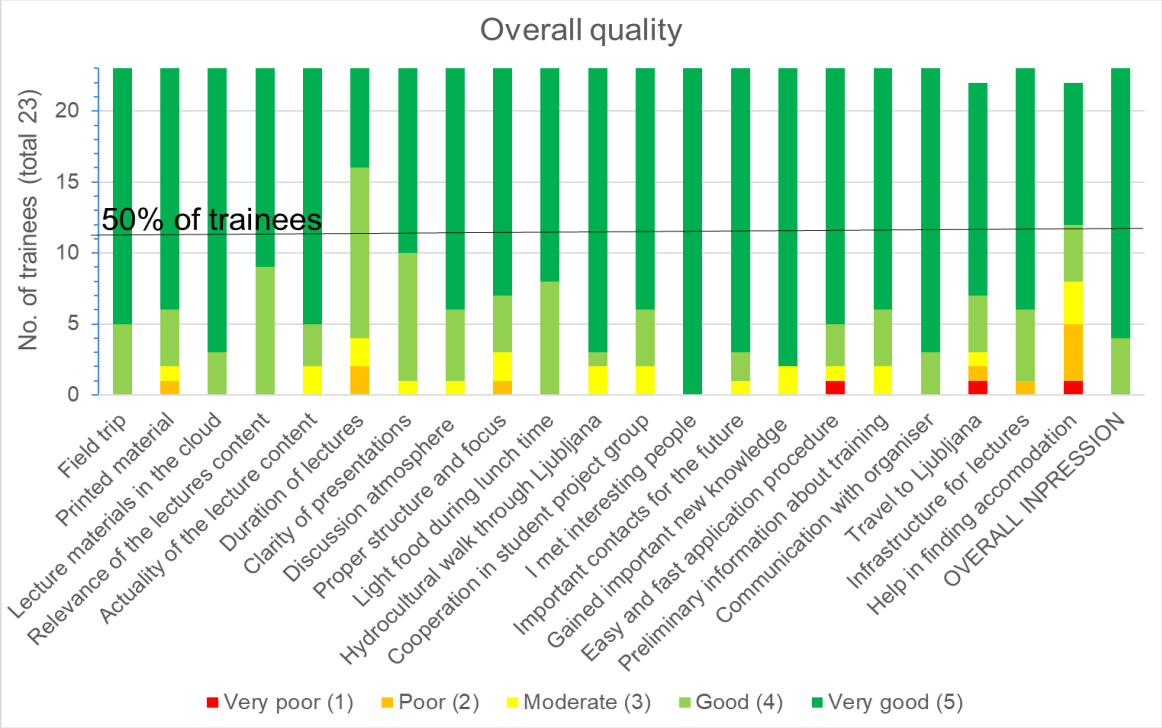

Figure 4: Attendants' assessment of quality of different aspects of the Summer School in Ljubljana 2023.

5 OTHER EDUCTIONAL ACTIVITIES PERFROMED INSIDE CA18219 GEOTHERMAL-DHC

In total, 9 activities including the before mentioned Summer- and Training Schools have been achieved in CA18219 Geothermal-DHC, which involved around 180 trainees in total.

Although main efforts have been dedicated to the in-person training schools described in chapter 4, the subsequently listed set of online educational activities has been offered by CA18219. Most of the activities were linked to virtual mobility grants (VMG) offered to trainers covering useful skills for young professionals.

Table 1: Overview of educational activities inside CA18219 apart from the main training schools.

Date	Title of training	Audience size (# of trainees)	Short description
4 April 2022	***Master Class on Geothermal Energy for Heating and Cooling Networks***	25 PAX	Masterclass on geothermal energy use with speakers from CA18219; the training was organized in the framework of an international master call at the Technical University of Lisbon and the Innoenergy - Knowledge Innovation Community Link to material
10 May 2022, 15 May 2022	***Online Training series "How to host an interactive virtual or hybrid meeting"***	15 PAX	The webinar series consisted of two events (10 May and 15 May); the second webinar hosted a masterclass; the training was linked to a virtual mobility Grant. Link to material.

4 April to 5 April 2023	***Geothermal-DHC session at the European Geothermal PhD Days 2023 in Glasgow***	30 PAX	CA18219 offered scholarships and speakers for a dedicated session on geothermal energy use in heating and cooling networks and organized a workshop on communication between science and society.
20 February 2024	***ECI Career Workshop and support for an online event to connect young researchers in the field of geothermal energy with industry***	10 PAX	This online training focused on professional self-promotion for young researchers and was linked to Virtual Mobility Grant. Link to material.

Apart from these activities, a webinar series on presenting the outcomes of Grants offered by CA18219 was launched in 2023. Awardees of all types of COST Grants (STSM, Virtual Mobility, ITC Conference Grants etc.) were asked to present their work after the accomplishment of the grant to CA18219 participants. This offered the opportunity to (a) share knowledge, (b) promote Grants offered by CA18219 and (c) promote the Grant Awardee. The documentation of the webinar series on the grants can be found at the output section of the CA18219 Geothermal-DHC web portal (www.geothermal-dhc.eu).

6 SUMMARY AND CONCLUSIONS

6.1 Summary of the educational activities achieved during the lifetime of CA18219 Geothermal-DHC

In total, CA18219 Geothermal-DHC (2019 – 2024) organized eight educational activities, which involved around 180 trainees, mostly consisting of PhD-students. The achieved educational activities can be divided into (1) key in-person / hybrid training schools and (2) other activities, mainly offered as virtual trainings and workshops. The key educational strategy of CA18219 consisted of the following elements:

- Collaborate with other international institutions and groups to enhance the impact of the educational activities and raise awareness on job opportunities linked to geothermal energy supplied heating and cooling;
- Adress the wide spectrum of geothermal energy in heating and cooling networks from different angles – thematic modules;
- Be inclusive and focus on the interdisciplinary aspects of geothermal energy use in heating and cooling networks – building bridges between geoscience, engineering and social sciences;
- Draw the interest of young professionals in tertiary education to move into the geothermal market.

The CA18219 training schools

All educational events that were conducted were aiming to achieve the balance of theoretical lectures, fieldwork and “hands-on” activities to efficiently transfer the knowledge about concepts that enable geothermal heating and cooling, as well as some specific methods that are important in geothermal exploration and exploitation.

Focus of three events was similar, but not the same: t he summer school in Slovenia and Croatia was focused both on shallow and to mid-depth geothermal energy. The summer school in Cyprus was oriented on shallow geothermal energy use, while summer school in Delft was focused on renewable district heating and cooling systems with introduction of underground thermal energy storage. The final summer school in Slovenia held in 2023 was oriented on high-temperature geothermal resources and

cooling possibilities. All four events had a goal to bring important technologies closer to young experts. Most were PhD students. However, due to underrepresentation of geothermal energy in higher education, most of them found even the explanations of basic concepts interesting and useful. This is irrefutable proof that geothermal energy needs to be introduced in a wide range of program curricula. primarily in the fields of geoscience and mechanical engineering), but also drilling and mining, energy engineering, finances, social acceptance and similar.

Activities outside the training schools

Other trainings offered by CA18219 were focusing on improving relevant "soft skills" of young researchers, such as communication and self-promotion. To raise the awareness on geothermal energy use in heating and cooling networks, CA18219 supported two educational activities organized by third parties: 1) A masterclass webinar on geothermal heating and cooling networks in 2022, organized by the he Technical University of Lisbon and the Innoenergy - Knowledge Innovation Community and 2) the European Geothermal PhD Days conference in 2023.

6.2 Conclusions

Educating young people about geothermal energy is crucial in promoting sustainable energy practices and fostering environmental awareness. Learning about good geothermal energy practice enables them to recognize its potential as a reliable and clean energy alternative, helping to mitigate the negative impacts of fossil fuels on our planet. It also empowers them to understand the benefits of utilizing this renewable energy source, such as reduced greenhouse gas emissions and energy independence.

Although campaigns to raise awareness of the importance of using renewable energy sources have been systematically implemented for many years, geothermal was often neglected. here is still room for raising the level of information for the general public about the benefits of diversifying the energy sector, especially the advantages of switching to renewable energy sources, both in electricity production, and in other spheres of energy use. An example that proves the slowness of the preparation for energy transition is the fact that educational programs in the field of energy are still mostly focused on fossil fuels. These programs provide valuable knowledge to students, enabling them to faster transfer in the field of geothermal energy. However, many aspects relevant for sustainable geothermal exploration and development of geothermal projects are underrepresented or simply missing. Thus, there is an evident need for interdisciplinary programs that are aiming to promote and offer knowledge on combinations on renewable energy sources and technologies, also geothermal.

In contrast to other renewable energy sources, such as biomass, wind-energy or photovoltaic, geothermal energy is affected by a strong uncertainty in planning due to prediction limitations of the hydrogeological subsurface conditions. To meet these challenges, new methods need to be developed to de-risk geothermal investments, either by engineered approaches or by financial means. For that reasons, successful solutions can only be found by joining key disciplines like geosciences including subsurface engineering, surface engineering including HVC, legal sciences as well as economics. Due to its economic nature, upfront costs dominate the life cycle costs of geothermal energy use. De risking of geothermal investments, as mentioned above, also relies on reducing the demand side of heating and cooling systems by modernizing the building- as well as heating network infrastructure. This leads to a certain economic exclusiveness of geothermal energy applications ("a technology for the rich"), which needs to need to be reduced to make access to clean geothermal energy available for all households in Europe. This addresses key societal challenges, which need to be considered by future professionals in the filed of geothermal energy development. The same applies to a safe and environmental friendly way to use geothermal energy, which is not accomplished in all countries using geothermal energy so far. Therefore, future fields of education and trainings shall also include environmental impact

assessment on a life-cycle basis and quality management to ensure an environmental friendly use of geothermal energy.

7 LESSONS LEARNED AND RECOMMENDATIONS TOWARDS INTERDISCIPLINARY TRAINING RELATED TO GEOTHERMAL ENERGY USE IN HEATING AND COOLING NETWORKS

In course of planning the educational activities, the organizers considered feedback from the previous activities. In that sense, the organization of the summer school in Slovenia and Croatia paved the way to following events. Programs of events were adapted in such a way as to cover all the topics that have been identified as interesting by the attendants of that first event, more time was dedicated to discussion, special care was taken to cover not only technical, but also social aspects of introduced technologies. Emphasize was given to aspects of events that were well received – this is mostly related to ample amount of field work.

The most important lesson however is that there is a lack of training activities in the field of geothermal energy and there is an increased demand for experts. This brings responsibility to the academic community, which must find ways to respond to this demand. And while training schools of limited duration are shown to be well accepted by the PhD students, they were also shown to be insufficient. It is of utmost importance to introduce basic geothermal energy concepts in higher education, on graduate, even undergraduate level. Recommendations and Outlook on follow-up activities

7.1 Interdisciplinary training schools on geothermal energy use in heating and cooling networks

Guidelines for selection of trainers and trainees – reach diversity

- Number of trainees: 15 to 30 based on an application procedure which considers educational background, career stage, geographical background and social inclusiveness - average share of at least 40% of each gender;
- Ensure the application procedure that the applicant commits himself/herself to attending the training school – motivation and input should be proven by motivation letters, and ongoing or proposed research activities linked to the topic of the training school;
- From various graduate academic levels also allowing for master students based on the quality of the application to attend the training school;
- Trainers and/or trainees from at least 3 different thematic backgrounds and regions – seek collaboration with regional universities at the location of the host to ensure ECTS credits for successful applicants;
- Trainers with an industrial background help to build a bridge from academia to praxis and should be encouraged to support training schools.

Check list for organizing a training school

- Total duration 5 to 7 days including field trips;
- Attendance mainly in-person with possibility for hybrid for a number of key sessions in justified cases (illness, travel visa);
- Field trips in the beginning of the training school are very helpful for icebreaking and a soft start of the training;
- Vary the methods and ensure a high level of interaction and engagement of the trainees by hands-on exercises and field studies, if possible;
- Ensure an active involvement of the trainees by:

    - Pitching sessions, during which the students present their background and work related to the topic of the training school (based on their application);
    - Organize a 1 to 1,5 days group work related to the topics of the training schools – the groups need to present their results at the end of the training school;
- Publish a booklet (book of abstracts for student conference / field assignments / agenda);
- Give certificate of attendance and ECTS credits, if possible;
- Assure financial coverage of the event and attendance of participants by scholarships;
- Present good case studies on project development from industry perspective;
- Do not over-fill the programe with too many lectures and allow sufficient space for networking and unstructured knowledge transfer – at least 25% of each training day should be reserved for unstructured interaction by ensuring breaks and at least 15 minutes after every lecture for discussion
- Organize social events and allow for enough time for team building at all stages of the training school;
- "Meet and greet sessions" for interconnecting trainees to regional decision makers, like companies, investors, policy-makers and authorities are very helpful to connect academic students to work-practice and raise awareness on the training school among regional stakeholders.

The important part of this educational concept are the learning outcomes that were largely influenced by deeper understanding of the knowledge that needs to be adopted by young experts in order to enable them to work efficiently on projects focused on the research and exploitation of geothermal energy in district heating and cooling. Namely, learning outcomes are not shaped only with respect to demands of the work market, but they must be shaped from the certain baseline of knowledge that is expected from the attendants entering the program. The training events helped to establish this baseline, as well as to incorporate the social aspect of the geothermal exploitation. That's why these are ready to be shared with academia and to be implemented in curricula of PhD programs, possibly even Master programs.

7.2 Strategy on continued education on geothermal energy use in heating and cooling networks beyond the lifetime of CA18219 Geothermal-DHC

Our aim is to keep organizing at least one training school per year!

The COST programme should also support graduate students and young professionals who can be re-direct into geothermal but are not yet (interested) in PhD level.

Financing for trainers and trainees should be assured to have higher participation and interest in trainings.

The next few years it is possible to organize trainings through CA21156 FOLIAGE (already planned in May 2024 in Madrid as well as 2025 in Slovenia), later new solutions are needed. If funding is desired from the industry, it is usually required to promote their technologies which is not always in accordance with neutral, expert status. Most industry is not interested in open-loop systems, so it is difficult to expect such funding. European heat pump association might be able to help to search for funding. Better solution are new networking application – such as new COST projects, new EEA (EFTA) networking programmes, aimed at raising awareness (especially for management aspects) and gaining skills (for engineers and geoscientists).

Need for stronger promotion on different channels!

Currently, most trainees learned about the events from personal communication with supervisors, colleagues and similar. Their proposal for best promotion channels are:

- Personal contacts and contacts from previous trainings (emails, but be careful about personal information);
- Project group emails, LinkedIn, WhatsApp and similar channels (FOLIAGE, Geothermal-DHC will stay active for some time, SAPHEA...);
- Contacts from universities (no summary lists of geothermal experts exist so far);
- International Geothermal Association (IGA) newsletters;
- European Geothermal Energy Council activities;
- Women in Geothermal (WING) network;
- National geothermal associations
- International Association of Hydrogeology (IAH)

Much attention should be made on keywords and proper #hashtags should be used, e.g.:

#geothermalenergy, #training, #education, #egreenenergy, #energyproduction, #renewables #geoHCnetworks…

8 ANNEX 1 – LIST OF TRAINERS

Table 2: Overview of trainers of the CA18219 training schools.

Summer school	**Cyprus, 2021**	**Slovenia & Croatia, 2021**	**Delft, 2022**	**Slovenia, 2023**
TRAINERS	11	13	12	10
Alexandros Daniilidis			1	1
Bjarni Palsson				1
David Bruhn			1	
Erick Burns			1	
Georgios Florides	1			
Giuseppe Mandrone	1			
Gregor Goetzl	1	1	1	
Henk Witte			1	
Hrvoje Dorotić		1		1
Iva Kolenković Močilac		1		
Jeff Birkby				1
Jessica Maria Chicco			1	
Juliet Newson				1
Konsantinos Tsagarakis	1			
Lazaros Aresti	1			
Maja Turnšek		1		
María Sigríður Guðjónsdóttir				1
Marija Macenić		1		
Martin Bloemendal			1	
Mihael Brenčič		1		1
Nicholas Fry				1

Nina Rman		1	1	1
Paul Christodoulides	1			
Phil Vardon		1	1	
Philippe Dumas		1		
Rao Martand Singh	1	1	1	1
Rogier Duijff			1	
Saqib Javed	1			
Soren Andersen	1			
Søren Erbs Poulsen			1	
Soteris Kalogirou	1			
Staša Borović		1		
Tine Compernolle		1		
Tomislav Kurevija		1		
Vasiliki Gemeni	1			
TRAINEES	**21**	**19**	**25**	**24**
local	5	5	2	5
international	16	14	23	19
Female		7	8	11
Male		12	17	13
BSc student		0	0	1
MSc student		1	1	7
PhD student		14	23	10
Early Career investigator		2	0	0
Young professional		2	1	6
Countries of residence		12	12	13