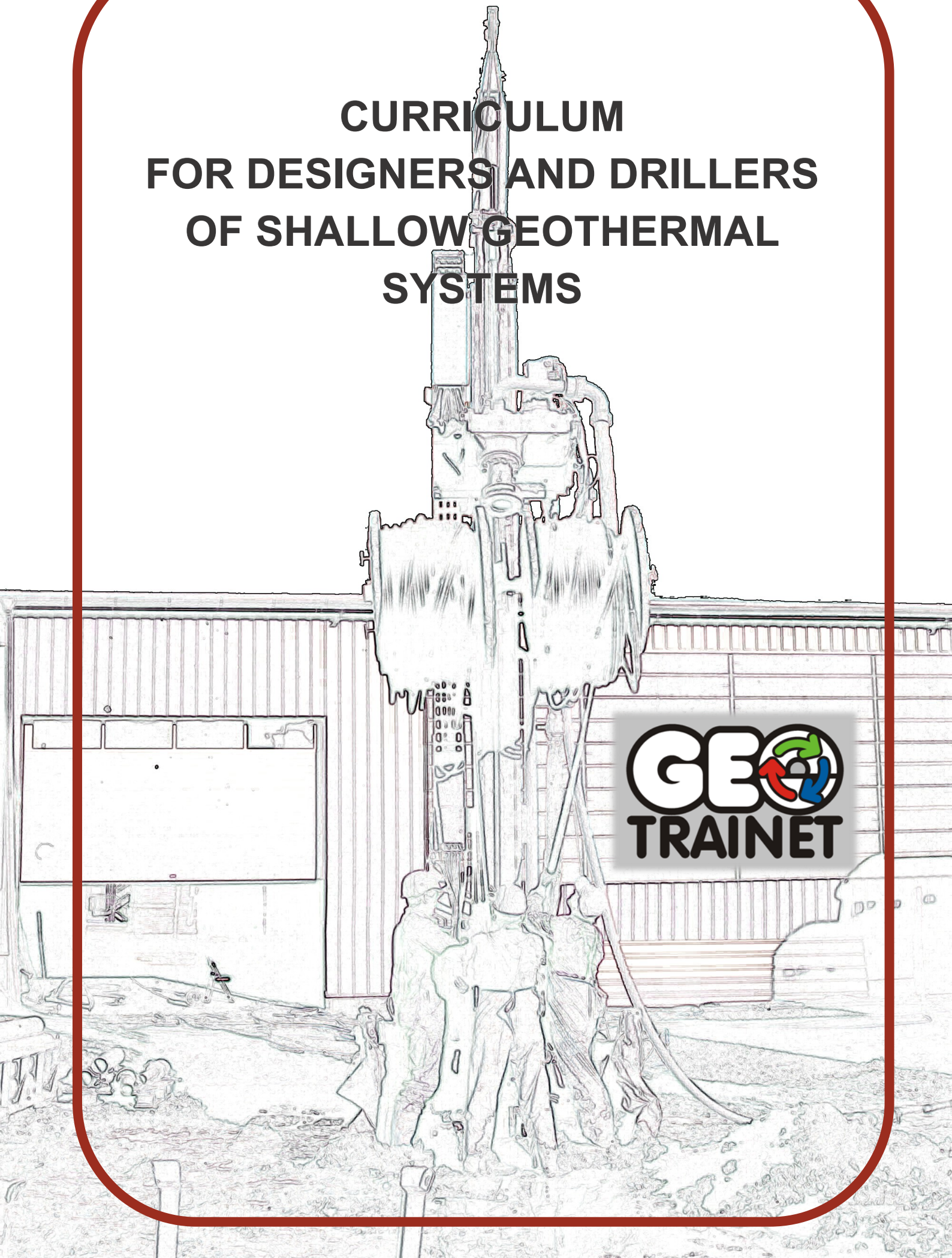
CURRICULUM FOR DESIGNERS AND DRILLERS OF SHALLOW GEOTHERMAL SYSTEMS



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1 Curriculum for Designers

The following table contains the curriculum for geothermal designers, including detailed information on the knowledge imparted during each of the seven sections of the course (Fundamentals and constraints; Introduction to design; Integration with the ground; Integration with the building; GSHP system alternatives; GSHP installation; Regulation).

In the right column the table also presents expected learning outcomes of the training courses for Designers. GEOTRAINET Learning outcomes are statements of what a learner is expected to know, and/or be able to demonstrate at a completion of a period of learning. The GEOTRAINET programme outcomes can be described as quality standards for competences, skills and knowledge. They have been ranged in the following categories:

- Underlying Basis
- Analysis, Design and Implementation
- Technological, Methodological and Transferable Skills
- Other Professional Skills

For each of the mentioned categories the levels of knowledge and skill are measured against the criteria of APPRECIATION, KNOWLEDGE, EXPERIENCE and ABILITY.

A	FUNDAMENTALS AND CONSTRAINTS	LEARNING OUTCOME
A1	**Overview of shallow geothermal systems** This subsection gives an overview of the natural and technical background, starting from ground temperatures and basic system concepts. As geothermal energy, in the public's perception, is often associated with volcanoes and geysers, the possibilities to use the shallow underground with moderate temperatures need to be explained. The difference in the concept of Ground Source Heat Pump (GSHP) and Underground Thermal Energy Storage (UTES) is presented, as well as the possible options for coupling the systems to the ground. The advantages and disadvantages of both closed systems (Borehole Heat Exchangers, BHE) and open systems (groundwater wells) are highlighted. The subsection is rounded up by information of market and prospects.	**UNDERLYING BASIS** • Knowledge of ground-coupling technology alternatives • Knowledge of GSHP limiting conditions
A2	**Limitation** This subsection considers the potential of shallow geothermal systems as well as limiting factors when it comes to apply them in practice. It is intended to make the students aware of the boundary conditions within which the design of shallow geothermal systems needs to be done, in respect to possible energy sources; geology / hydrogeology; climate; environmental issues; costs; regulations.	**ANALYSIS, DESIGN AND IMPLEMENTATION** • Ability to perform the feasibility study
A3	**Concept and feasibility studies** This subsection deals with the information required for performing a feasibility study and how to get this information. For such study, the following questions have firstly to be answered: Will a Ground Source Heat Pump (GSHP) with groundwater wells or Borehole Heat Exchangers (BHE) be allowed on a certain site? What is the underground geology in regard to thermal parameters, drilling, and environmental issues? What are the thermal loads to be covered? With this data the ground-side design can be assessed in a preliminary way. For the underground data acquisition, in the stage of a concept study typically no investigations penetrating into the underground (drilling, geophysics) are made, in order to keep costs low. Finally, the economic feasibility needs to be checked: What are the estimated investment and operation costs?	
B	**INTRODUCTION TO DESIGN**	**LEARNING OUTCOME**
B4	**Ground heat transfer** Some fundamentals of heat transport in the underground are covered in this subsection. Basically there are three possible kinds of heat transfer: Heat Conduction, Heat Convection, and Heat Radiation. Inside soil and rock, heat radiation can be neglected. Hence only two transport mechanisms need to be considered. In many cases, the actual heat transfer in the underground is a mixture of both conduction and convection, in varying degrees; in solid rocks without pore space, heat transfer occurs by conduction only.	**UNDERLYING BASIS** • Knowledge of Borehole Heat Exchanger Design Fundamentals
B5	**Design criteria** The most important design criteria for ground source heat pump systems are the following: High performance, high reliability, high system safety, cost effectiveness A high performance of the GSHP installation must be achieved. To achieve high system reliability over the lifetime of the whole system is not a sole question of proper design; much more important are: the installation work, the commissioning, overall quality control. The installation should use only certified, tested and approved material and system parts. To guarantee high system safety, both installation and the future operation have to follow exactly any manufacturers' and authorities' instructions and specifications. Beside these items, there is a main maxim to follow in the design procedure: simplicity. The systems should be as simple as possible. This maxim helps to minimize many of the possible system faults during operation.	

B6	**Borehole heat exchangers** In this subsection the BHE is discussed in all aspects, both in thermal transport theory and in practice. A BHE should allow for as little temperature difference as possible between surrounding ground and fluid inside the pipes. This can be expressed with borehole thermal resistance (rb), a summary parameter. For the pattern of groups of BHE it can be said that for heating-only installations a maximum thermal interaction with the surrounding ground is desired, since the intention is to extract the thermal energy from the ground (or to dissipate it into the ground). In case the ground should be used for storage of thermal energy (UTES), too much thermal interaction with the ground surrounding the storage volume in the ground is undesirable.	**ANALYSIS, DESIGN AND IMPLEMENTATION** • Knowledge of GSHP Design Criteria
C	**INTEGRATION WITH THE GROUND**	**LEARNING OUTCOME**
C7	**Geology** The geological framework is a mandatory issue in every shallow geothermal system design procedure. In comparison to conventional heating and cooling installations, the ground is the additional element in a GSHP. While designing a GSHP installation, an accurate knowledge of the geological conditions where the GSHP is located and the way of integrating this data while sizing the heat pump are key parameters in the success of the project. The differences between rocks and soil, the basic classification of different families of rocks, understanding its disposition in the ground, knowing the fundamentals of ground mechanical, thermal and hydrogeological behavior are necessary matters in the design of medium and large GSHP systems.	**UNDERLYING BASIS** • Knowledge of geological and geothermal parameters of the underground • Basic hydrogeological knowledge • Familiarity with different drilling and digging technologies
C8	**Drilling** Shallow geothermal systems are mainly based on boreholes and wells. Knowledge about the different drilling methods and tools, the field of application, their limitations, costs and risks are principal issues. In the same way the designer should know about casing systems, piping alternatives, filling and sealing materials, as well as methods of execution. This subsection supplies the information for choosing the appropriate drilling method for the planned system, for determining diameters or the necessity for auxiliary casing, and to forecast the costs in order to evaluate the technical and economical feasibility of different alternatives.	**ANALYSIS, DESIGN AND IMPLEMENTATION** • Appreciation of the complexity of geological problems and the feasibility of their solution • Knowledge about the choice of the optimum drilling method • Appreciation of the preparation of borehole reports including lithology and groundwater • Ability to perform the relevant documentation including identification and drawing of drilling locations
C9	**Site investigation (ground conditions / licenses and permits)** This subsection considers the importance of pre-investigation before finalizing a ground source heating and cooling (GSHP) design and commissioning a system. It considers three phases to pre-investigation: - Desk Study - Legal and Regulatory Issues - Site Investigation While the legal and regulatory side can only be treated more generally on a European scale (most relevant procedures are defined on national level and need to be outlined separately in courses for each country concerned), the site investigations are dealt with in more detail. In particular the two standard techniques are explained comprehensively: The well test (pumping test) for groundwater wells, and the Thermal Response Test (TRT) for closed systems, respectively.	
D	**INTEGRATION WITH THE BUILDING**	**LEARNING OUTCOME**
D10	**Heat pump technology** Heat pumping technologies are widely used for upgrading natural low-temperature energy from renewable sources, such as air, water, ground and waste heat, to useful temperatures. They are used for residential and commercial space and water heating, cooling, refrigeration and in industrial processes. The aim of this subsection is to inform designers about the technology of the heat pump so that they are able to make a correct choice in the design of a GSHP. The selection phase of a heat pump must be carried out subsequent to the thermal load analysis phase and after the internal distribution system is defined. The designer must understand the specific boundary conditions a heat pump imposes on the shallow geothermal (ground side) design.	**ANALYSIS, DESIGN AND IMPLEMENTATION** • Appreciation of Heat pump technology • Understanding thermal building load data assess-ment and the interaction between building loads and ground-side design
D11	**Energy load** Among the several parameters that are of importance in the design and development of an optimized ground coupled heat exchanger, the following relate to the energy load: - The climatic conditions - The building type and its energy demand profile This subsection focuses on the analysis of the building energy demand profile and on the detailed thermal load calculations of cooling and heating, which will be necessary for the general ground coupled heat exchanger design. Both represent basic aspects in the conception and final dimensioning of such system, as they affect the basic energy balance between the surrounding soil and the installation.	
E	**GSHP SYSTEM ALTERNATIVES**	**LEARNING OUTCOME**
E12	**Design of borehole heat exchangers (BHE)** A borehole heat exchanger (BHE) is meant to carry a fluid inside the underground and allow for exchange of heat between the underground and the fluid. The BHE consists of pipes containing the fluid and must include a design for the return of the fluid from the deepest point in the borehole back to the surface. Basic designs are discussed in this subsection, and some practical topics from subsection 6 are repeated.	**ANALYSIS, DESIGN AND IMPLEMENTATION** • Knowledge of issues concerning the GSHP system alternatives selection: heating/cooling; available ground area, BHE design • Knowledge of design methods and relevant software
E13	**BHE design examples** This subsection explains in part (a) the design of BHE for small buildings, which is normally done by using a specific extraction rate in W/m. Both methods according to VDI 4640 and to SIA 384/6 are demonstrated with an example, and compared to a calculation using EED for the same example. In part (b) a good practice case study for a large system with >100 BHE is given with the an example from Romania.	
E14	**Design of horizontal collectors** The horizontal array is the most demanding of all geothermal collector types in terms of the ground area required to produce a specified geothermal energy yield. For this reason it is very seldom used in urban or even suburban installations. Nonetheless, in rural settings or in regions of low density development, the horizontal array can have advantages over borehole geothermal collectors. The purpose of this subsection is to identify and discuss the factors which must be considered in the evaluation of a site for a possible horizontal collector.	**TECHNOLOGICAL, METHODOLOGICAL AND TRANSFERABLE SKILLS** • Gaining experience in practical computer-aided design sessions

F	GSHP INSTALLATION	LEARNING OUTCOME
F15	**Installation and grouting** Installing the Borehole Heat Exchanger (BHE) and grouting the borehole have the same importance for the completion and the future operation of the system as the drilling itself or as connecting the BHE to the Heat Pump. The following key points ensure a good job The borehole must be kept open until grouting has finished. Thus any auxiliary casing is removed after grouting. The BHE tubes need very careful handling during transport, on-site storage and installation. Grouting needs special attention and care. These are the three main functions of the grout: The installing and grouting work is done by the driller. But the designer should know what to expect from this working phase, and may also be assigned to supervise such activities.	**UNDERLYING BASIS** • Knowledge about construction of groundwater wells, installation of relevant pipes, pumps and control systems • Knowledge about the installation of borehole heat exchangers, grouting, backfilling or otherwise completion of the ground source system • Appreciation of welding of plastic pipes and other connection methods
F16	**Functional and quality control** System control, testing, commissioning, documentation, maintenance, and monitoring for the GSHP installations are discussed in this subsection.	**TECHNOLOGICAL, METHODOLOGICAL AND TRANSFERABLE SKILLS** • Ability to perform quality control
G	**REGULATION**	**LEARNING OUTCOME**
G17	**European legal situation and standards** Geothermal heating and cooling is an immature market in Europe as a whole so that there is little in the way of European level standardization or normalization of the design or installation of ground source heat pump systems. In some countries, the market has been in existence for longer and has developed to the point that there is a substantial market which has prompted development of the national standards for various aspects of the design and installation. This subsection sets out the situation on normative standards across Europe and considering national situations, and summarizes the key aspects of the most important available standards. The way forward in the development of further normalization is identified for discussion.	**OTHER PROFESSIONAL SKILLS** • Knowledge about European Legal Situation and Standards, both on ground and on building side • Knowledge about environmental issues
G18	**Energy efficiency building codes** The implementation of a project with an efficient HVAC GSHP system is impossible without knowledge of the technical details of the project and, at the same time, the legal aspects of the development. During the engineering activities of such a project, the specialists must consider all the regulatory elements required by the efficiency standards. The information presented in this subsection is required from the start of the feasibility study phase for a GSHP application, and is extremely useful at the stage of monitoring the application, so all engineering phases involved in a project with GSHP require knowledge of the concepts and guidelines discussed here.	
G19	**Environmental issues** Environmental aspects in respect to the protection of ground and groundwater are of paramount importance in any shallow geothermal project. The main environmental problems associated with GSHP are presented in this subsection; they include: Impact on ground/groundwater: - leakage of antifreeze or refrigerant - connecting different aquifers or aquifers to surface - drilling into artesian aquifers - thermal effects. Other impacts: - other adverse effects (swelling clays, anhydrite, etc.) - pollution during drilling	

2 Curriculum for Drillers

The curriculum for drillers and the contents of didactic material have been delivered by this GEOTRAINET panel of drilling experts. The experts have been involved also in the training activity. The experience during this training period has supported the improvement of the final course program as presented in this document. Over the lifetime of the project, the listed experts received support on specific topics from other persons involved in the GSHP industry, who cannot all be mentioned here. This additional input as well as the feedback from the training courses is appreciated very much.

The curriculum contains information and data necessary for the correct handling of drilling operation for GSHP, including the necessary field tasks for site testing. The content is divided in three sections; each section has subsections with the relevant topics. In total the curriculum has 20 subsections. Below the structure of the curriculum is presented, with the main concepts developed in each section and subsection.

A	**GENERAL TOPICS** The first section aims to give a general overview of the GSHP systems currently used in EU countries, and in what types of applications different systems are commonly used. Furthermore, an overview regarding the potential and limitations with respect to a number of important factors is given. Since drilling is an essential part of any GSHP system, an overview of methods and differences between countries as well as the importance of test drilling for designing purposes is covered. The first two subsections are common for both designers and installers.
A1	**Overview of shallow geothermal systems:** This subsection gives an overview of the natural and technical background, starting from ground temperatures and basic system concepts. As geothermal energy, in the public's perception, is often associated with volcanoes and geysers, the possibilities to use the shallow underground with moderate temperatures need to be explained. The difference in the concept of Ground Source Heat Pump (GSHP) and Underground Thermal Energy Storage (UTES) is presented, as well as the possible options for coupling the systems to the ground. The advantages and disadvantages of both closed systems (Borehole Heat Exchangers, BHE) and open systems (groundwater wells) are highlighted. The subsection is rounded up by information of market and prospects
A2	**Limitations:** This subsection considers the potential of shallow geothermal systems as well as limiting factors when it comes to apply them in practice. It is intended to make the students aware of the boundary conditions within which the design of shallow geothermal systems needs to be done, in respect to - Possible Energy sources - Geology / Hydrogeology - Climate - Environmental issues - Costs - Regulations
A3	**Drilling methods:** An overview and summary of the drilling methods relevant for shallow geothermal systems is given.
A4	**Test drilling (purposes):** This section covers basically the required field investigations for the relevant parameters and the part the drilling plays for these investigations.
A5	**Environmental concerns:** A driving force for the usage of GSHP systems is the potential positive impact the systems have on the global environment (especially for reduction of CO_2 emissions). On the other hand, there are local environmental concerns that have to be addressed in an early stage of any GSHP project. This subsection presents possible environmental problems while drilling, and geological situations that might present environmental risks when drilled into.
B	**SPECIFIC TOPICS FOR CLOSED-LOOP SYSTEMS** "Closed Loop" means systems with a heat carrier fluid which is circulated in a closed circuit inside the underground, commonly a Borehole Heat Exchanger (BHE) inserted into a vertical borehole. The fluid carries heat or cold into or out of the soil and rock around the borehole, normally at moderate temperature. The most common application is a single borehole or a couple of boreholes, used for a family house. The system is in most cases serving the house with space heating, occasionally the system is also used for comfort cooling, There are also large sized systems, including those with seasonal storage of heating and cooling (Borehole Thermal Energy Storage, BTES). This type of system is commonly applied for commercial and institutional buildings and consists of a large number of boreholes within a defined space. Closed-loop systems have a large geographical potential since they can be applied under almost any geological conditions. Furthermore, these systems have a limited thermal influence on the surroundings. Hence, they can be rather densely located and applied in urban areas. Drillers and installers will be involved in a number of actions for the construction of closed loop systems. The curriculum aims to cover actions needed for large scale applications, and issues required for smaller systems are incorporated into the large scale scheme.
B6	**Performance of test drillings:** Large BTES systems must always be carefully site investigated with respect to geological conditions and underground thermal properties. A normal part of these investigations are test drillings followed by thermal response test (TRT).

B7	**Performance of TRT (Thermal Response Test):** Test activities normally involve the driller/installer and have to be performed in way that gives the best possible results The driller typically is not concerned with the evaluation of the test, but needs to know the basic principle and the constraints to this test method, in order to provide the best possible conditions for the actual test operation.
B8	**Safety aspects:** Depending on specific site conditions and applied drilling methods safety aspects is always an important issue. Often there are country specific laws and regulations to be followed.
B9	**Drilling an installation of BHE:** The actual construction involves drilling (often on a limited space and with several drilling rigs), and installation of BHE. The performance of this work can be done differently, but the result must be a functional system with a high degree of accuracy. In connection to the construction, grouting is an important step (only under some crystalline hard-rock circumstances like in Scandinavia grouting might be omitted).
B10	**Connection plastic welding:** The connections of the ground pipes to headers, manifolds, connection pipes, and the building system must be done by proven technology, commonly by plastic welding. The welding methods, equipment, quality requirements, standards etc. are considered.
B11	**Filling with heat carrier and de-aeration:** Filling requires proper mixing (in case of brines), flow and pressure control, and a thorough de-aeration before commissioning of the system. In particular with glycol-based brines de-aeration needs proper attention, sufficient flow rates and several repetitions, as these media tend to produce foam in the presence of air.
B12	**Functional testing (procedure and documentation):** To secure that a perfectly tight and safe system has been constructed, the final step involves a number of pressure and flow tests. The results of these tests must be properly documented and will in fact be the contractual guarantee for the driller/installer.
C	**SPECIFIC TOPICS FOR OPEN-LOOP SYSTEMS** In an “Open Loop” system ground water is used to carry heat and cold out of or into water-bearing geological formations (aquifers). The contact with the aquifer is obtained by using water wells. These can be abstraction or injection wells, and in many cases the wells can have both functions. Since aquifers have a limited geographical potential and that usage of groundwater is regulated in most countries, the open loop systems are less frequent than the closed loop systems. On the other hand, if properly constructed, the efficiency is higher. The most common applications are for large-scale heating and cooling of commercial and institutional buildings. They are also used for process cooling in the industrial sector as well as for district heating and cooling. The aquifers can be used directly for cooling, but the major applications are done with seasonal storage of heat and/or cold (named Aquifer Thermal Energy Storage, ATES). Pumping and injection of groundwater is a challenge, since it will hydraulically influence a large area around the wells. There is also a permit situation that has to be considered in an early stage of a project. For this reason, the site investigations have to cover detailed information’s, not only related to the aquifer, but also to the surrounding hydrogeological conditions and other usage of land.
C13	**Performance of test wells (MWD, geophysical logging, hydrochemical sampling):** Test wells need to be adapted to the specific questions the designer plans to investigate, and have to be constructed by the driller in accordance to these requirements. Data collection can already begin during the drilling process (measurement while drilling, MWD), e.g. by monitoring pressure, advancing velocity, water inflow or losses, etc. Geophysical logging as well as hydrochemical sampling typically is not done by the driller itself, but by specialized companies; however, drillers need to know the basic requirements for these activities, in order to support them on site. From a technical point of view, water chemistry is a central issue to consider for estimation of potential problems with scaling, corrosion and well clogging.
C14	**Performance of pumping test (data collection):** A pumping test in a test well is crucial for determination of aquifer characteristics. While the evaluation of such test and the subsequent design steps are not part of the typical drilling job, the actual pumping and data acquisition often has to be performed by the drillers. In a test well, temporary pumping equipment and water-level gauges are used.
C15	**Production wells – types and construction methods:** Well design and the related installations are other issues that need to be specially considered in order to construct a functional system. The various well completion methods with screens, filter etc. are explained.
C16	**Tests after completion:** After construction the system must be carefully tested. This can include another pumping test, this time for confirming the actual sustainable well yield. Within this stage the controlling equipment (flow, temperature and pressure) must also be carefully checked.
C17	**Well installations, well house, mains and fittings:** Installations within the well (submersible pumps, sensors) or on top of the well (line-shaft pump motors, valves, connections) often are part of the driller´s job. Also the protective housing of the equipment on top of the well (either underground in a well cellar, or above ground in a well house) needs to be constructed by drillers frequently.
C18	**Functional tests of the total system:** After completion of the individual components, the entire systems needs to be tested propery construction the system must be carefully tested. In this stage the controlling equipment (flow, temperature and pressure) must also be carefully checked.
C19	**Documentation, required documents:** Proper documentation is needed for the licensing authorities as well as for later reference. Certain documentation in some countries is governed by standards, other is at the discretion of the driller. The minimum requirements are presented in this subsection.
C20	**Maintenance instruction and service:** Finally, since the open loop system is sensitive for disturbances (clogging etc.), maintenance and service are other subjects that need to be considered.

FIELD TRIPS

It is of importance that course attendees are given the possibility to visit GSHP plants already constructed. This will give them the opportunity to study technical solutions in details, but also to have experienced information from people operating the plant. The study visits should cover both closed and open loop systems and there should be documents available describing the plants to be visited.

Field trip to Verheyden Putboringen drilling site in January 2011

FINAL DISCUSSIONS

At the end of training the attendees should have the possibility to have a final discussion to ask questions that may not have been covered during the lectures or the field trip.

LEARNING OUTCOMES

At the end, the level of skills achieved and certified as a result of the proposed training courses will require the installer to demonstrate the following key competences:

- understanding geological and geothermal parameters of the underground and knowing their determination, nomenclature and identification of soil and rock types, preparing borehole reports including lithology, groundwater, etc.; basic geological and hydrogeological knowledge
- familiarity with different drilling and digging technologies, choice of the optimum drilling method, ensuring protection of the environment (in particular groundwater) while drilling,
- ability to install borehole heat exchangers, to grout, backfill or otherwise complete the ground source system, and to perform pressure tests; skills for welding of plastic pipes and other connection methods,
- ability to construct groundwater wells, to install the relevant pipes, pumps and control systems
- ability to perform the relevant documentation incl. identification and drawing of drilling locations

The entire content of these two curricula is deepened in the training manuals developed for European designers and drillers of GSHP which intends to provide relevant and accessible support for ongoing education in this sector:

Geotrainet Training Manual for Designers of Shallow Geothermal Systems. Geotrainet,
European Federation of Geologists, Brussels, 192pp.
ISBN: 978-2-9601071.

Geotrainet Training Manual for Drillers of Shallow Geothermal Systems. Geotrainet,,
Brussels, 113 pp.
ISBN: 978-2-9601071-1-1.

The use of this manual is recommended by the GEOTRAINET consortium for all European training activities in the field of shallow geothermal design and drilling.

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