Geo3En Geothermal Energy European Education Network

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Course Catalog

Summary report Intellectual Output 3

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1 Introduction

The renewable energies market shows an exponential development in a complex geopolitical context with an evident need for societies to lower dependence on fossil fuels and implement measures to adapt to climate change and protect environment. In order to achieve these urgent and ambitious goals, qualified engineers are required at all steps of the geothermal value chain.

The present deliverable is one of the major outputs of the Geo3EN program as it encompasses the whole consortium efforts in constructing a new Master program curriculum dedicated to geothermal engineering education.

The Geo3EN vision of geothermal engineering considers all facets of geothermal energy utilization as well as the associated multitude of competences required to evaluate the resource, achieve feasibility studies, produce economical and technical designs, explore the reservoir potential and operate power plans.

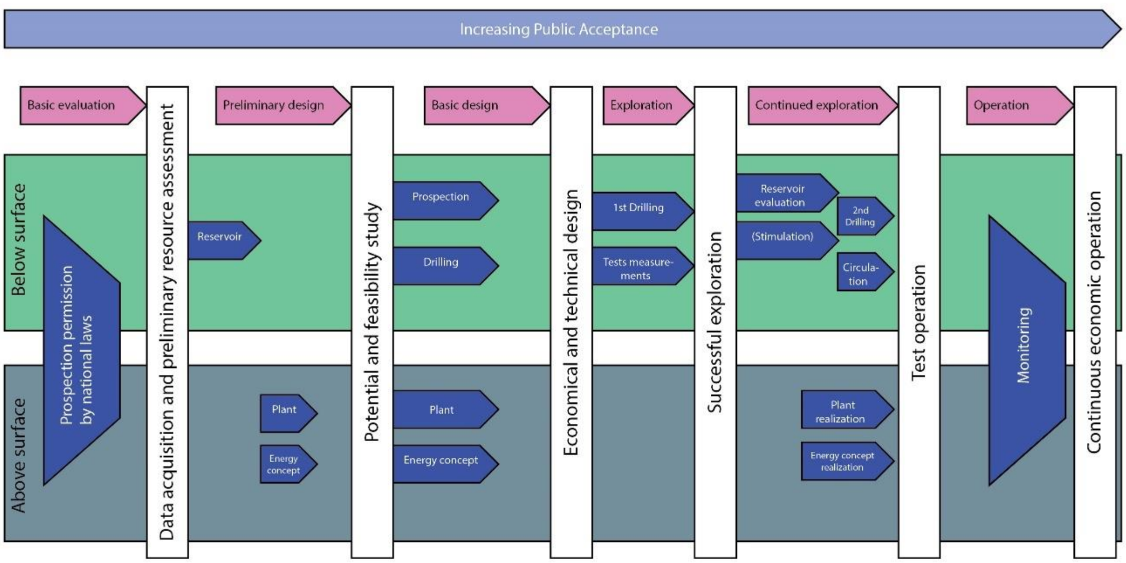


Figure 1: Phases of geothermal projects

The curriculum covers the fields of geosciences, energy production, conversion and transport, economic intelligence and communication. The task is extremely challenging and it is illusory to imagine that a single engineer profile could gain all the above-mentioned competences given 1) the mass of knowledge to be acquired in two years and 2) the variety of students' backgrounds applying to the master program.

Based on a series of competence matrices (intellectual outputs 1 and 4) reviewed several times by a multitude of stakeholders from the European territory the Geo3EN consortium figured out that given the present day and near future employment market, 4 different master profiles are needed namely:

- Geothermal electrical engineers
- Geothermal and energy science engineers
- Geothermal reservoir engineers
- Geothermal reservoir geoscientists

In order to reach these 4 Masters degrees and considering 1) the administrative constraints of the partners, 2) the educational backgrounds of students, several study tracks promoting international exchanges between the partners are presented and course syllabuses are given.

The concept of the Geo3EN course catalog has been tested during an intensive study program (intellectual outputs 2 and 6) and received positive feedback from the students (intellectual output 10). It confirms the consortium in its vision of the proposed curriculum philosophy.

2 Study tracks

This section presents the organization of the curriculum to be followed by the students.

This organization is in line with a series of administrative constraints on one hand and the variety of educational student background applying to the curriculum on the other hand.

2.1 Administrative constraints

At first, the curriculum needs to comply with the administrative constraints from the different organizations involved in the project. Each institution has its own requirements in terms of number of semesters and ECTS credits to be spent at a given place This point if of crucial importance regarding dual degrees plus exchange agreements.

2.1.1 UniLaSalle

UniLaSalle requires students to receive 30 ECTS credits per semester and a minimum number of 3 semesters on site. The third semester can be accomplished in a partner University provided that 1) the educational content is in line with the curriculum contents agreed between the partner and UniLaSalle and 2) UniLaSalle participates to the recruitment. Students having received education in France prior to their Master must spend 17 weeks in a foreign University. This rule does not apply to foreign students as their stay at UniLaSalle in France is considered as an internship experience at international level.

In addition, students are required to spend a total of at least 28 weeks of internship. Priority is given to industry but in certain circumstances internship can be accomplished within research laboratories.

For the present Master project given in English students must present a B2 language certificate in English and a B1 level in French.

Applications are examined in terms of marks records. An interview is also scheduled in order to judge from candidate motivation.

The Master thesis is given after successful evaluation of a written report and accompanying defense.

2.1.2 TU Darmstadt

TU Darmstadt graduation depending on the tracks require the following conditions to be fulfilled: 30 ECTS per semester and 2 semesters minimum at TU Darmstadt

For the geoscience tracks, several courses have to be followed and are proposed in the framework of this master program. Master students have to have completed a Bachelor degree in the same track as the courses required in the BSc at the TU Darmstadt, and having validated the equivalence, evaluated by the studies dean coordination.

2.1.3 University of Reykjavik

Iceland School of Energy offers four 24 month 120 ECTS master's degrees with two of these programs being available to students within the dual degree arrangement, MSc in Sustainable Energy and MSc in Sustainable Energy Engineering. The Sustainable Energy program is open for students with a bachelor's degree in various disciplines. Our students come from backgrounds in business, engineering, social sciences, and natural sciences. To apply for the Sustainable Energy Engineering program, an undergraduate degree in an engineering related field is required.

Applicants are required to have completed, or be in the final year of, their undergraduate degree for consideration for our graduate programs. For applicants still in their final year, satisfactory completion of their degrees will be conditional for entry.

Applications must include:

- CV / Resume
- Official University Transcripts (hard copy and digital accepted)
- 2 Letters of Reference (sent to admissions@ru.is directly from referee's institutional email)
- Photocopy of Passport
- Personal Statement (500 word max)
- English Language Test Score Certificate (if applicable)
- A grade point average of 8 out of 10 or equivalent

For dual-degrees or exchanges, students from Reykjavík University must have taken 60 of 120 ECTS at Reykjavík University. There is no residency requirement for these 60 ECTS taken at Reykjavík University.

2.1.4 University of Zagreb

Faculty of electrical engineering and computing (FER) offers three master programs in English (Electrical Engineering and Information Technology, profile Electrical Power Engineering; Information and Communication Technology, profile Control Systems and Robotics; Computing, profile Data Science). They last two years (4 semesters, 120 ECTS points, 30 credits per semester) and include a Master Thesis in the final semester.

Admission requirements: A successfully completed an appropriate (engineering) bachelor or integrated study with a workload equivalent to that of 180 ECTS or higher. English language proficiency equivalent to B2 English level according to the CEFRL is required.

Student obligations include regular attendance of all forms of classes (lectures, exercises, laboratory work, etc.). In addition to the required courses, there are also elective courses that the student must enroll in depending on the number of necessary credits (1-2 courses per semester). Students will be recognized for ECTS credits earned at other universities for courses that are similar to courses from the FER curriculum. Accordingly, students may spend one semester at a foreign university, but their ECTS credits will only be recognized if the courses are similar, which is confirmed by the FER ECTS coordinator.

2.2 Students backgrounds

As mentioned in the introduction, the geothermal sector requires a multitude of competences and therefore a variety of students' educational profiles will be accepted for candidatures.

In order to organize student recruitment campaigns, the consortium has chosen to divide student candidatures in two groups: 1) students with no geological educational backgrounds and 2) students with geological educational backgrounds.

This organization is in line with the diagram of figure 1 in which geothermal projects are classically described in "below surface" and "above surface" engineering. The hereafter presented curriculum follows this dichotomy and will preferably orient students with initial geological competences towards reservoir engineering at depth. Students with no initial educational background will in turn be encouraged to follow lectures dealing with surface installations, marketing, entrepreneurship and energy science engineering.

The Geo3EN novelty is to establish transverse competences between surface and reservoir engineers. The consortium is convinced that successful worldwide development of geothermal energy is conditioned to team work and activities understanding between these two communities. This vision of geothermal engineering training has proven to be successful during the Intensive Study Program given in year 2022 (Intellectual Outputs 2, 6 and 10). The received positive evaluation coupled to the quality of students reports further strengthens the willingness of the Geo3EN partners to continue their efforts in developing this common training program at an international level.

2.2.1 Students with no geological educational background

It has been decided to open the program candidatures to students having preferentially an educational background in the fields of energy engineering, electrical engineering, marketing and business economics plus management. This list is not exhaustive, and candidature relevance will be examined on a case-by-case basis. Candidatures from students having obtained at least a Bachelor degree with a minimum of 180 ECTS of relevant institutions are specifically targeted

As previously mentioned, these students are expected to work "above surface" and find employment opportunities either in business and economic intelligence, or in more technical aspects related to powerplant operation, energy production, transformation and transport.

Both profiles will receive some basics in reservoir geology and reservoir engineering in order to be able to communicate and understand "below surface" problematics. This basic knowledge is found in a pool of lectures (Base Line Courses pool) where students will select a series of courses corresponding to a minimum of 4 ECTS credits.

The exchange between these students and students oriented towards reservoir engineering is strongly promoted by the Geo3EN consortium. It is considered of primary importance in order to 1) better plan reservoir exploitation economics strategies on the long term, 2) correctly dimension surface installations taking into account local energy needs and existing infrastructures and 3) offer reliable and precise information as a prerequisite to gain investors' confidence.

These students are expected to gain outstanding communication skills during their curriculum as they will later be at the forefront to stakeholders in order to ensure public acceptance of geothermal projects.

2.2.2 Students with geological educational background

Geothermal energy development requires a precise understanding of reservoir geology as a prerequisite to reliable reservoir exploitation potential modeling. Candidatures from students having obtained at least a Bachelor degree with a minimum of 180 ECTS in a Faculty of geosciences or geoscience engineering school are specifically targeted. In addition, the consortium will also consider candidatures from students in the fields of chemistry and physics as these disciplines are of common use in the field of rock mechanical and petrophysical properties determination plus flow modeling in reservoirs.

The students will receive all necessary competences to work as reservoir geologist in engineering offices or large operating powerplants. There is a large variety of activities to be covered in terms of resource prospecting, well conception, reservoir stimulation strategies designs, seismic monitoring, to cite just a few.

The dedicated tracks will include many transverse competences in allowing an easy and straightforward communication with "above surface" engineers. This exchange is important as well in order to fulfill application needs by designing reservoir exploitation strategy in line with investors demands. Basic knowledge in terms of surface installations, energy engineering and marketing is found in a pool of lectures (Base Line Courses pool) where students will select a series of courses corresponding to a minimum of 4 ECTS credits.

Given the relative lack of geothermal reservoir understanding compared to tremendous knowledge gained in the oil and gas industry, fundamental geoscience research is needed at present day within the geothermal community. It is believed that the Geo3EN Master program will encourage successful students to continue their education in the field of research by applying to PhD positions. The enrolment of research institutions in Geo3EN and access to research facilities and culture are perfect prerequisite to do so.

2.3 Track description

Given 1) the multitude of competences needed in geothermal business, 2) the variety of educational backgrounds from students applying to the program and 3) the previously discussed gap between "above surface" and "below surface" engineers, the Geo3EN consortium has established the curriculum presented in figure 2.

This curriculum complies with all administrative constrains from the partner engaged and will lead to 5 different double degrees:

- ULS/UR Geothermal electrical engineering
- TUDA/UR Geothermal and energy science engineering

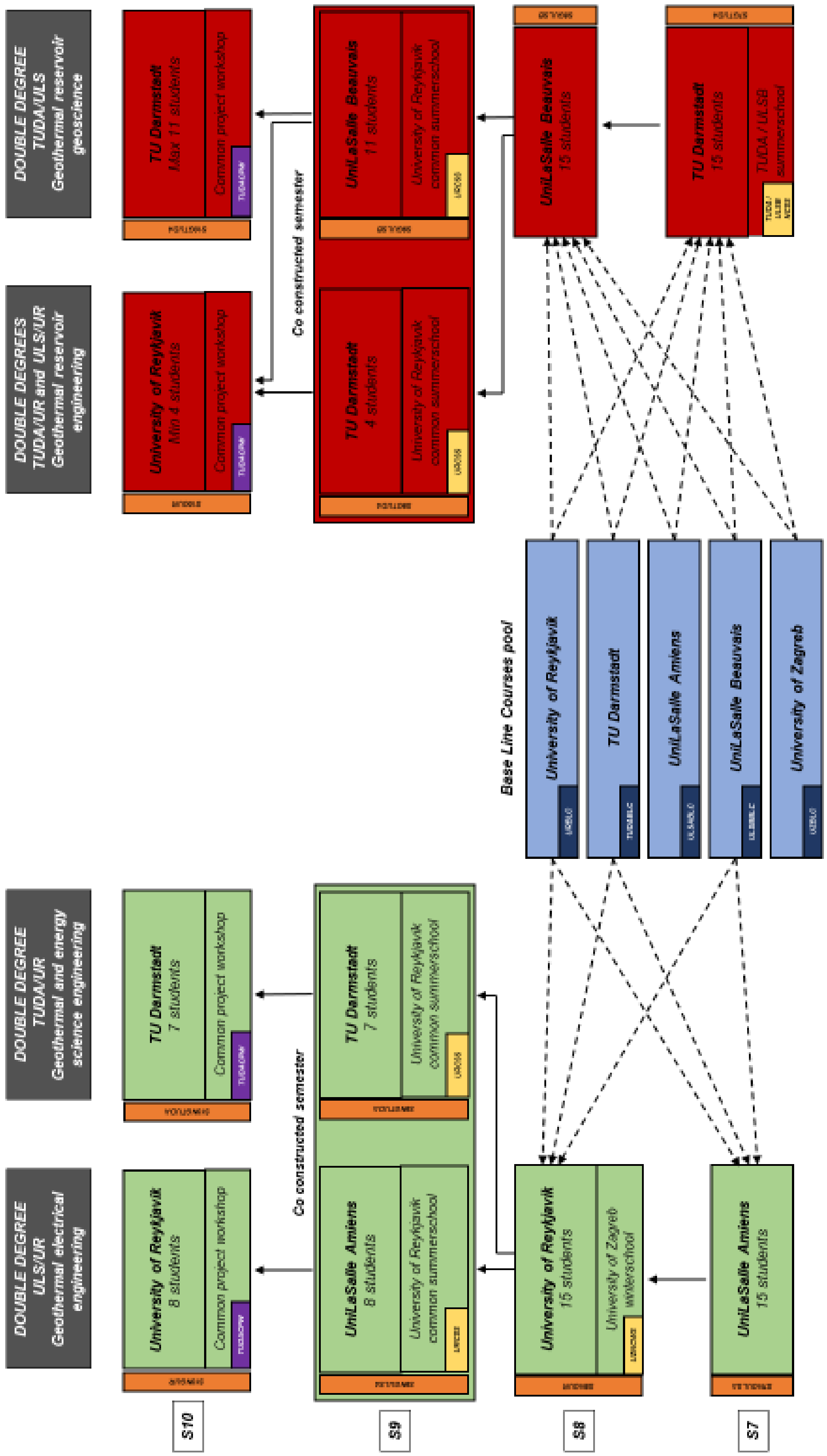
- TUDA/UR Geothermal reservoir engineering
- ULS/UR Geothermal reservoir engineering
- TUDA/ULS Geothermal reservoir geoscience

The curriculum is scheduled for a minimum number of 30 students divided in two main combination of tracks corresponding to “above surface” (green tracks) and “below surface” (red tracks) engineering.

It is again emphasized that the curriculum aims at bridging the gap between these traditionally separated communities by means of:

- Intensive teaching of baseline courses during Semesters 7 and 8 (blue table)
- Intensive teaching of transverse competences and softskills
- Common events in the field (common summer school during semester 9)
- Common projects (common project workshop during semester 10)

This novel integrated approach is unique to the Geo3EN curriculum and has proven to be successful during Intense Study Program testing (Intellectual Outputs 2, 6 and 10).


DOUBLE DEGREE TUDA/ULS Geothermal reservoir geoscience
DOUBLE DEGREES TUDA/UR and ULS/UR Geothermal reservoir engineering
TU Darmstadt Max 11 students
Common project workshop
University of Reykjavik Min 4 students
Common project workshop
Co constructed semester
UniLaSalle Beauvais 11 students
University of Reykjavik common summerschool
TU Darmstadt 4 students
University of Reykjavik common summerschool
UniLaSalle Beauvais 15 students
TU Darmstadt 15 students
TUDA / ULSB summerschool
Base Line Courses pool
University of Reykjavik
TU Darmstadt
UniLaSalle Amiens
UniLaSalle Beauvais
University of Zagreb
DOUBLE DEGREE TUDA/UR Geothermal and energy science engineering
DOUBLE DEGREE ULS/UR Geothermal electrical engineering
TU Darmstadt 7 students
Common project workshop
University of Reykjavik 8 students
Common project workshop
Co constructed semester
TU Darmstadt 7 students
University of Reykjavik common summerschool
UniLaSalle Amiens 8 students
University of Reykjavik common summerschool
University of Reykjavik 15 students
University of Zagreb winterschool
UniLaSalle Amiens 15 students
S10
S9
S8
S7

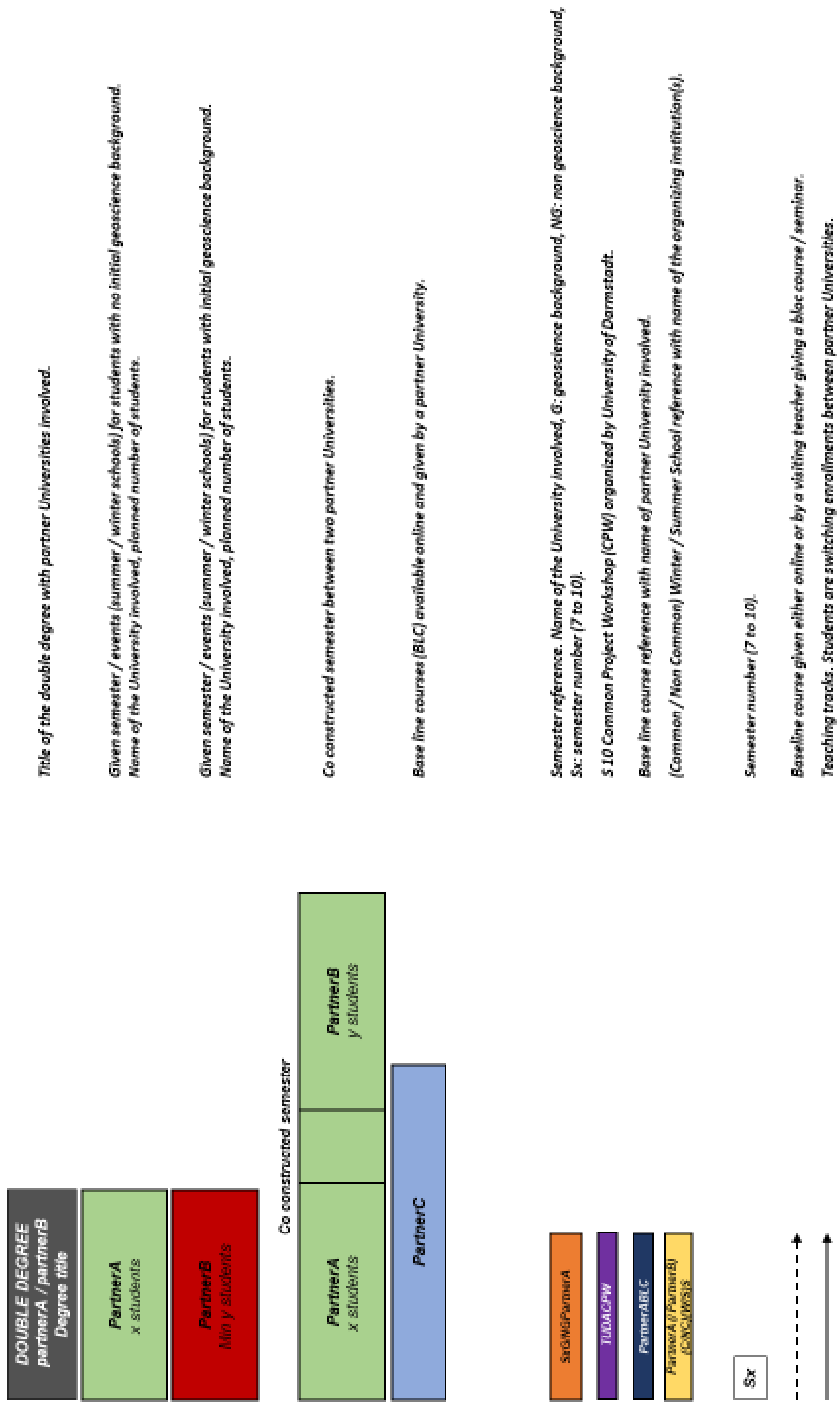


Figure 2: Geo3EN proposed curriculum

2.3.1 Geothermal engineering above surface

The tracks combination is preferentially opened to students with no initial geological background. It is represented in green on figure 2.

Students integrate the curriculum at semester 7 at UniLaSalle Amiens, France (semester reference ULSANG7). They receive intensive training in the field of energy engineering with theoretical lectures dealing with energy production, conversion and transport, power management and griding (see the complete syllabus in section 3).

Semester 8 (semester reference URNGS8) is given at University of Reykjavik. This semester starts with a winterschool (reference UZNCWS) dealing with power engineering at University of Zagreb, Croatia. Semester 8 is dedicated to economics, markets, finance and regulation as presented in section XX.

During semesters 7 and 8 students will get access to a pool of Base Line Courses given by University of Reykjavik (reference URBLC), TU Darmstadt (reference TUDABLC) and UniLaSalle Beauvais (ULSBBLC). As mentioned earlier these BLC are chosen by students, but they are encouraged to follow lectures dealing with geothermal engineering, geology and entrepreneurship.

At co constructed semester 9 level, students are given the choice to move back to UniLaSalle Amiens, France (semester reference ULSANGS9) or to pursue their education at the TU Darmstadt campus in Germany (semester reference TUDANGS9). During semester 9 at UniLaSalle Amiens, students will deepen their knowledge in power systems design and operation with a special emphasis on geothermal electricity production. For students having chosen semester 9 at TU Darmstadt, emphasis is given to geothermal energy production and integration in mixed energy systems including other renewables, fossils and nuclear sources. The detailed content of these semesters is given in sections 3.2 and 3.3.

In any case a mandatory common summerschool (reference URCSS) in Iceland is organized at begin of semester 9 by the University of Reykjavik. This event is for students the first possibility to work on a team project. Competence exchanges and experienced are promoted, in order to follow the Geo3EN philosophy and to train students to real conditions they will later deal during their career.

In order to complete their curriculum, students have the choice to achieve semester 10 at University of Reykjavik (reference URNGS10) or at TU Darmstadt (reference TUDANGS10). In both cases the semester starts at TU Darmstadt in the form of a common project workshop (reference TUDACPW). During this workshop students deal again with competences exchanges by working on a geothermal plant installation feasibility study.

Semester 10 at University of Reykjavik permits students to obtain a double degree ULS/UR in geothermal electrical engineering and economics. Besides basic competences in geothermal engineering, geology and entrepreneurship, students are specialized in electrical energy production and related business.

Semester 10 at TU Darmstadt permits students to obtain a double degree TUDA/UR in geothermal and energy science engineering. Besides basic competences in geothermal engineering, geology and entrepreneurship, students are specialized in energy engineering and technical development plus integration of geothermal resources in energy grids.

2.3.2 Geothermal engineering below surface

The tracks combination is preferentially opened to students with an initial geological background. It is represented in red on figure 2.

Students integrate the curriculum at semester 7 at TU Darmstadt, Germany (semester reference TUDAGS7). They receive intensive training in the field of regional geology, engineering geology and geo information systems (see the complete syllabus in section 3). Semester 7 starts with a summerschool (reference TUDA/ULSBNCSS) jointly organized between TU Darmstadt and UniLaSalle Beauvais. This excursion consists in a transect across the Upper Rhine Graben with some insights in reservoir geology.

Semester 8 (semester reference ULSBGS8) is given at UniLaSalle Beauvais. Semester 8 is dedicated to in depth understanding of processes active in geothermal reservoir and includes 2 excursions in the field.

During semesters 7 and 8 students will get access to a pool of BLC given by University of Reykjavik (reference URBLC), UniLaSalle Amiens (reference ULSABLC), ULS Beauvais (reference ULSBBLC) and University of Zagreb (reference UZBLC). As mentioned earlier these BLC are chosen by students, but they are encouraged to follow lectures dealing with finance and regulation, electrical and energy engineering plus entrepreneurship.

At co constructed semester 9 level, students are given the choice to either stay at UniLaSalle Beauvais (semester reference ULSBGS9) or to pursue their education at the TU Darmstadt campus (semester reference TUDAGS9). During semester 9 at UniLaSalle Beauvais, students will deepen their knowledge in geothermal reservoir characterization using cutting edge techniques of computer assisted 3D visualization. For students having chosen semester 9 at TU Darmstadt, emphasis is given to geothermal reservoir simulations in terms of fluid flow and temperature evolution, well design and petrophysics. The detailed content of these semesters is given in sections 3.4 and 3.5.

In any case a mandatory common summerschool (reference URCSS) in Iceland is organized at begin of semester 9 by the University of Reykjavik. This event is for students the first possibility to work on a team project (see program in section 3). Competence exchanges and experienced are promoted, in order to follow the Geo3EN philosophy and to train students to real conditions they will later deal during their career.

In order to complete their curriculum, students have the choice to achieve semester 10 at University of Reykjavik (reference URGS10) or at TU Darmstadt (reference TUDAGS10). In both cases the semester starts by a common project workshop (reference TUDACPW) organized by TU Darmstadt. During this workshop students deal again with competences exchanges by working on a geothermal plant installation feasibility study.

Semester 10 at University of Reykjavik permits students to obtain either a double degree TUDA/UR or ULS/UR in geothermal reservoir engineering. Besides basic competences in finance and regulation, electrical and energy engineering plus entrepreneurship, students are specialized in reservoir properties evolution during exploitation phases.

Semester 10 at TU Darmstadt permits students to obtain a double degree TUDA/ULS in geothermal reservoir geoscience. Besides basic competences in finance and regulation, electrical and energy engineering plus entrepreneurship, students are specialized in reservoir geometry and fluid / rock processes active before and during exploitation phases.

3 Modules syllabus

3.1 Base Line Courses pool

3.1.1 University of Reykjavik

Module URBLC1: Geothermal reservoir engineering / modeling. 4 ETCS

Introductory geothermal reservoir engineering, through lectures and several practical projects and assignments, with the aim of providing the student with basic knowledge on the different aspects of the discipline as well as some experience in tackling practical problems. The acquired knowledge concern 1) Basic theory of fluid and energy flow in geothermal reservoirs, 2) Utilization of geothermal systems, 3) the nature and response of systems to utilization, 4) Approaches to geothermal resource management and monitoring geothermal systems and 5) Analytical and numerical modelling of geothermal systems. The obtained skills are: 1) Apply scientific and engineering knowledge to build conceptual models of geothermal systems, 2) Apply analytic models to understand the performance of geothermal systems under utilization, 3) Design geothermal reservoir models for numerical simulation and perform computer simulations using reservoir simulation code, 4) Design a monitoring system to extract key data from the system and 5) Interpret monitoring data for system management. The acquired competence are: 1) Reservoir monitoring, 2) Reservoir modelling, and 3) Reservoir management.

Module URBLC2 / URNGS8M6: Markets and regulations. 3 ECTS

This course provides an overview of modern energy markets, policy and market regulation, with a primary focus on the industry in the US and Canada. The primary emphasis is electricity pricing and market oversight; some lectures will include the role of liquid and gas fuel markets as well. The class is based on guest lecturers from industry and public regulatory institutions. Readings will be available on-line from journal articles and excerpts from text materials. Grading will be based on in-class participation, 2 in-class quizzes a short essay and a final examination.

Module URBLC3: Power plant design. 4 ECTS

Upon completion of the course students should have the ability to:1) Structure a feasibility study, 2) Describe and construct the major conceptual drawings for a power project, 3) Evaluate technical and economic considerations for major equipment and projects, 4) Assess the major factors affecting technical performance of a thermal power plant, 5) Assess the major factors affecting financial performance of a power project and 6) Identify basic construction and maintenance safety practices. The acquired knowledge concerns Thermodynamics, plant layout, operating principles of turbomachinery and major power plant equipment. The students will gain skills in 1) Plant layout, 2) Piping design and pump selection, 3) Thermal plant major equipment characteristics, 4) Equipment sizing and selection, 5) Cost estimating and the procurement process, 6) Project financial performance, 7) Sustainability reviews and 8) Safety in design, construction plus maintenance. Students acquire competences in performing conceptual design for thermal power plants.

Module URBLC4: Energy technology. 4 ECTS

To introduce and give an overview of the field of energy by presenting basic concepts and laws of thermodynamics, fluid mechanics and heat transfer. Topics covered include thermodynamic systems, properties of pure substances and phase changes, ideal gas, real gas, state equations and thermodynamic variables, work, heat and the first law of thermodynamics, the second law, reversible and irreversible processes, the Carnot cycle and the Kelvin temperature scale, entropy, heat engines, Otto, Diesel, Brayton and Stirling cycles, steam cycles, refrigeration and heat pumps, heat transfer, heat conduction in one and two dimensions, steady state and transient, convection, free and forced, radiation, the laws of Stefan-Boltzmann and Planck, surface properties, shape factors, and radiation heat exchange between surfaces, heat exchangers, duty and properties.

Module URBLC5: Energy geology. 4 ECTS

An intensive module that serves as an introduction to geology for engineers, including geological modelling and conceptual modelling of geothermal systems. After the course the student can apply knowledge of how to read geological maps, understand rock classifications, interpret structural data, log core, the contribution of geological knowledge to conceptual models of earth energy systems, and the use of modelling software to describe subsurface conditions. After the course the student can assess the position of geologists in an energy development team and understand the skills and knowledge that earth science professionals contribute to an energy development or research project.

Module URBLC6 / URNGS8M7: Energy financial assessment. 4 ECTS

The lecture aims at 1) understand the theoretical basis for profitability assessment and the time value of money, 2) understand the relations and the difference between company financial statement, 3) discuss and explain with the concepts and principles of accounting and financial management, 4) understand the difference between feasibility studies and business plans and the objectives of each, 5) understand Multi Criteria Decision Making and 6) understand what working capital is.

Module URBLC7: Innovation in geothermal. 6 ECTS

On the completion of the course the student shall be able to formulate technically complex ideas with respect to geothermal utilization and develop and implement them for a competitive market. Through case studies in geothermal innovation and their own ideas, the student will learn how to develop ideas through the Canvas Business Model method, build a business plan, feasibility study, carry out a financial plan and test the idea by developing and testing a prototype.

3.1.2 TU Darmstadt

Module TUDANGBLC1: Introduction to business administration. 3 ECTS

The course is an introduction to business administration for students not familiar with the subject. From the origins of the subject to its current differentiation into its areas of specialization, the course offers insights into the broad spectrum of business administration. Main topics to be covered are general basics of business administration (legal forms and definitions), some marketing concepts, basic features of production management (process optimization and quality management), organization and personnel management, basics of financing and investment appraisal as well as basic knowledge in accounting and controlling.

Module TUDANGBLC2: Energy finance. 3 ECTS

With the agreed energy turnaround, the nuclear phase-out and the even faster shift towards renewable forms of energy in the future, the associated financing issues have once again gained considerable political importance. On the one hand, the event will discuss financing issues for the renewable energy sector. This industry segment can be used to look at the entire corporate life cycle with its specific financing problems, starting with early-stage risk financing by institutional financiers (venture capital), through the growth and establishment phase, which also includes IPOs, to consolidation with corporate takeovers (M&A) and outsourced project financing. On the other hand, it is also about the costs of the energy transition from the perspective of today's dominant conventional electricity suppliers. This raises the question of the changes in capital costs due to the nuclear phase-out and the costs incurred when existing power plants have to be dismantled or removed. In addition, the sale of the electricity grids and the use of the financial resources that are freed up are of importance here.

Module TUDAGBLC1: Characterization of deep geothermal systems from various geological contexts. 2 ECTS

This course will decipher the question on how to integrate the geological knowledge of an area to quantify the geothermal potential, following geological concepts, integration of geological data from various sources, geophysics, fieldwork, and borehole data, to achieve the multi-scale and multi-disciplinary approach of the system.

Module TUDAGBLC2: Structural modeling. 2 ECTS

Content will here focus on geomodelling, its fundamentals, how to build explicit structural model, followed by practical courses to the students to discover geomodelling software and to construct a 3D model areas of interest URG reservoirs from MEET and or DGE Rollout projects datasets.

Module TUDAGBLC3: Geostatistical methods. 2 ECTS

This course will include an introduction to geostatistics, with data analysis and data quality estimation. The notions of variograms, how to calculate and model them, the principles, how to interpret it and how to use it later in the properties modelling workflow. The rest of the baseline course will focus on the different possible methods to model rock properties in geological models, e.g., kriging methods, stochastic simulation methods, etc.

3.1.3 UniLaSalle

Module ULSABLC1: Thermodynamics. 2.5 ECTS

This lecture covers fundamental aspects in thermodynamics, correctly define parameters characterizing a thermodynamic system, and study system evolution as a function of external exchanges. The program gives a series of concepts and definitions dealing with pressure, temperature, work and heat, first principle of thermodynamics (energy conservation), second principle of thermodynamics (system evolution). A series of applications are given (engines, cooling, heat pumps).

Module ULSABLC2: Thermics. 2 ECTS

This lecture aims at understanding the different heat transfer mechanisms: 1) conduction : Fourier law, heat propagation equation, thermal resistance, 2) natural or forced convection: Newton law, exchange coefficients calculations, thermal resistance, 3) thermal radiation (black, grey and real bodies, Planck, Wien and Stefan laws, radiatives thermal exchanges between black and grey surfaces in a cavity. Applications in the field of building engineering and management are given.

Module ULSABLC3: New energy sources. 2 ECTS

The lecture aims at describing the operation, use and (micro) griding of new renewable energy sources (solar, wind, geothermal, hydroelectric, biomass) taking into account electrothechnical, socio-economics, environmental and energetical aspects. All these sources require the use of electric equipment, electromechanics and mechanics dedicated to energy conversion from a non-constant and intermittent physical form to a modular, tunable and exploitable electrical form usable by costumers. The course includes a project (TP-PROJET) aiming at studying, model, simulate and control an electric or electro mechanic conversion chain (PV system). The students will 1) learn to optimize hybrid microgrids in the framework of sustainable development and energy saving, 2) get an overview of renewable energy sources with an associated review of energy conversion chain and MPP principle (variable primary source, technology, principles, efficiency and impacts) and 3) study the different forms of electrical energy storage with a detailed description of storage main elements: chemical (batteries and accumulators), mechanical (hydraulic, electromechanics), thermal (thermal capacity, MCP, heat transfer), electromagnetic (super-condo, SMES).

Module ULSBBLC1: Geochemistry. 3 ECTS

This course presents a series of tools dedicated to analysis of samples gained in the field. Techniques of sample description are demonstrated and all fundamental aspects of mineral geochemistry with applications to mineral resources, soil and rock geochemistry, isotope geochemistry (stable isotope tracers: δ18O and δD; radioactive isotope tracers Sr / Rb-Sr), hydrothermalism related processes, organic geochemistry with applications to reservoirs and fluid inclusions analysis techniques are presented.

Module ULSBBLC2: General geology. 5 ECTS

Basis of cartography, igneous petrology, sedimentary petrology, microscopy (magmatic minerals). General geology (plate tectonics, geodynamics, concept of geological timescale (relative and absolute dating), geomorphology. Field work (outcrop evaluation, geological object observation, techniques of measurements, positioning in space, field book management, synthesis, teamwork).

Module ULSBBLC3: Basic Geo Information System techniques. 3 ECTS

Basic GIS techniques (project construction, georeferencing, 2D spatial analysis) in ArcGIS. Excel (workbook manipulation). SQL Database building.

Module ULSBBLC4: Sampling and sub surface data analysis. 4 ECTS

This course gives the basics in the field of ore geology, isotope chemistry, organic and mineral chemistry applied to reservoirs and fluid inclusion analysis techniques.

Module ULSBBLC5: Dynamic of porous media. 5 ECTS

The lecture deals with fundamentals in hydrogeology (water cycle, notion of aquifer), reservoir geology (rock petrophysics, fracturation, concept of saturation), porous environment mechanics, geothermal energy (technological and legal aspects, presentation of the different types of geothermal exploitation).

Module ULSBBLC6: Drilling and wireline. 5 ECTS

The lecture presents the drilling tools and mechanical aspects, borehole monitoring, wireline interpretation (quicklook, data analysis and interpretation, numerical data treatment techniques).

Module ULSBBLC7: Identification of geo and bio energies. 4 ECTS

This course aims at offering an overview in terms of exploration and exploitation of primary energy resources (methane production, algae cultures, Hydrogen, Uranium, geothermal, fossil fuels, marine renewable energies), energy storage, carbon compensation measures either biological (agroforest, algae, biomass) or geological (depleted reservoirs, abandoned salt mines, mineral sequestration in basalts). The fundamental aspects of carbon neutrality strategies and associated new employment opportunities in the energy sector are presented.

Module ULSBBLC8: Quantification of geo and bio energies. 2 ECTS

The lecture deals with a double approach: 1) evaluation of fossil resources with a dedicated effort on sedimentary fluid evaluation: a case study "Uranium in sedimentary provinces" is proposed and 2) feasibility study of combined renewable energy production project (geothermal and biogas).

Module ULSBBLC9: Innovation, carbon neutrality and territories. 2 ECTS

The lecture is driven by decision makers, stakeholders and investors in the market of renewable energies at local, regional and European scale. Emphasis is given on the challenges and perspectives of energy mixes and carbon reservoirs. A case study dealing with local wood production and associated energy production taking into account production efficiency, economic sustainability and carbon neutrality is proposed. Results are to be presented during a symposium for local entrepreneur and governing entities at the end of the course.

Module ULSBBLC10: Integrated approaches for geo and bio energies. 4 ECTS

The lecture presents an overview of natural energy storage solutions. Technologies dealing with Carbon Capture Utilization and Storage, Bio reservoirs, Energy strategic storage are extensively presented with inputs from industrials leaders in these fields.

Module ULSBBLC11: Soft skills. 4 ECTS

This lecture is dedicated to a presentation of soft skills needed in professional missions and responsibilities. In addition to the fundamental sciences which constitute the common core of the first years of the curriculum, these skills are established through teaching relating to interpersonal skills, management and teamwork, ethics, project management, professional posture and efficiency, personal development, information systems and business plan. An introduction to a "sustainable development" dimension through the acquisition of competences in line with the Sustainable Development Goals (SDGs) listed by UNESCO is given. Based on a wide range of teaching methods, the course is built around scientific experts and bibliographical references that will be provided during the lessons.

Module ULSBBLC12: Entrepreneurship. 4 ECTS

This series of lectures aims at mastering innovation concepts and methodology ranging from activity creation, collective intelligence and design thinking at international level. It is aimed to promote engineers able to coordinate innovative projects, able to integrate within transdisciplinary collective intelligence processes. Several modules cover a variety of thematic: 1) personal development and entrepreneurial stance, 2) territorial ecosystems, 3) research dedicated to innovation, 4) value creation and economical models, 5) entrepreneur opportunities, innovation, marketing and data analysis, 6) financing, business plan and business game, 7) risk analysis, 8) negotiations and leading markets.

3.1.4 University of Zagreb

Module UZBLC1: Introduction to power engineering. 2 ECTS

The introductory lecture is about the importance of energy (electricity) supply, about production and consumption of energy (electricity), about the electric power system and electrical energy, about the peculiarities of the electric power system and the overall energy demand and supply. The electric power system consisting of power plants, substations, transmission lines, control systems and consumer devices is briefly described to the students. The basic idea of electricity production by electromechanical conversion in synchronous generators is described next. The concept of a turbine in different types of power plants is presented to explain that the turbine and the generator are the basic components of a power plant, regardless of the energy source (fossil fuel, hydropower, wind energy, geothermal energy). Sources of energy, amounts of energy obtained from different sources, the difference between power and energy, the price of electrical energy and the energy mix in different European countries are described in a graphic and simple way in order to make students aware of the basic quantities and terms so that they can more easily follow dedicated lectures.

Module UZBLC2: Power plant operation. 2 ECTS

In power plants internal energy (of an energy source) is converted into electricity. Types of internal energy are gravitational potential energy, chemical energy, nuclear energy of fission and fusion, kinetic energy, mass–energy equivalence and internal caloric energy. In thermal power plants the energy source (geothermal, solar, nuclear, chemical) is converted first in heat energy (in the steam generator), then in the turbine in mechanical work, and finally in electric energy in the electric generator. Thermal power plant consists of four main components: boiler, turbine, condenser and pump. Thermal power plant is basically a closed thermodynamic system, where each component is an open system. For each system basic physical principles of mass and energy conservation, and conversion oh heat into work, to fluids that enable energy uptake, storage, transmission and conversion of initial forms of energy into useful electrical energy and mechanical work are presented and discussed. The Rankine cycle is the basic cycle in steam turbine power plants. It uses steam-water mixture as working fluid. Processes are explained, and numerical examples are solved, both with isentropic expansion in the turbine as well as irreversible adiabatic expansion. At the end, procedures for increasing the efficiency in steam and gas turbine power plants are covered. In addition, numerical examples are presented so that students understand what values of efficiency, work, heat, pressure, temperature, enthalpy, etc. are expected in thermal power plants.

Module UZBLC3: Fluid machinery. 2 ECTS

A fluid machine is a device which converts the energy stored by a fluid into mechanical energy (turbines) or vice versa (pumps, compressors). The energy stored by a fluid mass appears in the form of potential energy, kinetic energy and intermolecular (internal) energy. The mechanical energy is usually transmitted by a rotating shaft (turbo machinery). The turbine type depends on the driving fluid. Steam turbines are used at power plants to generate electricity using high temperature and high-pressure steam. Gas turbines use high temperature and high-pressure combustion gases. Wind turbines use kinetic energy of wind and hydrokinetic turbines use kinetic energy of water: Pelton impulse turbines, Francis and Kaplan reaction turbines. Direction of flow could be axial, radial, or mixed flow, while the interaction of fluid and rotor blades is either of impulse type (uses dynamic head only – velocity) or reaction type (uses both dynamic (velocity) and static heads (pressure). The emphasis of this course is on turbines in geothermal power plants: steam turbines and turbines for organic fluids. The working principle of steam turbines is explained. Turbines are divided into stages: impulse and reaction stages. In the impulse stage the whole pressure drop is in the nozzle (whole enthalpy drop is changed into kinetic energy in the nozzle) and in the reaction stage the pressure drop is both in stationary blades and in rotary blades (enthalpy drop changed into kinetic energy both in stationary blades and in the moving blades in rotor). The turbine construction, regulation, compounding, monitoring instrumentation, sealing system, classification are discussed as well.

Module UZBLC4: Geothermal power plants. 2 ECTS

There are three main types of geothermal power plants: dry steam power plants, flash steam power plants and binary cycle power plants. Their operation, components, temperature-entropy diagrams, efficiency, operating parameters are discussed in detail. In dry steam power plants saturated steam is extracted from the well and after expansion in the valve directed to the centrifugal separator that separates impurities from the incoming steam. Steam then expands in the turbine, some of the steam condenses and the remainder is condensed in the condenser. The cycle is similar to the Rankine cycle but it is an open cycle as the liquid is re-injected back into the well. In flash steam power plants the geothermal fluid is in the liquid state (saturated liquid!) which is expanded through an expansion valve resulting in a two-phase flow. The produced vapor is directed to the steam turbine to generate electricity while the remaining liquid is re-injected to a re-injection well like in the dry steam power plant. Regarding the temperature and efficiency the fluid in the flash steam plant is at a lower temperature and thus efficiency is lower than in the dry steam power plant. If the temperature of the geothermal fluid is too low to be used in a flash steam plant, then the internal energy of the geothermal water is used to heat up an organic fluid in the binary cycle power plant in a special type of heat exchanger. A secondary fluid such as hydrocarbon or fluorocarbon is used instead of water to run the organic Rankine cycle (ORC) turbine. The advantage of the organic fluid is that it becomes superheated after expansion in the turbine which results in better thermodynamic turbine performance.

Module UZBLC5: Electric machines and transformers. 2 ECTS

An electric machine is a device that converts electrical energy to mechanical (motor) or/and mechanical energy to electrical (generator). Generators convert mechanical energy from a prime mover to electrical energy through the action of the magnetic field. Transformers convert AC electrical energy at one voltage level to AC electrical energy at another voltage level at the same frequency. Synchronous machines are AC machines that have a field circuit supplied by an external DC source. The introductory lectures cover the construction of synchronous machines, measuring parameters, rotation speed, internal generated voltage of a synchronous generator, equivalent circuit, phasor diagram, power, torque, active and reactive power generation, characteristics of the generator when it works independently or when connected to the grid. The power-flow diagram, power losses, voltage and speed regulations are also covered. The main types of transformers are explained: unit transformers connected to the output of a generator and used to step its voltage up to the transmission level, substation transformers used at a substation to step the voltage from the transmission level down to the distribution level, distribution transformers for converting the distribution voltage down to the final level, voltage or current transformers for electrical measurements. The operation of the transformer is analyzed using the equivalent circuit in order to account for the copper losses, eddy current losses, hysteresis losses and leakage flux. Voltage regulation, efficiency, phasor diagram and 3-phase transformer connections are also covered.

Module UZBLC6: Transmission and distribution of electric energy. 2 ECTS

Transmission and distribution networks carry electricity from power plants to electrical substations and individual consumers. Transmission networks include transformer stations, energy transformers, compensators and transmission lines. Different types of conductors (HTLS – High Temperature Low Sag conductor and ACSR – Aluminum conductor steel-reinforced conductor) and poles (tension and supporting lines) are explained. Electrical substations are facilities which connect generator to transmission network, different levels of transmission systems and transmission to distribution networks. Substations consist of the following components: transformers, disconnectors, earthing switches, supporting isolators, current/voltage transformers, circuit breakers, surge arresters, busbars, lighting and other protection systems. A short description of each component is provided and explained on the example of a real facility. In addition, a typical layout of the substation based on the voltage level is presented. Power system equilibrium, power flows, frequency control, transmission losses, AC vs. DC transmission, investments costs, etc. are also described. Introduction to smart grid concepts (wide area monitoring systems, flexible AC transmission systems, phase shift transformers, dynamic thermal rating, dynamic voltage regulation) is given as well. Distribution lines, radial operation, distribution cables and new concepts in distribution systems (electric vehicles, demand response, multi-energy, ancillary services, reserve provision, distributed storage) are briefly described.

Module UZBLC7: Heat exchangers and heat pumps. 2 ECTS

Heat exchangers are devices that facilitate the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with each other (hydraulically separated). They are classified on the basis of fluid type (gas to gas, gas to liquid, liquid to liquid), flow pattern (single pass, multi pass), shape and geometry (shell and tube, double pipe, plate type), direction of flow (parallel flow, counter flow, cross flow, hybrid flow). In binary cycle power plants a main heat exchanger is an air cooled device that serves as a condenser for the organic fluid where heat is rejected directly to ambient air. A mathematical model of the heat exchanger is explained that includes the parameters: the overall heat transfer coefficient, fouling factor, logarithmic mean temperature difference, heat exchanger efficiency. This is done for both the parallel flow and counter flow heat exchangers. Heat pumps use reversed heat cycles to transfer heat from a low-temperature reservoir to a high-temperature reservoir. Heat pumps are made as horizontal and vertical, compression and absorption type. The operation of the heat pump is described in detail, and several numerical examples are also solved.

Module UZBLC8: High voltage technology. 2 ECTS

In this course, an introductory overview of high voltage technologies is given. The topics covered in more or less details are the following: generation of high voltages, HV AC test transformers, cascade of transformers, measurement of HV in HV lab and HV substation, voltage divider and spark gap, voltage measuring transformers, applicability of HV in industry and transmission of electrical energy, analytical methods for electrical field problem solving, ionization and deionization of gases, the origins and effects of the AC and impulse corona, materials in the electrical field, dielectric losses and polarization, electromagnetic field in the proximity of the HV transmission lines and substations, solid dielectrics, partial discharges, electrical, thermal and electromechanical breakdown of solid dielectrics, liquid dielectrics, electrical breakdown theory, generation of high DC voltages, electrostatic generator, generation of impulse voltages, Tesla's coil (Tesla transformer), temporary overvoltages, switching overvoltages, physical basis of lightning flashes, theory of electro-geometric model of lightning strike, basics of lightning location systems, gas insulated switchgear, surge protection, basics of traveling waves, overvoltage classification according to IEC 60071-1, traveling waves in overvoltage protection, wave equation, reflections and refractures of traveling wave, Petersen's rule, multiple reflections, lattice diagram, temporary overvoltages simulation, Ferranti effect, ferroresonance, emergence and switching-off of faults, switchings of unloaded transmission lines, cables and transformers, origin and development mechanism of lightning strike, application of lightning location system in power system, lightning protection of overhead transmission lines, overvoltage protection of the switchgear, transformers and generators, theory and calculation of magnetic field – practical examples, measurement of magnetic induction in HV laboratory.

3.2 Double degree UniLaSalle / University of Reykjavik: Geothermal electrical engineering

3.2.1 Semester S7NGULSA. 30 ECTS

Module ULSANGS7M1: Electrical networks. 3 ECTS

The objectives of the course are 1) study of a modern electrical network from power generation to utilization. A special emphasis is given to environmental concerns, energy production and consumption stability 2) analysis and conception of electrical network taking into account its sustainability. The lecture starts with 1) a general introduction dealing with energy sources, network functions and architecture, non central production and statistics. The program is followed by 1) electrical networks considerations (energy transport: serial impedance, polyphase lines capacities, multi wire propagation, lines models and transport capacity), 2) disturbed regimes and default currents (symetric components Fortescue, non equilibrium regime transformator study, short circuit current calculation), 3) power partitioning studies (load flow, Gauss-Seidel and Newton-Raphson method, decoupling techniques and 4) voltage and power adjustment and electrical grid stability.

Module ULSANGS7M2: Thermodynamics. 1.5 ECTS

The lecture id intended to give all necessary know how in order to 1) achieve energy and mass balance assessments, 2) calculate heat quantities exchanges between a given system and external environment when considering classical transformations, and 3) calculate efficiency and delivered power when dealing with a variety of thermal machinery. The program gives fundamental knowledge in 1) entropy, enthalpy and thermodynamic diagrams, 2) combustion, 3) thermodynamic cycles (cooling, heat pumps and thermal engines).

Module ULSANGS7M3: Command electronics. 1.5 ECTS

The lecture aims at implement all necessary elements needed in the command of static converters. The program describes the commutation (natural of forced) cells, mechanisms of communication enhancement, cooling system sizing, command electronics (far vs. close commanding), command syncing, conception, drivers selection, protection and grounding, modeling.

Module ULSANGS7M4: Power electronics. 3.5 ECTS

The lecture describes the different types of static hard switch convertors. The program presents 1) basic principles of energy conversion, the characteristics and modes of switches, power sources (nature and association), 2) DC/DC conversion, structures with and without galvanic insulation, choice and sizing, 3) DC/AC conversion, 3 phases power inverter (full wave command and MLI), 3 phases power inverter (characteristics, operation and applications), choice and sizing and 4) AC/DC conversion, 3 phase rectifier (commanded and non commanded), choice and sizing.

Module UZS7M2: Power generation. 3.5 ECTS

Basic characteristics of the power plants: types, power capabilities, energy production. Power plants (hydro, thermal, nuclear). Main power plant systems and equipment. Water, steam and gas turbine types. Nuclear reactor as heat source. Heat balance diagrams and power generation cycles for different plants. Characteristics and choice of main power plant electric equipment. Startup and shutdown of the plant and power change capabilities. One-line station connection diagram. Choice of synchronous generator parameters. Generator static and dynamic limits, Q-P diagram (reactive/active power). Active and reactive power generation. Generator synchronization. Analysis of generator operation and loading. Onsite power systems. Emergency power sources. Grounding system of the plant. Process measurements. Power plants construction cost, operation and maintenance cost, and total production cost. Electricity price. Power plant operation in liberalized market.

Module UZS7M3: Power system analysis. 3.5 ECTS

Introduction to Power Systems Analysis. Network Equations. Network models: generators, lines and transformers, voltage control devices. Admittance and impedance matrices. Numerical methods for load flow. Gauss and Gauss-Seidel methods. Newton-Raphson and Fast Decoupled Load Flow. Sparse matrix algebra in network calculations. Simplified load flow models. DC models. 3-phase load flow. Fault analysis.

Module UZS7M4: Energy efficiency and demand side management. 3.5 ECTS

Energy situation in the world and in Europe. Energy resources, energy transformations and direct consumption of energy (efficient usage of energy in industry and buildings). Demand side management and its value. Basic types of energy consumption and energy management strategy in industry and buildings. Possibilities for improvements and for financing of energy efficiency programs. Energy management in industry and buildings. Technical and human components of energy management programs. Principles for implementation of energy management and environment protection programs, motivation, leadership and team work models. Regulation of energy sector and organization of energy market. Economical and social regulation. Regulatory bodies. Regulation of monopoly or public service. Regulation of energy subjects entrance in the sector and control of energy market operation. Control of quality standards implementation. Energy trading on the liberalized energy. Reasons and way to demand side management.

Module UZS7M5: Power system protection. 3 ECTS

Definitions and terminology of power system protection. Electromechanical, static, digital and numerical relays. Overcurrent protection. Distant protection. Connecting distance relays. Automatic reconnection. Differential protection of generators and transformers. Longitudinal differential protection of high voltage lines. Numerical distance protection and fault locator. Voltage and frequency protection. Thermal protection. Protection of electricity networks. Bus protection. Switch breaker protection. Transformer protection. Generator and Block Generator Transformer Protection. Protection of high voltage synchronous and asynchronous motors. Current and voltage measuring transducers and sensors. In-plant communications (wired and optical connections, Ehternet). Program blocks. Failure log and analysis (Comtrade record, Digsi, Reval, Master). Selection and adjustment of protection devices of individual components of the power system. Testing, parameterization and commissioning.

Module UZS7M6: Introduction to smart grids. 3 ECTS

Strategic documents for energy transition and smart energy systems. Introduction, concepts, methods and advance solutions for power, heat, water/gas networks. Energy systems/networks of future (biogas, hydrogen). Integrated approach to operation and planning of smart energy systems. Smart islands and smart cities. Explanation of concepts, methods and solutions for smart transmission and distribution power systems. Prosumers, electric vehicles and market mechanisms for flexible end-users.

S7NGBLC1: lectures to be chosen in the TUDA, UR and ULSB BLCP. 2 ECTS

S7NGBLC2: lectures to be chosen in the TUDA, UR and ULSB BLCP. 2 ECTS

3.2.2 Semester S8NGUR. 30 ECTS

Module URNGS8M1: Energy economics. 4 ECTS

This course will give students a broad overview of a variety of theoretical and empirical topics related to energy economics. The knowledge deals with 1) Basic principles of energy economics, 2) Understanding of a broad overview of a variety of theoretical and empirical topics related to energy economics, 3) Apply methods from mathematics and economics science to analyze complex systems in energy systems or their peripheries 4) Analyze economics of energy project, 5) Analyze and communicate experimental, numerical and statistical data, 6) Apply standard scientific principles to develop analytical solutions to a range of practical problems. Students acquire skills in 1) Applying methods from economics science to analyze complex systems in energy systems or their peripheries, 2) Analyzing economics of energy projects, using current best-practice methods, 3) Applying research methodology and critical thinking, including the fundamentals of scientific writing, literature search, evaluate a scientific paper, and be aware of research ethics, 5) Giving an oral energy economics presentation and write a scholarly research report. The acquired competences are: 1) apply analytical skills and methodologies to recognize, analyze, synthesize and implement operational solutions to energy related problems, 2) Apply standard economics principles to develop analytical solutions to a range of energy problems, 3) Interpret and apply existing economic theories, models, methods and results, both qualitatively and quantitatively, within the field of energy economics

Module URNGS8M2: Economics of energy markets. 3 ECTS

The aim of the course is to deepen students understanding of economic concepts related to energy. The course builds on the knowledge acquired in the Introduction to Energy Economics course. Students acquire knowledge about important markets in all three blocks and important theories that are applied to the analysis of energy markets. Understand concepts, key drivers in energy markets and terminology, among others: different electricity market models, nodal pricing, zonal pricing, uniform auction, merit order dispatch; Knowledge of chosen public policies concerning environment. The obtained skills are: 1) ability to retrieve, understand and present energy related data (from energy databases) Ability to solve basic oligopoly models (Cournot, Bertrand; Stackelberg), 2) ability to apply economic models. Ability to formulate models for analysis of certain topics/simple economic problems and 3) ability to discuss different economic concepts relating to energy markets. Students acquire competences in understanding of how different energy markets function. They have 1) deeper understanding of chosen topics relating to energy markets, 2) have developed the necessary learning skills and independence for further studies in energy economics and 3) have developed the necessary understanding of economics concepts, which will allow him/her to follow and participate in public debates and analysis of energy related issues.

Module URNGS8M3: Environmental impact assessment. 3 ECTS

Environmental Impact Assessment (EIA) is the process by which the anticipated effects on the environment of a proposed development or project are measured. In this course the process of an EIA will be discussed, and students will get the opportunity to develop their own EIA on a topic they select. The students will have the opportunity to get in contact with relevant stakeholders and acquire first-hand experience in the field of environmental impact assessments. The course is structured in three parts: i) lecturing of theoretical and field methods frequently used within the EIA process, ii) interaction with local businesses to acquire first-hand experience and iii) hands on training by writing an EI statement on a selected topic. The students should develop an environmental system understanding, enhance their awareness for environmental problems and get the opportunity to developed potential solutions to mitigate, compensate and reverse persistent environmental challenges.

Module URNGS8M4: Energy and policy innovation. 4 ECTS

Students will embark on a journey where the interplay between energy policy and climate change is explored, and its current and future impact on the Arctic, and the regions' resources are analyzed and discussed. Topics included are; energy and environmental policymaking, stakeholder negotiations, policy evaluation in a local and international context and energy policy's impact on climate change and its multiple effects on societies (water issues, environmental issues, etc.).

Module URNGS8M5: Energy financial assessment. 4 ECTS

The lecture aims at 1) understand the theoretical basis for profitability assessment and the time value of money, 2) understand the relations and the difference between company financial statement, 3) discuss and explain with the concepts and principles of accounting and financial management, 4) understand the difference between feasibility studies and business plans and the objectives of each, 5) understand Multi Criteria Decision Making and 6) understand what working capital is.

Module URNGS8M6: Markets and regulations. 3 ECTS

This course provides an overview of modern energy markets, policy and market regulation, with a primary focus on the industry in the US and Canada. The primary emphasis is electricity pricing and market oversight; some lectures will include the role of liquid and gas fuel markets as well. The class is based on guest lecturers from industry and public regulatory institutions. Readings will be available on-line from journal articles and excerpts from text materials. Grading will be based on in-class participation, 2 in-class quizzes a short essay and a final examination.

Winterschool UZNCWS. 5 ECTS

Computer and laboratory exercises covering material in the field of power engineering. Computer exercises are aimed at introducing students to the design of power plants, operating parameters and to clarify the physical processes in individual components of the power plant. The theoretical part will include numerical examples of calculations of power and energy in thermal power plants, hydropower plants and renewable energy sources. In addition, calculations of electrical networks, power flows and current and voltage conditions in electrical circuits will be presented. Practical exercises in the laboratory include various electrical measurements, electrical insulation testing, and work on the simulator of thermal power plants and hydropower plants.

S8NGBLC1: lectures to be chosen in the TUDA, UR and ULSB BLCP. 2 ECTS

S8NGBLC2: lectures to be chosen in the TUDA, UR and ULSB BLCP. 2 ECTS

3.2.3 Semester S9ULSA. 30 ECTS

Module ULSANGS9M1: Heat pumps. 1 ECTS

The lecture aims at presenting 1) the heating technics by means of heat pumps, 2) heat pump standards and technology. The lecture presents 1) some theory and applications related to heat pumps, 2) heat pumps componants (heat exchangers, regulator, compressor, working fluids and secondary components: filters, indicators), 3) operating modes (monovalency, bivalency), 4) air, water and geothermal, 5) norms, sizing and device selection and 6) commissioning and maintenance.

Module ULSANGS9M2: District heating. 1 ECTS

The lecture presents 1) the different techniques used in district heating, 2) the methods involved to determine large scale heating needs and 3) the characteristics of main boilers types. The lectures are divided in 5 groups: 1) large scale heat needs evaluation, 2) boilers types (biomass, fuel oil, gas, geothermal, solar energy, cogeneration), 3) boiler and pipe sizing, 4) regulations (financing, environmental) and 5) maintenance.

Module TUDANGM4: Renewable energies, energy scenarios and climate protection. 5 ECTS

evaluation of methods of energy scenarios conception, testing for renewable energy balance integration

Module UZS9M1: Power system dynamics and control. 4 ECTS

Control characteristics of energy processes in power system production and transmission facilities. Load - frequency control in power systems. Droop curve, load damping. Primary, secondary and tertiary load - frequency control system structure in power systems. Frequency collapse and underfrequency load shedding. Reactive power - voltage control in power systems. Voltage control devices. Voltage collapse and undervoltage load shedding. Dynamic characteristics of electric machines, network, loads and interconnections. Unit behavior during failure. Angle stability. Small signal stability and transient stability. Power system voltage stability. Long term stability. Power system stabilizers. Dynamics models of electric power systems elements.

Module UZS9M2: Electric power distribution systems. 5 ECTS

Configuration of distribution networks. Load forecasting, Analysis of the distribution networks. Building and operation. Network elements. Substation design. Distribution system/network operator. Quality of supply. Connections and interconnections - practice and standards. Active distribution network Distributed resources. Distributed generation (DG) impact on planning and operation. Micro-grids and virtual power plants. DG and network security. Economics of DG. Introduction to network optimization.

Module UZS9M3: Power system planning and operation. 3 ECTS

Exploitation characteristics of electric power system. Operational system states (normal, transient, emergency, critical, restorative). Daily electric power system load curve. System load curve approximation. Load curves: weekly, monthly and annually. System operation planning (daily, monthly and annually). Analytical functions for system operation planning. Analysis and checking of realized system operation. Load Forecasting (parable method, second order polynomial method, xpotentially method, logarithm parable method, Gompertz method, logistic method, empiric equation). Unit scheduling. Midterm unit commitment. Load following. Energy imbalance. System reserve (ready-import, spinning, stand by quick start, stand by slow start). Interconnection. Power and energy exchange between systems. System island operation. System blackout and restoration. Analysis of recently system blackouts. Grid code.

Module UZS9M4: Electric power equipment maintenance. 3 ECTS

Basic terms and definitions about equipment maintenance. Failure cause. Features of equipment quality. Maintenance strategies and types. Maintenance strategy selection. Maintenance planning and management. Activity preparation as crucial point of maintenance. System checking during maintenance. Periodic maintenance scheduling. Service life. Costs analyses. Characteristics of maintenance results. Optimal number of reserving components. Repair. Replacement. Maintenance based on legislative. Historical data and statistics. Significance of maintenance in respect on technical limits. Maintenance activity. Results of total productive maintenance. Long-term purpose of maintenance. Maintenance and quality. Maintenance in open market environment. Maintenance information system. Testing techniques. Component monitoring. Technical data acquisition and diagnosis. Damage identification, types and estimation.

Module UZS9M5: Feasibility studies: principles, tools and applications. 3 ECTS

This module presents all steps necessary to achieve geothermal projects feasibilities studies using a real shallow geothermal feasibility study case: After some reminder about the local regulation, students will conduct a step by step feasibility based on a real case and divided as follow:

Part 1: Context and geological study (geography, local constraints, project manager requests, finding geological information to know the local underground within 200 meters deep)

Part 2: Sizing of the geothermal solutions. Thanks to the building energetic needs, it would be possible to size to of the main geothermal shallow solutions (groundwater or vertical probe geothermal system).

Part 3: Payback time and CO2 emissions. The aim is to compare two payback time calculation methods, a simplified one and a complex one taking into account multiple parameters (investment price, maintenance, renewal fees, energy cost variations). The financial contributions will be described and integrated in the payback times.

Based on the data of the different parts of the study, it would then be possible to choose only one technology and decide if the geothermal energy is the best option in geological, technological and economical ways. At the end of the feasibility, a visit of the site will be conducted.

In a second step, feasibility studies completion for geothermal projects other than shallow are considered. In order to do so, the DMS-TOUGE tool is presented. This software is a MATLAB-based tool and open-access standalone application that estimates different important economic indices for a defined geothermal scenario, provides MCDM ((Multi Criteria Decision Making) analysis and facilitates the decision-making process. Among other outputs related to performance such as yearly or monthly production data, calculated avoided CO2 emissions, the economic outputs are the system's levelized cost of energy (sLCOE), net present value (NPV) and internal rate of return (IRR) that are usually used to evaluate the potential energy production related projects. The available end-use options are electricity generation, direct-use heating power production, and combined heat and power (CHP). Evaluations are made for EGS resources with temperatures from 50-170°C, and either for an air-cooled or water-cooled binary power plant.

Summerschool URCSS. 5 ECTS

A modularized Lecture Series is presented on the topics of geothermal energy in Iceland, natural state & utilization of high-temperature geothermal systems, resource impact of geothermal utilization, geothermal fluids, and the economics of geothermal utilization. Each module will contain a lecture, five readings, and one to two short quizzes based on both the lecture and the readings. The online course will be followed by site-visits to relevant areas in Iceland. Field notes and readings associated with the site-visits will be provided to students via the Canvas site under Modules. Discussion sessions will be held in the field during and after each of the site visits. The areas the students will visit is Reykjanes, Hengill, Þjórsárdalur and the Fjallabak Protected Area. The student projects will be presented on the final day of the summerschool.

3.2.4 Semester S10NGUR. 30 ECTS

Common project workshop 5 ECTS

The common project workshop proposed by TUDA is conceived to gather all the datasets, and apply all the knowledge and know-how acquired during the previous semesters. Students will combine, geological, economical and surface installation related datasets to estimate the potential, through the use of a decision making tool, of geothermal technologies (after having followed the DMS TOUGE training). They work here in multi-disciplinary teams gathering above surface and below surface engineering knowledge.

Master Thesis URNGS10M1: Research Proposal. 2 ECTS

Within the first 15 days of S10, a student at RU must complete a thesis proposal that has been signed by the proposed research supervisor. A student proposing to complete S10 at RU is advised to organize the preparation of a thesis proposal during S9.

Master thesis URNGS10M3: Thesis Project. 28 ECTS

The layout and form of the thesis shall in general be according to good practice for a thesis of this type. The student shall consult his/her supervisor on an appropriate structure for the thesis, appendices to the thesis and the reference system, taking into account established practice within the specific field of research. Each department within the School of Science and Engineering may set rules that further specify the form and layout of the thesis, including a recommended template. In general, the thesis is expected to contain the following:

- Front cover (standard)
- Front page (standard format)
- Title page (standard format)
- Abstract (in English and Icelandic)
- Signature page (standard format)
- Acknowledgements (optional)
- Preface (optional)
- Table of contents
- List of tables
- List of figures
- List of drawings and enclosed material, e.g. CD (as appropriate)
- Introduction
- Methods
- Results
- Discussion
- Conclusion
- References
- Appendices (as appropriate)
- Back cover (standard)

The front cover, front page, title page and back cover have a specific form as shown in the attached examples and shall contain all information requested. No variation from this form is permitted. If the thesis is written in English, the title on the title page shall be in English; however, an Icelandic translation of the title must be presented with an Icelandic abstract, and vice versa if the thesis is written in Icelandic. An abstract is mandatory, both in English and Icelandic. The maximum length of abstract is 300 words. At the end of the abstract there should be a list of up to five keywords reflecting the content of the thesis. A printed version of the thesis s. hall be on white paper, size A4 and weight 80 g/m2 . In general, the font should be Times or Times New Roman of size 12 points.

Guidelines for page numbering and layout:

● Page numbering is normally i, ii, iii, iv, ... for material preceding the first chapter of the thesis (i.e. for abstract, signature page, acknowledgements, preface, table of contents etc.) and then 1, 2, 3, starting from the 1st chapter (Introduction) and continuing throughout the thesis, including the appendices.

● Page numbers should in general be centered at the bottom of each page.

Only in exceptional cases may the thesis have a different form. While the thesis itself has to comply with the layout instructions in regards to the cover pages, abstract and the signature page, it can consist mainly of publishable research paper manuscripts. In this case, the manuscript(s) shall be preceded by a detailed section of introduction to the research topic with a corresponding in-depth literature review and detailed description of the methods used in the MSc project. The minimum length of this section shall be 20 pages excluding a reference list. This format of the MSc thesis should only be used if the supervisor of the thesis assesses the outcome of the MSc project to be publishable in indexed peer reviewed journals in the relevant field of research. If this format of the MSc thesis is used, the student's supervisor has to request a formal acceptance of both the student's Department Head and the Director of Graduate Studies, with a letter summarizing the findings of the project, the novelty beyond the state of the art and the contribution of all authors of the manuscript. This request has to be sent to the Department Head and the Director of Graduate Studies prior to t-50 (where “t” is the graduation date). The Department Head and Director of Graduate Studies can forward the request to the Graduate Study Council for further evaluation if they find it necessary.

Thesis defense procedure is outlined in the following sections as well as relevant deadlines. The examiner of the thesis report is selected by the Department Head in consultation with the supervisor(s). The choice of examiner needs to be approved by the Director of Graduate Studies. The examiner shall have the qualifications necessary to supervise the thesis, but must not have collaborated in the project on which the thesis is based and must fulfil the rules of Reykjavík University on impartiality of examiners. The oral examination shall be open to the public and shall be announced through appropriate channels with at least 3 days notice. The examination should take the form of an approximately 30 minute presentation by the student, followed by questions from the examiner, School representative (most often the Department Head), supervisor(s) and the audience. The Reykjavik University, School of Science and Engineering August 15th 2017 3 audience then leaves the room and the examiner(s), supervisor and School representative have the opportunity to put further questions to the candidate and, as appropriate, request modifications to the thesis. Subsequently, the candidate leaves the room and the examiner, School representative and supervisor(s) deliberate and decide upon the grade. Normally, the student will be informed of the grade the next day. If the thesis is subject to confidentiality, or for other valid reasons approved by the Director of Graduate Studies, the oral examination may be closed to the public.

The official completion of the MSc thesis is signified by the student submitting the final electronic (PDF) version of the thesis, signed by himself/herself, the supervisor(s) and the examiner to the SSE office and uploaded to Skemman, (see www.skemman.is). See also RU´s rules for submission of theses and final projects (Reglur um skil á lokaritgerðum og lokaverkefnum við Háskólann í Reykjavík, www.ru.is/bokasafn/skemman). If a student plans to graduate in a particular graduation ceremony, the following deadlines must be respected. Should any of the deadlines below not be respected the student will have to wait for the following graduation ceremony before he/she can graduate. Students are responsible for adhering to these deadlines and are advised to deliver their work in good time. The deadline schedule for the purpose of graduation is as follows (where t is the graduation date and the numbers refer to the number of days prior to graduation):

- Final draft of thesis delivered to supervisor a) t-50 b)
- Supervisors comments delivered to student t-40 c)d)
- Thesis delivered to supervisor(s), examiner and Department Head t-20 c)
- Examiner confirms that thesis may be put up for defence t-17 c)
- Defence t-14 c) ● Grade posted to the Registrar by SSE office t-11c)
- Graduation t c)

a) Paper and/or electronic form, as requested by the supervisor(s) and/or examiner.
b) Date can be modified by mutual agreement of the supervisor, student and examiner.
c) Firm deadlines.
d) Or within 10 days after the supervisor has received the final draft, whichever comes first.
e) Or within 5 days after the defence, whichever comes first.

GRADING

The appointed examiner shall evaluate the thesis and the oral defense of the thesis, together with the supervisor(s) and the department´s representative. One grade shall be awarded for the thesis and defence. The minimum passing grade is 6.0, see Guidelines for grading MSc theses in the appendix. The following factors shall be taken into account: ▪ Significance and originality of work ▪ Scientific and technological challenge and results ▪ Methodological quality ▪ Presentation The number of ECTS credits awarded for the Master’s project shall be taken into account. Thus, significantly more demands in terms of originality, quantity and scientific quality of the work should be placed on the student for a 60 ECTS thesis than a 30 ECTS thesis.

GUIDELINES FOR GRADING MSc THESES

The guidelines below describe typical projects in different grading brackets. This is meant for examiners and instructors in grading master‘s theses. The projects need not fulfil every aspect of these desciptions in order to be awarded the corresponding grade.

Superior (9,0-10,0) The project is excellent. The handling of the material shows considerable originality and independent thought. Considerable skill in the definition and organized solving of the problem. Very good understanding of concepts. Academic approach and handling of material. Exemplary methods in collection and processing of data. Use of references is very precise and supports the projects well. The thesis may well lead to a publishable article. Exceptionally well polished thesis with very good grammar, spelling and language use. The thesis is in English. The student‘s performance in the defense is excellent.
First grade (7,5-8,5) The project is very good and handling of material is good and somewhat original. Clear understanding of the material and the definition of the problem is good and the solving well organized. Data gathering and processing without major weaknesses and intelligent use of references. The thesis is well arranged and grammar, spelling and language is good. The student‘s performance in the defense is either good or very good.

Second grade (6,0-7,0) The project is acceptable. Handling of material is fair and some independent thinking. Definition and analysis of project reflects some understanding. Data collection and processing is without major flaws. Deficiencies in the literature review. Flaws have not been addressed despite the instructor‘s suggestions. Language, grammar and spelling is fair. The student‘s performance in the defense is fair.

Fail (1,0-5,5) The project is unacceptable. The project has major flaws that have not been addressed despite the instructor‘s suggestions. Limited understanding of the material. Definitions and analysis do not show understanding of what is relevant in solving the problem at hand. Major errors or misunderstanding. Data collection and analysis has deficiencies and literature review is weak. The subject is not adhered to or major inconsistencies. Language, grammar and spelling is fair or poor. The student‘s performance in the defense is fair or poor.

3.3 Double degree TU Darmstadt / University of Reykjavik: Geothermal and energy science engineering

3.3.1 Semester S7GTUDA

This semester 7 is identical to the one presented in section 3.2.1.

3.3.2 Semester S8GULSB

This semester 8 is identical to the one presented in section 3.2.2.

3.3.3 Semester S9NGTUDA. 30 ECTS

Module TUDANGM1: Chemistry for Engineers and scientists. 5 ECTS

Scientific fundamentals for chemical processes: Chemical thermodynamics; Ideal and real mixtures; Phase diagrams; Chemical kinetics; Catalysis; Electrochemistry. Chemistry of fuels. Knowledge of inorganic substances and materials relevant for energy conversion and the efficient usage of energy: Synthesis of characterization of solids; Oxides; Refractory materials; Ionic conductors; Electrode materials; Physical properties.

Module TUDANGM2: Materials science for renewable energy systems. 5 ECTS

material science for renewable energies requires engineering approach to increase the renewable energy implementation, with innovative sustainable material development.

Module TUDANGM3: Renewable energies, energy scenario and climate protection. 5 ECTS

evaluation of methods of energy scenarios conception, testing for renewable energie balance integration

Module ULSANGS9M1: Heat pumps. 1 ECTS

The lecture aims at presenting 1) the heating technics by means of heat pumps, 2) heat pump standards and technology. The lecture presents 1) some theory and applications related to heat pumps, 2) heat pumps componants (heat exchangers, regulator, compressor, working fluids and secondary components: filters, indicators), 3) operating modes (monovalency, bivalency), 4) air, water and geothermal, 5) norms, sizing and device selection and 6) commissioning and maintenance.

Module ULSANGS9M2: District heating. 1 ECTS

The lecture presents 1) the different techniques used in district heating, 2) the methods involved to determine large scale heating needs and 3) the characteristics of main boilers types. The lectures are divided in 5 groups: 1) large scale heat needs evaluation, 2) boilers types (biomass, fuel oil, gas, geothermal, solar energy, cogeneration), 3) boiler and pipe sizing, 4) regulations (financing, environmental) and 5) maintenance.

Module UZS9M2: Electric power distribution systems. 5 ECTS

Configuration of distribution networks. Load forecasting, Analysis of the distribution networks. Building and operation. Network elements. Substation design. Distribution system/network operator. Quality of supply. Connections and interconnections - practice and standards. Active distribution network Distributed resources. Distributed generation (DG) impact on planning and operation. Micro-grids and virtual power plants. DG and network security. Economics of DG. Introduction to network optimization.

Module UZS9M5: Feasibility studies: principles, tools and applications. 3 ECTS

This module presents all steps necessary to achieve geothermal projects feasibilities studies using a real shallow geothermal feasibility study case: After some reminder about the local regulation, students will conduct a step by step feasibility based on a real case and divided as follow:

Part 1: Context and geological study (geography, local constraints, project manager requests, finding geological information to know the local underground within 200 meters deep)

Part 2: Sizing of the geothermal solutions. Thanks to the building energetic needs, it would be possible to size to of the main geothermal shallow solutions (groundwater or vertical probe geothermal system).

Part 3: Payback time and CO2 emissions. The aim is to compare two payback time calculation methods, a simplified one and a complex one taking into account multiple parameters (investment price, maintenance, renewal fees, energy cost variations). The financial contributions will be described and integrated in the payback times.

Based on the data of the different parts of the study, it would then be possible to choose only one technology and decide if the geothermal energy is the best option in geological, technological and economical ways. At the end of the feasibility, a visit of the site will be conducted.

In a second step, feasibility studies completion for geothermal projects other than shallow are considered. In order to do so, the DMS-TOUGE tool is presented. This software is a MATLAB-based tool and open-access standalone application that estimates different important economic indices for a defined geothermal scenario, provides MCDM ((Multi Criteria Decision Making) analysis and facilitates the decision-making process. Among other outputs related to performance such as yearly or monthly production data, calculated avoided CO2 emissions, the economic outputs are the system's levelized cost of energy (sLCOE), net present value (NPV) and internal rate of return (IRR) that are usually used to evaluate the potential energy production related projects. The available end-use options are electricity generation, direct-use heating power production, and combined heat and power (CHP). Evaluations are made for EGS resources with temperatures from 50-170°C, and either for an air-cooled or water-cooled binary power plant.

Summerschool URCSS. 5 ECTS

A modularized Lecture Series is presented on the topics of geothermal energy in Iceland, natural state & utilization of high-temperature geothermal systems, resource impact of geothermal utilization, geothermal fluids, and the economics of geothermal utilization. Each module will contain a lecture, five readings, and one to two short quizzes based on both the lecture and the readings. The online course will be followed by site-visits to relevant areas in Iceland. Field notes and readings associated with the site-visits will be provided to students via the Canvas site under Modules. Discussion sessions will be held in the field during and after each of the site visits. The areas the students will visit is Reykjanes, Hengill, Þjórsárdalur and the Fjallabak Protected Area. The student projects will be presented on the final day of the summerschool.

3.3.4 Semester S10NGTUDA. 30 ECTS

Common project workshop 5 ECTS

The common project workshop proposed by TUDA is conceived to gather all the datasets, and apply all the knowledge and know-how acquired during the previous semesters. Students will combine, geological, economical and surface installation related datasets to estimate the potential, through the use of a decision making tool, of geothermal technologies (after having followed the DMS TOUGE training). They work here in multi-disciplinary teams gathering above surface and below surface engineering knowledge.

Master Thesis TUDANGS10M1: Research concept. 8 ECTS

Before starting the master thesis, students have to prepare a research concept involving bibliographical review of their forecasted topic, construction of their master thesis scientific research question, and accompanied by a forecast planning of the mater thesis. It involves scientific research investigation, as well as project management.

Master Thesis TUDANGS10M2: Research seminar (defense). 8 ECTS

The defense of the master thesis has to be performed within the research seminar in front of other members of the institute and accessible to the public.

Master thesis TUDANGS10M3: Report. 9 ECTS

The master thesis is evaluated and the grant involves or not the validation of this module.

3.4 Double degrees TU Darmstadt / University of Reykjavik and UniLaSalle / University of Reykjavik: Geothermal reservoir engineering.

3.4.1 Semester S7GTUDA. 30 ECTS

Module TUDAGS7M1: Regional Geology. 5 ECTS

The guiding principle is the geodynamic development of Central Europe on the basis of modern plate tectonic models. Exemplary data from sedimentology (sedimentary basins), petrology (metamorphism), structural geology (mountain building), geophysics (crustal structure, plate tectonics, palaeomagnetics), geochemistry (magmatism, crustal evolution) and geochronology (magmatism, crustal age, sediment provenance, stratigraphy) are included. The lecture is divided into four blocks: (i) Geological division of Europe and ancient crustal formation phases (Baltic Shield formation, Cadomian, Caledonian), (ii) Variscan cycle in Central Europe (including Alps), (iii) Central European Platform (overburden to Cenozoic fracture tectonics and magmatism), (iv) Alpine Cycle (development and construction of the Alps from Permian to

Quaternary uplift and erosion history). Geological maps, profiles and crustal scale sections from Central Europe are discussed and partly drawn by the students themselves. In addition, there are exercises on geochemistry and geochronology and the presentation of rock specimens. Smaller field excursions in the immediate vicinity of Darmstadt can be included on a case-by-case basis.

Module TUDAGS7M2: Engineering geology II. 5 ECTS

Engineering geology II: Exploration and modelling: Geotechnical categories, planning of exploration programmes, interface survey, stereographic projection techniques, drilling, soundings, borehole geophysics for engineering geological purposes, engineering geophysics, reflection seismics, presentation of exploration results in subsurface models. Practical course Engineering Geology II: Engineering geological terrain methods: Mapping of a rock slope, interface survey with geological compass and tape measure, interface survey with laser scanner, test hammer, ultrasound measurements, sampling with core drill.

Module TUDAGS7M3: Geothermal energy II. 5 ECTS

High and low enthalpy systems, Hydrothermal systems, Petrothermal systems, Enhanced Geothermal Systems (EGS), Exploration, Thermofacies, Thermophysical parameters, Geohydraulic parameters, Geophysical exploration, Logging methods and reservoir testing, Hydraulic and rock mechanics principles of hydraulic stimulation, Fracking: fluids and mechanics, Special methods in reservoir stimulation.

Module TUDAGS7M4: Geo Information Systems II. 3 ECTS

Indepth knowledge of the most relevant functions of the ArcGIS software, and their application in GIS-based multicriteria analyses and GIS-based geostatistical analyses using exemplary data sets. Furthermore mobile GIS functionalities will be introduced, like well databases (GeODin). GIS functionalities regarding geological 3D modeling will be addressed. In particular the class comprises the following aspects: - Database structures - Spatial Analyst - 3D Analyst - Geostatistical Analyst - Multicriteria Analyses - Automation of workflows, model builder, batch processing annotation - Web publishing with the ArcGIS Publisher & ArcReader - Introduction to well databases - Introduction to mobile GIS solutions (GIS-based field work)

Module TUDAGS7M5: Geo Information Systems III. 3 ECTS

The module teaches basic knowledge in the use of Gocad. Gocad (Geological Objects Computer Aided Design) is a computer-aided method for 3D modelling of geological objects and bedding conditions in the subsurface. It is particularly suitable for geophysical, geological and reservoir applications. The software is widely used in the oil and gas industry and is only available in isolated cases at German universities. Acquiring competence in 3D modelling is a key qualification with regard to professional perspectives, especially in the field of raw material exploration. The course covers the following basics of 3D modelling: - Basics and user interface - Interpolation algorithms - Objects: Digitizing, editing, regions, properties - Data import: georadar data, images, boreholes - Surfaces: Construction, interpolation, boundary conditions, integration of faults - SGrid: attribution of a geological body - Interoperability with other PC applications (GIS, SKUA, groundwater modelling programs). Created 3D content is fed into various quantitative analyses. For example, the potential for near-surface geothermal energy is described in the context of case studies.

Summerschool TUDA/ULSBNCSS

The summerschool starts with a transect across the Upper Rhine Graben, between Vosges and Black Forest massifs and go South to the Jura massif. Main deformation structures corresponding to Hercynian heritage and Oligocene opening are investigated. Students are given the opportunity to 1) recognize early compressional features, 2) normal faults and trans tensional structures related to graben opening and ore mineral veins depositions in abandoned mines, 3) sample rocks in both basement (granite and gneiss) and cover (sandstones and limestones). During a visit in an unexploited mine, students are given the opportunity to acquire imagery data and construct a high resolution virtual model of a gallery in which exceptional outcropping fault overprinting relationships are found. The second part of the summerschool takes place at TUDA. During this week of laboratory work, students have 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 to the students High-tech analytics and an interdisciplinary laboratory concept offer a broad spectrum of investigation options.

S8GBLC1: lectures to be chosen in the TUDA, ULSA, ULSB, UR and UZ BLCP. 2 ECTS

S8GBLC2: lectures to be chosen in the TUDA, ULSA, ULSB, UR and UZ BLCP. 2 ECTS

3.4.2 Semester S8GULSB

Module ULSBGS8M1: Brittle and ductile deformation processes. 3 ECTS

The lecture presents the different mechanical response of geological materials subjected to stress. The basic principle of brittle and ductile deformation are presented and a particular emphasis is given on deformation mechanisms active at the crystal scale. In depth microstructural (grain size distribution and grain shape prefered orientation analysis) and textural analysis (Crystallographic Prefered Orientation measurements by means of Electron Back Scattered Diffraction and rock texture interpretation) of highly strained rocks are proposed.

Module ULSBGS8M2: Fluid rock interaction processes. 3 ECTS

Principles of low-grade metamorphism. Part 1 will be dedicated to the clay minerals in order to show the properties of these minerals and the impacts they can have on the physical properties and their genesis within the systems. Part 2 will be devoted to the different methods used to identify, but also to characterize the P-T evolution of clay minerals. These methods are mainly based on X-ray diffraction.

Module ULSBGS8M3: Geothermal market in EU. 3 ECTS

The lecture is given by invited members of the Association Française des Professionnels de la Géothermie plus internal human ressources at ULSB and consists in a series of lectures and site visits. The lecture program is as follows:

Day 1 (morning): Presentation of shallow geothermal systems in France

1) French shallow geothermal key figures and structuration, main actors, 2) main shallow geothermal technologies, 3) building uses: valorization of heating and cooling in the buildings, 4) French support schemes and regulation

Day 1 (afternoon)

Shallow geothermal site visit

Day 2 (morning): Deep geothermal systems in France (context and framework)

1) history of deep geothermal energy in France and worldwide, 2) panorama of deep geothermal energy and regulatory framework, 3) support schemes and French mitigation scheme (Fonds SAF environnement), 4) French energy programming plan (PPE)

Day 2 (afternoon): Deep geothermal systems in France

1) deep geothermal in France, fractured reservoirs (volcanic zones and graben): exploration methods in fractured contexts, drilling, reservoir connection and resources exploitation, 2) deep geothermal in France (sedimentary zones): exploration methods, drilling and resource exploitation, 3) operation and management, environmental monitoring

Day 3 (morning)

1) social acceptability, 2) business models of power plants projects (Bouillante case study), 3) business models of heating projects (DH development and industrial case studies)

Day 3 (afternoon)

Deep geothermal site visit

Two additional days are dedicated to presentations dealing with an overview of all shallow technologies used in France. Building uses with heat pumps and tempered geothermal loops and principles of bi-energy. Perks and downsides of shallow geothermal systems.

Module ULSBGS8M4: Fractured reservoir characterization. 3 ECTS

In this module, students will learn how to characterize individual fractures using a multidisciplinary approach. The results will be integrated in a discrete fracture network (DFN) model. The access to the hierarchical and mechanical relationships between fracture systems can be led by multi-scale approach, which helps the modeling and prediction of the hydraulic reservoir properties. This approach is based on studying several geometric fracture attributes such as the distribution of orientations, lengths, widths, spacings and fracture densities largely considered in spatial organization analysis, from large scale (e.g, fractured reservoir) to micro scale (e.g, thin section scale). A detailed multi-scale study is planned using seismic data, well data, well samples, and large-scale maps (1) to analyze the fracture connectivity, (2) evaluate the fracture system in the complex tectonic setting, and (3) understand the fluid flow patterns at the whole fractured reservoir.

Module ULSBGS8M5: 3D static modeling. 2ECTS

The lecture is dedicated to an overall presentation of the Petrel software widely used by the oil and gas industry in order to interpret seismic data, perform well correlation, build reservoir models, visualize reservoir simulation results, calculate volumes, produce maps and design development strategies to maximize reservoir exploitation.

Module ULSBGS8M6: Seismic interpretation. 4 ECTS

The lecture presents the different techniques used in terms of seismic signal acquisition and processing. A series of exercises are proposed in order to interpret seismic lines either on paper or on a working station (Kingdom suite). A particular emphasis is given to seismic geomorphology and structural analysis. The interpretation process is subdivided into three interrelated categories: structural, stratigraphic, and lithologic. Structural seismic interpretation is directed toward the creation of structural maps of the subsurface from the observed three-dimensional configuration of arrival times. Seismic sequence stratigraphic interpretation relates the pattern of reflections observed to a model of cyclic episodes of deposition. The aim is to develop a chronostratigraphic framework of cyclic, genetically related strata. Lithologie interpretation is aimed at determining changes in pore fluid, porosity, fracture intensity, lithology, and so on from seismic data. Direct hydrocarbon indicators (DHI, HCIs, bright spots, or dim-outs) are elements employed in this lithologic interpretation process.

• Reminders of the basic principles of seismic interpretation,

• Seismic stratigraphy and its contribution to sequence stratigraphy,

• Practical exercises in seismic picking and mapping on paper and using software (Kingdom Suite): identification and characterization using geophysical data (seismic lines, well logs and multibeam bathymetry) from basins, structures and remarkable sedimentary systems/bodies (basins on passive and active margins, salt diapirs, salt rafts, gravity slides, mass transport complex, roll-over, channels, submarine dunes, deep-sea cones, etc.).

Module ULSBGS8M7: Analogue study field excursion 1. 4 ECTS

"The Aquitanian basin field trip consists in:

1) a visit of an exceptional outcrop exposure to be used in terms of subsurface fluid flows. The system is considered as an easy to reach analogue of a shallow geothermal system. The analogue permits to map the lateral continuity of a drainage area and establish a hydrological flow model. Activities like drone assisted LIDAR mapping, ground photogrammetry, stratigraphic log profiling are programmed. Petrographical and petrophysical investigation in terms of microfacies and grain size analyses, organic material maturity, porosity and permeability are planned in the laboratories at TU Darmstadt and UniLaSalle.

2) a visit of geothermal installations where heat is gained from co-produced hot brines during oil extraction activities from Vermilion fields. Three visits are planned at Tom d’Aqui green houses, Condorcet high school and district heating at Les Portes du Pyla."

Module ULSBGS8M8: Analogue study field excursion 2. 4 ECTS

This field trip in the Upper Rhine Graben is intended to study geological processes active in paleo hydrothermal reservoirs by means of in-depth structural analysis of key outcrops found in abandoned mines within Vosges and Black Forest massifs. Rock polyphase deformation and varying amounts of strain will be recognized directly in the field. Virtual 3D outcrop models will be prepared at the UniLaSalle GeoLab, using imagery dat acquired during TUDA / ULSB NCSS. In addition, students are given the opportunity to visit high enthalpy exploitation sites within the French and German territories where geothermal brines are being extracted from fractured basement rocks in a continental rift system.

S8GBLC1: lectures to be chosen in the TUDA, ULSA, ULSB, UR and UZ BLCP. 2 ECTS

S8GBLC2: lectures to be chosen in the TUDA, ULSA, ULSB, UR and UZ BLCP. 2 ECTS

3.4.3 Semester S9GTUDA. 30 ECTS

Module TUDAGS9M1: Drilling techniques. 5 ECTS

Introduction to deep drilling technology and geothermal power plant technology including presentation of the essential plant components and necessary process engineering: Drill Rigs I (Hook load, Hoisting, Top Drive, Drill String, Drill Pipe, Stabilizer, Bits, ROP), Drill Rigs II (Mud System, Solids Control System, BOP), Well Completion (Casing, Cementation, Wellhead), Well Control (Well Hydraulics, Blowouts, Kill Methods), Trouble Shooting & Special Services (Fishing, Perforation, Fracking, Side Tracking, Coring), Drilling Operations (Directional Drilling, Mudmotors, MWD/LWD, UBD), Borehole Logging and Geophysical Measurements, 2D-3D-VSP Seismology; Risk Assessment; Thermodynamics for CHP/Power Plant Engineering; Dry Steam, Flash & Double Flash Geothermal Power Plants, Binary Cycles (ORC/Kalina, district heating).

Module TUDAGS9M2: Coupled geothermal systems. 4 ECTS

Shallow, Medium Depth and Coupled Systems: Shallow drilling technology, Cylinder well, eGRT, DTS, OFDR, Geology, Medium depth systems, Coupling solar thermal, Fundamentals of pipe flow, Construction materials I: Cements, backfill construction materials, construction materials II: pipes, planning of large systems, cases of damage, QA measures, shallow and medium-depth storage tanks (cascading). Geothermal laboratory and field practical course: depth-related temperature measurements in geothermal probes for temperature profile determination, thermal response test and enhanced thermal response test, drill core logging and correlation with the measurement results, characterization of an outcrop with drill core sampling, determination of geothermal parameters in the laboratory; processing of set tasks in small groups. Temperature logs, GRT; DTS, eGRT; sampling and fracture logging (Stereonet) in the outcrop under rock permeability; permeameter; thermoscanner; TK04 and LG-/WLF-measuring devices; porosimeter; thermal water analysis; Thermo-Triax demonstration.

Module TUDAGS9M3: Petrophysics of reservoirs, laboratory and geophysical approaches. 2 ECTS

Here the goal of the course is to provide the students with a synopsis of the variety of methods to extract and detremine rock porties from laboratory experimetal approach to geophysical logs interpretation, and geophysical methods combination, and geophysical data interpretation.

Module TUDAGS9M4: Geo hydraulic and well construction. 6 ECTS

The module aims at bringing students with different academic backgrounds (geosciences or engineering) to an equal level of fundamental knowledge in geohydraulics as well as well design and construction topics. The students acquire solid knowledge of geohydraulics and quantitative geohydraulic methods in hard rock. They are able to apply the methods they have learned and to assess their results. They are also able to design groundwater wells and plan their construction.

Module TUDAGS9M5: Geo symposium. 1 ECTS

Presentation and discussion of current research-oriented topics from the geosciences by external (mostly) or institute speakers. Research concept: Preparation of a research concept and plan in individual work, usually related to a possible content orientation of the Master's thesis. Based on a geoscientific question, the planned methodology and (also temporal) organization of the work are developed on the basis of the appropriate literature and suggestions are made for the analysis and interpretation of the expected results. Research seminar: Presentation and discussion of ongoing and/or completed research work including master's theses and dissertations.

Module ULSBGS9M3: Data Science. 2 ECTS

Taking into account the tremendous amount of data produced by the industrial sector in the domain of Energy production, conversion and transport, data science is a fundamental competence for the next generation of engineers. The lecture presents the fundamentals of the data science problematic and how to deal with data by means of algorithm treatment and machine learning. In addition, all competences in 1) data collection, data mining and data preparation to analysis, 2) machine learning algorithm Python programming, 3) algorythm cloud deployment using Big Data tools and 4) results communication are given.

Module ULSBGS9M5: Exploration geophysics. 2 ECTS

This module presents an overview of seismic data acquisition and interpretation based on several examples gained from a variety of geophysical campaigns. The objectives of the lecture are to:

• Understand acquisition methods in marine seismology and their applications,

• Understand the different stages in acquisition planning and the difficulties involved,

• Grasp the principles behind 3D marine seismic data processing, use these data for the purposes of petroleum exploration and reservoir characterization,

• Use and interpret seismic attributes,

• Understand the principles of seismic geomorphology and perform interpretations in carbonate and siliciclastic systems.

Module UZS9M5: Feasibility studies: principles, tools and applications. 3 ECTS

This module presents all steps necessary to achieve geothermal projects feasibilities studies using a real shallow geothermal feasibility study case: After some reminder about the local regulation, students will conduct a step by step feasibility based on a real case and divided as follow:

Part 1: Context and geological study (geography, local constraints, project manager requests, finding geological information to know the local underground within 200 meters deep)

Part 2: Sizing of the geothermal solutions. Thanks to the building energetic needs, it would be possible to size to of the main geothermal shallow solutions (groundwater or vertical probe geothermal system).

Part 3: Payback time and CO2 emissions. The aim is to compare two payback time calculation methods, a simplified one and a complex one taking into account multiple parameters (investment price, maintenance, renewal fees, energy cost variations). The financial contributions will be described and integrated in the payback times.

Based on the data of the different parts of the study, it would then be possible to choose only one technology and decide if the geothermal energy is the best option in geological, technological and economical ways. At the end of the feasibility, a visit of the site will be conducted.

In a second step, feasibility studies completion for geothermal projects other than shallow are considered. In order to do so, the DMS-TOUGE tool is presented. This software is a MATLAB-based tool and open-access standalone application that estimates different important economic indices for a defined geothermal scenario, provides MCDM ((Multi Criteria Decision Making) analysis and facilitates the decision-making process. Among other outputs related to performance such as yearly or monthly production data, calculated avoided CO2 emissions, the economic outputs are the system's levelized cost of energy (sLCOE), net present value (NPV) and internal rate of return (IRR) that are usually used to evaluate the potential energy production related projects. The available end-use options are electricity generation, direct-use heating power production, and combined heat and power (CHP). Evaluations are made for EGS resources with temperatures from 50-170°C, and either for an air-cooled or water-cooled binary power plant.

Summerschool URCSS. 5 ECTS

A modularized Lecture Series is presented on the topics of geothermal energy in Iceland, natural state & utilization of high-temperature geothermal systems, resource impact of geothermal utilization, geothermal fluids, and the economics of geothermal utilization. Each module will contain a lecture, five readings, and one to two short quizzes based on both the lecture and the readings. The online course will be followed by site-visits to relevant areas in Iceland. Field notes and readings associated with the site-visits will be provided to students via the Canvas site under Modules. Discussion sessions will be held in the field during and after each of the site visits. The areas the students will visit is Reykjanes, Hengill, Þjórsárdalur and the Fjallabak Protected Area. The student projects will be presented on the final day of the summerschool.

3.4.4 Semester S10GUR. 30 ECTS

Common project workshop 5 ECTS

The common project workshop proposed by TUDA is conceived to gather all the datasets, and apply all the knowledge and know-how acquired during the previous semesters. Students will combine, geological, economical and surface installation related datasets to estimate the potential, through the use of a decision making tool, of geothermal technologies (after having followed the DMS TOUGE training). They work here in multi-disciplinary teams gathering above surface and below surface engineering knowledge.

Master Thesis URNGS10M1: Research Proposal. 2 ECTS

Within the first 15 days of S10, a student at RU must complete a thesis proposal that has been signed by the proposed research supervisor. A student proposing to complete S10 at RU is advised to organize the preparation of a thesis proposal during S9.

Master thesis URNGS10M3: Defense. 28 ECTS

The layout and form of the thesis shall in general be according to good practice for a thesis of this type. The student shall consult his/her supervisor on an appropriate structure for the thesis, appendices to the thesis and the reference system, taking into account established practice within the specific field of research. Each department within the School of Science and Engineering may set rules that further specify the form and layout of the thesis, including a recommended template. In general, the thesis is expected to contain the following:

- Front cover (standard)
- Front page (standard format)
- Title page (standard format)
- Abstract (in English and Icelandic)
- Signature page (standard format)
- Acknowledgements (optional)
- Preface (optional)
- Table of contents
- List of tables
- List of figures
- List of drawings and enclosed material, e.g. CD (as appropriate)
- Introduction
- Methods
- Results
- Discussion
- Conclusion

- References
- Appendices (as appropriate)
- Back cover (standard)

The front cover, front page, title page and back cover have a specific form as shown in the attached examples and shall contain all information requested. No variation from this form is permitted. If the thesis is written in English, the title on the title page shall be in English; however, an Icelandic translation of the title must be presented with an Icelandic abstract, and vice versa if the thesis is written in Icelandic. An abstract is mandatory, both in English and Icelandic. The maximum length of abstract is 300 words. At the end of the abstract there should be a list of up to five keywords reflecting the content of the thesis. A printed version of the thesis s. hall be on white paper, size A4 and weight 80 g/m2 . In general, the font should be Times or Times New Roman of size 12 points.

Guidelines for page numbering and layout:

● Page numbering is normally i, ii, iii, iv, ... for material preceding the first chapter of the thesis (i.e. for abstract, signature page, acknowledgements, preface, table of contents etc.) and then 1, 2, 3, starting from the 1st chapter (Introduction) and continuing throughout the thesis, including the appendices.

● Page numbers should in general be centered at the bottom of each page.

Only in exceptional cases may the thesis have a different form. While the thesis itself has to comply with the layout instructions in regards to the cover pages, abstract and the signature page, it can consist mainly of publishable research paper manuscripts. In this case, the manuscript(s) shall be preceded by a detailed section of introduction to the research topic with a corresponding in-depth literature review and detailed description of the methods used in the MSc project. The minimum length of this section shall be 20 pages excluding a reference list. This format of the MSc thesis should only be used if the supervisor of the thesis assesses the outcome of the MSc project to be publishable in indexed peer reviewed journals in the relevant field of research. If this format of the MSc thesis is used, the student's supervisor has to request a formal acceptance of both the student's Department Head and the Director of Graduate Studies, with a letter summarizing the findings of the project, the novelty beyond the state of the art and the contribution of all authors of the manuscript. This request has to be sent to the Department Head and the Director of Graduate Studies prior to t-50 (where “t” is the graduation date). The Department Head and Director of Graduate Studies can forward the request to the Graduate Study Council for further evaluation if they find it necessary.

Thesis defense procedure is outlined in the following sections as well as relevant deadlines. The examiner of the thesis report is selected by the Department Head in consultation with the supervisor(s). The choice of examiner needs to be approved by the Director of Graduate Studies. The examiner shall have the qualifications necessary to supervise the thesis, but must not have collaborated in the project on which the thesis is based and must fulfil the rules of Reykjavík University on impartiality of examiners. The oral examination shall be open to the public and shall be announced through appropriate channels with at least 3 days notice. The examination should take the form of an approximately 30 minute presentation by the student, followed by questions from the examiner, School representative (most often the Department Head), supervisor(s) and the audience. The Reykjavik University, School of Science and Engineering August 15th 2017 3 audience then leaves the room and the examiner(s), supervisor and School representative have the opportunity to put further questions to the candidate and, as appropriate, request modifications to the thesis. Subsequently, the candidate leaves the room and the examiner, School representative and supervisor(s) deliberate and decide upon the grade. Normally, the student will be informed of the grade the next day. If the thesis is subject to confidentiality, or for other valid reasons approved by the Director of Graduate Studies, the oral examination may be closed to the public.

The official completion of the MSc thesis is signified by the student submitting the final electronic (PDF) version of the thesis, signed by himself/herself, the supervisor(s) and the examiner to the SSE office and uploaded to Skemman, (see www.skemman.is). See also RU´s rules for submission of theses and final projects (Reglur um skil á lokaritgerðum og lokaverkefnum við Háskólann í Reykjavík, www.ru.is/bokasafn/skemman). If a student plans to graduate in a particular graduation ceremony, the following deadlines must be respected. Should any of the deadlines below not be respected the student will have to wait for the following graduation ceremony before he/she can graduate. Students are responsible for adhering to these deadlines and are advised to deliver their work in good time. The deadline schedule for the purpose of graduation is as follows (where t is the graduation date and the numbers refer to the number of days prior to graduation):

- Final draft of thesis delivered to supervisor a) t-50 b)
- Supervisors comments delivered to student t-40 c)d)
- Thesis delivered to supervisor(s), examiner and Department Head t-20 c)
- Examiner confirms that thesis may be put up for defence t-17 c)
- Defence t-14 c) ● Grade posted to the Registrar by SSE office t-11c)
- Graduation t c)

a) Paper and/or electronic form, as requested by the supervisor(s) and/or examiner.
b) Date can be modified by mutual agreement of the supervisor, student and examiner.
c) Firm deadlines.
d) Or within 10 days after the supervisor has received the final draft, whichever comes first.
e) Or within 5 days after the defence, whichever comes first.

GRADING

The appointed examiner shall evaluate the thesis and the oral defense of the thesis, together with the supervisor(s) and the department´s representative. One grade shall be awarded for the thesis and defence. The minimum passing grade is 6.0, see Guidelines for grading MSc theses in the appendix. The following factors shall be taken into account: ▪ Significance and originality of work ▪ Scientific and technological challenge and results ▪ Methodological quality ▪ Presentation The number of ECTS credits awarded for the Master’s project shall be taken into account. Thus, significantly more demands in terms of originality, quantity and scientific quality of the work should be placed on the student for a 60 ECTS thesis than a 30 ECTS thesis.

GUIDELINES FOR GRADING MSc THESES

The guidelines below describe typical projects in different grading brackets. This is meant for examiners and instructors in grading master‘s theses. The projects need not fulfil every aspect of these desciptions in order to be awarded the corresponding grade.

Superior (9,0-10,0) The project is excellent. The handling of the material shows considerable originality and independent thought. Considerable skill in the definition and organized solving of the problem. Very good understanding of concepts. Academic approach and handling of material. Exemplary methods in collection and processing of data. Use of references is very precise and supports the projects well. The thesis may well lead to a publishable article. Exceptionally well polished thesis with very good grammar, spelling and language use. The thesis is in English. The student‘s performance in the defense is excellent.
First grade (7,5-8,5) The project is very good and handling of material is good and somewhat original. Clear understanding of the material and the definition of the problem is good and the solving well organized. Data gathering and processing without major weaknesses and intelligent use of references. The thesis is well arranged and grammar, spelling and language is good. The student‘s performance in the defense is either good or very good.

Second grade (6,0-7,0) The project is acceptable. Handling of material is fair and some independent thinking. Definition and analysis of project reflects some understanding. Data collection and processing is without major flaws. Deficiencies in the literature review. Flaws have not been addressed despite the instructor‘s suggestions. Language, grammar and spelling is fair. The student‘s performance in the defense is fair.

Fail (1,0-5,5) The project is unacceptable. The project has major flaws that have not been addressed despite the instructor‘s suggestions. Limited understanding of the material. Definitions and analysis do not show understanding of what is relevant in solving the problem at hand. Major errors or misunderstanding. Data collection and analysis has deficiencies and literature review is weak. The subject is not adhered to or major inconsistencies. Language, grammar and spelling is fair or poor. The student‘s performance in the defense is fair or poor.

3.5 Double degree TU Darmstadt / UniLaSalle: Geothermal reservoir geoscience.

3.5.1 Semester S7GTUDA

This semester 7 is identical to the one described in section 3.4.1.

3.5.2 Semester S8GULSB

This semester 8 is identical to the ones presented in section 3.4.2.

3.5.3 Semester S9GULSB. 30 ECTS

Module ULSBGS9M1 Geo modeling and geo energies. 6 ECTS

This lecture is intended to give a series of cutting-edge competences to students willing to achieve a career in the sectors of 1) energy (geothermal, Uranium extraction, oil and gas, Hydrogen capture), 2) storage (gas and CO2), 3) risk assessment (coast erosion), 4) oceanic environment exploitation and protection and 5) mining exploration and exploitation. The acquired skills are prerequisite for any future industrial and research geologist aiming to reasonably exploit geological resources. Emphasis is given to numerical tools used by geologists in companies' workflows and research centers. In depth use of the Schlumberger software suite for static 3D reservoir modeling is then integrated to reservoir evolution simulation using Mike and Feeflow softwares. The course includes an expedition on the Tethys oceanic research ship with exploration geophysics data acquisition in the Mediterranean Sea in order to build a gravity driven sedimentary basin model.

• Produce a static 3D model by following the dedicated workflow,

• Demonstrate hindsight and critical analysis skills to validate the data used,

• Carry out a prospect evaluation from the geological summary to calculations of volumes and risks,

• Interpret models with an analytical and critical approach to the results obtained,

• Communicate with reservoir engineers using their terminology and understanding their needs and objectives.

Content:

• Petrel training (30 hours): stages in the production of a static 3D model using real data, integration of this model in the prospect evaluation workflow.

• Introduction to reservoir engineering (6 hours): basics of reservoir geology, flow and principles of dynamic modeling.

Module ULSBGS9M2 Geo Information Systems and photogrammetry. 4 ECTS

The lecture gives an intensive training in GIS techiques (Python and ModelBuilder automatisation, 3D models in ArcGIS, GIS Datamodel, Web GIS and use of ArcGIS API for JavaScript), photogrammetric acquisition and treatment and remote sensing (classification, error estimates and confusion matrices). Regarding photogrammetry, a particular emphasis is given to the different techniques of data acquisition in the field (UAV assisted and ground photogrammetry techniques) and fracture network model extraction from 3D models, to be used in reservoir characterization and simulation.

Module ULSBGS9M3 Data science. 2 ECTS

Considering the tremendous amount of data produced by the industrial sector in the domain of Energy production, conversion and transport, data science is a fundamental competence for the next generation of engineers. The lecture presents the fundamentals of the data science problematic and how to deal with data by means of algorithm treatment and machine learning. In addition, all competences in 1) data collection, data mining and data preparation to analysis, 2) machine learning algorithm Python programming, 3) algorithm cloud deployment using Big Data tools and 4) results communication are given.

Module ULSBGS9M4 Numeric science. 3 ECTS

UniLaSalle has developed a teaching methodology and a series of innovative pedagogical tools with a strong emphasis on 1) learning by doing, 2) mentoring, 3) interactivity and lecture feedback by students using a series of tools (Wooclap, Kahoot) and 4) immersive methods using novel scenarized contents in virtual and augmented reality. In order to develop this novel approach with an application in the field of earth sciences a lecture package consisting in virtual construction of geothermal reservoirs analogues in abandoned hydrothermal ore deposits mine galleries is proposed. This approach benefits from strong support of ULS IT department and GeoLab infractructures and know how. A 360° vision lens camera with two opposite objectives capturing a spherical picture is used and raw output is treated to get an equilateral or spherical pictures. Using a well-planned scenario with added petrophysic and petrographical information available from research projects, students are proposed to virtually travel within the reservoir, by creating a video capsule using a Lnodal system. Autonomous and wireless virtual reality helmets technology allow a group of students to build a structural model to be verified in the field. This technology allow to prepare the field campaign well in advance, avoiding difficult field conditions while lowering the journey duration in the mine and associated costs.

Module ULSBGS9M5 Exploration geophysics. 2 ECTS

This module presents an overview of seismic data acquisition and interpretation based on several examples gained from a variety of geophysical campaigns. The objectives of the lecture are to:

• Understand acquisition methods in marine seismology and their applications,

• Understand the different stages in acquisition planning and the difficulties involved,

• Grasp the principles behind 3D marine seismic data processing, use these data for the purposes of petroleum exploration and reservoir characterization,

• Use and interpret seismic attributes,

• Understand the principles of seismic geomorphology and perform interpretations in carbonate and siliciclastic systems.

Module TUDAGS9M3: Petrophysics of reservoirs, laboratory and geophysical approaches. 2 ECTS

Here the goal of the course is to provide the students with a synopsis of the variety of methods to extract and determine rock properties from laboratory experimental approach to geophysical logs interpretation, and geophysical methods combination, and geophysical data interpretation.

Module TUDAGS9M6: Isotope hydrology and dating. 3 ECTS

Natural and artificial isotopes, stable isotopes, radiogenic isotopes; isotopes in rivers, soils and groundwater; groundwater dating techniques; field sampling and laboratory methods; introduction to modeling of isotope signals.

Module UZS9M5: Feasibility studies: principles, tools and applications. 3 ECTS

This module presents all steps necessary to achieve geothermal projects feasibilities studies using a real shallow geothermal feasibility study case: After some reminder about the local regulation, students will conduct a step by step feasibility based on a real case and divided as follow:

Part 1: Context and geological study (geography, local constraints, project manager requests, finding geological information to know the local underground within 200 meters deep)

Part 2: Sizing of the geothermal solutions. Thanks to the building energetic needs, it would be possible to size to of the main geothermal shallow solutions (groundwater or vertical probe geothermal system).

Part 3: Payback time and CO2 emissions. The aim is to compare two payback time calculation methods, a simplified one and a complex one taking into account multiple parameters (investment price, maintenance, renewal fees, energy cost variations). The financial contributions will be described and integrated in the payback times.

Based on the data of the different parts of the study, it would then be possible to choose only one technology and decide if the geothermal energy is the best option in geological, technological and economical ways. At the end of the feasibility, a visit of the site will be conducted.

In a second step, feasibility studies completion for geothermal projects other than shallow are considered. In order to do so, the DMS-TOUGE tool is presented. This software is a MATLAB-based tool and open-access standalone application that estimates different important economic indices for a defined geothermal scenario, provides MCDM ((Multi Criteria Decision Making) analysis and facilitates the decision-making process. Among other outputs related to performance such as yearly or monthly production data, calculated avoided CO2 emissions, the economic outputs are the system's levelized cost of energy (sLCOE), net present value (NPV) and internal rate of return (IRR) that are usually used to evaluate the potential energy production related projects. The available end-use options are electricity generation, direct-use heating power production, and combined heat and power (CHP). Evaluations are made for EGS resources with temperatures from 50-170°C, and either for an air-cooled or water-cooled binary power plant.

Summerschool URCSS. 5 ECTS

A modularized Lecture Series is presented on the topics of geothermal energy in Iceland, natural state & utilization of high-temperature geothermal systems, resource impact of geothermal utilization, geothermal fluids, and the economics of geothermal utilization. Each module will contain a lecture, five readings, and one to two short quizzes based on both the lecture and the readings. The online course will be followed by site-visits to relevant areas in Iceland. Field notes and readings associated with the site-visits will be provided to students via the Canvas site under Modules. Discussion sessions will be held in the field during and after each of the site visits. The areas the students will visit is Reykjanes, Hengill, Þjórsárdalur and the Fjallabak Protected Area. The student projects will be presented on the final day of the summerschool.

3.5.4 Semester S10GTUDA. 30 ECTS

Common project workshop 5 ECTS

The common project workshop proposed by TUDA is conceived to gather all the datasets, and apply all the knowledge and know-how acquired during the previous semesters. Students will combine, geological, economical and surface installation related datasets to estimate the potential, through the use of a decision making tool, of geothermal technologies (after having followed the DMS TOUGE training). They work here in multi-disciplinary teams gathering above surface and below surface engineering knowledge.

Master Thesis TUDANGS10M1: Research concept. 8 ECTS

Before starting the master thesis, students have to prepare a research concept involving bibliographical review of their forecasted topic, construction of their master thesis scientific research question, and accompanied by a forecast planning of the mater thesis. It involves scientific research investigation, as well as project management.

Master Thesis TUDANGS10M2: Research seminar (defense). 8 ECTS

The defense of the master thesis has to be performed within the research seminar in front of other members of the institute and accessible to the public.

Master thesis TUDANGS10M3: Report. 9 ECTS

The master thesis is evaluated and the grant involves or not the validation of this module.

4 Summary

The presented course catalog is one of the main outputs from the Geo3EN program as it manages a whole series of constraints in terms of 1) initial educational student background, 2) administrative requirements from the different partners, 3) stakeholder feedback, 4) Intensive Study Program lectures and site visits experience and student feedback, 5) reasonable program costs.

The program is international and novel as it permits students to acquire a common trunk of competences, skills and knowledge allowing communication and understanding between engineers specialized in geothermal related activities above and below surface. This program covers all range of exploitable temperatures in terms of heat and electricity production and includes business economics, environmental impact assessment and communication.

It is believed that the current geopolitical situation and public awareness of the necessity to take measures in favor of climate protection will cause a drastic increase of qualified engineers demand in the renewable energy sector during the next decade. The presented program is pioneering and comes at the right time.