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Geothermal Energy Capacity Building in Egypt

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ABSTRACT

This paper presents the main objectives and expected outputs of the project Geothermal Energy Capacity Building in Egypt (GEB), funded by the European Union program Erasmus+, within the Key Action 2: Cooperation for innovation and the exchange of good practices (CBHE-JP - Capacity Building in higher education - Joint Projects). Five Egyptian universities (Cairo, Suez Canal, Ain Shams, Aswan and Egypt Japan University of Science and Technology), two Egyptian governmental/industrial bodies (New and Renewable Energy Authority and South Valley Egyptian Petroleum Holding Company), and three European universities (Bologna, Zagreb and Valladolid) are the partners in this project. GEB duration is 3 years, from the beginning of 2021 to the beginning of 2024.

GEB builds the capacity of the Egyptian Higher Education Institutions (HEIs) and develops a higher education engineering graduate diploma on geothermal energy in Egypt. The main objective of this diploma is to supply the national market with qualified engineers/graduates in the field of geothermal energy, with special attention to applications in cooling and heating processes. The program will also include topics on geothermal power plants, project management, and monitoring systems with available technologies customized to the different applications of geothermal energy in the national circumstances.

This project will provide the opportunity for building an engineering knowledge foundation, both theoretical and practical, for the future use of geothermal energy in Egypt. The project's expected outcomes include the first graduate diploma in Geothermal Energy, the first educational pilot plant, geothermal energy centers (i.e., qualified staff and laboratories at each Egyptian university) and the establishing of the Egyptian Society of Geothermal Energy. The graduate diploma is the seed that will lead to generations of knowledgeable and well-trained engineers/graduates who can supply the national demand. The educational pilot plant, along with geothermal energy centers, would be used in the practical training of the diploma graduates and the dissemination of practical knowledge to local enterprises. Finally, the Egyptian Society of Geothermal Energy (which will be composed of qualified staff from the Egyptian partners) would represent a qualified engineering society, able to offer consultancy to universities, local enterprises and national decision makers.

1. INTRODUCTION

The need for energy and its related services, to satisfy national, social and economic development, welfare and health, are increasing. Focusing on renewable energy to meet the energy demand of future generations, as well as to mitigate climate change, is a reasonable approach. Egypt is considered to be a new-born country in this field of energy. In Egypt, the expansion in the use of geothermal energy is hindered by many obstacles such as the gap in engineering knowledge, a lack of well-trained engineers, a lack of investments, of awareness of the geothermal energy benefits, and of encouraging renewable energy policies, etc.

Energy contributes to economic growth through domestic development and as an additional income through exporting the excess. Oil, natural gas, and coal represent the main energy resources in Egypt. To meet the general needs of energy, Egypt imports oil, which further burdens the national economy, especially with the inflation of the Egyptian currency against the U.S. dollar. As a result, the government has started lifting energy subsidies, causing a rise in the cost of energy (oil, gas or electricity) nationally. Thus, the use of renewable energy sources in Egypt has become a necessity (Ibrahim, 2012). The need to develop alternative indigenous power resources is becoming ever more urgent, and it is worth noting that the Egyptian government is taking action in the right direction with its new Sustainable Energy Strategy 2035, funded by the EU. Geothermal energy technology has been in use for decades in many countries. Besides the well-known potentials of the more conventional renewable energy resources (wind and solar), Egypt also has the promising potential of geothermal energy (Elbarbary et al., 2018; Abdel Zaher et al., 2018; Lashin, 2015) (Figure 1). Geothermal energy for cooling and heating is currently of potential interest for techno-economic investments in Egypt (Ismael et al., 2018).

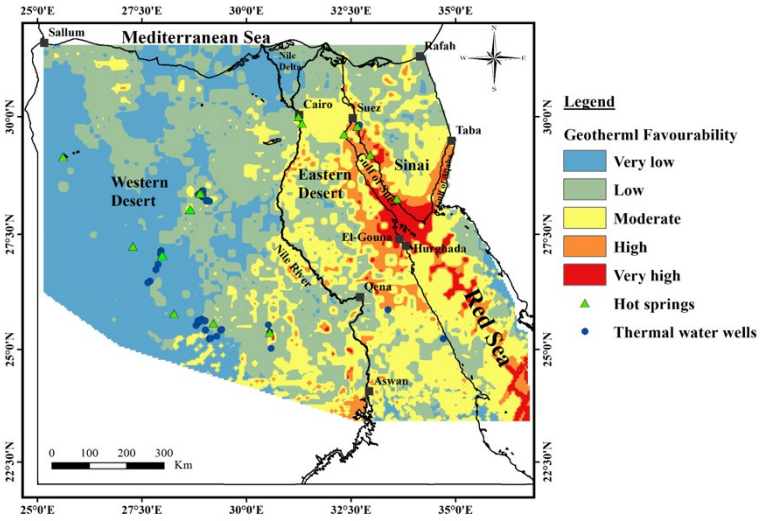

Figure 1: Geothermal resources in Egypt, after (Abdel Zaher et al., 2018)

The project consortium consists of 7 Egyptian (EG) partners, 3 European (EU) partners, and 4 EU/EG associated partners. The Egyptian partners are five HEIs: Cairo University (CU), Suez Canal University (SCU), Ain Shams University (ASU), Aswan University (ASWU), and Egypt Japan University of Science and Technology (E-JUST), and two governmental/industrial partners: New and Renewable Energy Authority (NREA), South Valley Egyptian Petroleum Holding Company (GANOPE). The three European HEIs are University of Bologna (UNIBO), University of Valladolid (UVA), and University of Zagreb (UNIZG). The four associated partners are the industrial and engineering companies TELUR (Spain), ECOFOREST (Spain), BONIAN (Egypt), and GEORENCO (Germany-Egypt). The project consortium forms a good geographic distribution strategy (Figure 2). The total project budget is 956,867.00 € and the project is coordinated by Cairo University.

Figure 2: The geographic distribution of the project consortium. (Maps, *Google Maps*. Accessed December 14, 2020)

The project aims to build up the capacity of the Egyptian HEIs in the field of geothermal energy. The capacity will be built up through a number of specific objectives: (i) improving the scientific skills of the Egyptian staff in the field of geothermal energy, (ii) improving the competences of the Egyptian HEIs in geothermal energy, (iii) building a new graduate engineering diploma in geothermal energy, (iv) constructing an Egyptian-European collaboration in the field of geothermal energy, (v) setting up a stable network between the participating Egyptian HEIs in the geothermal energy field, and (vi) raising awareness of the importance of geothermal energy in authorities, local enterprises, non-participating Egyptian HEIs, and citizens.

The EG HEIs aim to establish a solid engineering scientific foundation. Thus, qualified academic staff who can carry out the teaching and practical training activities of the proposed engineering graduate diploma is essential. Improving the scientific skills of the staff of the participant EG HEIs can be achieved through attending intensive short courses in the field of geothermal energy in Europe and in Egypt, taught by the EU partners. The main purpose of these courses is to fill the knowledge gap and improve (i) the theoretical geological, thermodynamic, and geothermal energy knowledge through lectures and (ii) practical knowledge through laboratory sessions, technical visits to the geothermal pilot plants in Europe (as an example the one at UNIBO) and site visits provided by the associated EU partners. The technical knowledge of the EG staff will be further enhanced through technical training provided by the associated EU partners (for heating and cooling applications). In addition, a visit to a geothermal plant in southern Europe for power generation will take place. Additionally, the participation of EG staff in the design and implementation of the first educational pilot plant at CU, along with the development of well-equipped laboratories, would further improve the competence of the EG staff in the HEIs in the field of geothermal energy.

The EU staff will coordinate and supervise the development of the diploma structure and modules, while the EG staff will prepare the modules and teaching activities. The diploma structure will allow a wide range of students to be accommodated with backgrounds in geology, geo-engineering, mechanical/electrical engineering, and mining/petroleum engineering through providing courses for filling the students' knowledge gap at the early stage of the teaching activities of the diploma. The current engineering curricula in Egyptian universities lacks specific modules, training materials and laboratories dealing with geothermal design and the implementation aspects in Southern Mediterranean conditions. Therefore, it is necessary to create modules specialized in geothermal engineering, so as to establish a new high-quality diploma in engineering and the associated laboratories to provide graduates from EG HEIs the special skills required in the geothermal energy sector.

Geothermal energy centers, represented by the trained EG staff and well-equipped labs (to be purchased) in each Egyptian HEI, would be developed. These centers would be responsible for carrying out the teaching and practical training activities in the diploma and, in general, ensure the sustainability of the project outcomes. These centers would form the direct link between the Egyptian HEIs, forming a geothermal energy network. They would also represent the scientific and managerial board of the Egyptian Society of Geothermal Energy (to be developed). A consortium of EU partners and Egyptian partners would then be formed to develop modules and laboratories suitable for a capacity building platform in geothermal energy for on-campus teaching in Egypt, linked with industry and official organizations.

All governmental HEI (CU, SCU, ASWU and ASU) are accepting student enrolment from all social classes, including vulnerable ones. Student support mechanisms covering living and accommodation expenses are also available for students coming from economically disadvantaged social classes. Some activities of the project will include students from different governorates in order to achieve equal opportunities. SCU (located in Eastern Egypt) and ASWU (located in southern Egypt) will play an important role in attracting students from geographically dispersed locations to enrol in the program. The free enrolment of students, during the project's duration, would further support students from economically disadvantaged social classes. The project is not complementary to previous/existing funded projects nationally or internationally, but it is founded on the most advanced training and education programs offered by European universities offering geothermal classes.

2. METHODOLOGY

There are three milestones to the project:

1- Capacity building of the EG HEIs and staff.

2- Development of a new graduate engineering diploma.

3- Creation of market-oriented geothermal energy centers to encourage an aware society.

Activities and methodologies to achieve Milestone 1:

The partners of the EG HEIs have academic staff with two different backgrounds, which are the two basic sciences for the geothermal energy field: geoengineering and geology (geological background) and mechanical engineering (thermodynamic and energy engineering background).

Building the capacities of the EG academic staff will be done through two main phases (1 and 2). However, a phase 0 will be significant and necessary: EG staff with a geological background will teach a course on basic geology aspects to the EG staff with a thermodynamic background and vice versa.

Phase 1 aims at i) building up the knowledge of the geology group in advanced thermodynamics and building up the knowledge of the thermodynamics group in advanced geology, ii) improving the geology and thermodynamics knowledge, needed/applied in the geothermal energy field for both groups. Phase 2 concerns building up the capacities of the EG academic staff in specialized topics of geothermal energy.

In phase 1, the three EU universities will provide intensive short courses for the EG academic staff in the EU, which should start at the beginning of the project. Phase 1 is divided into 4 main successive stages:

- Stage 1: The EG academic staff receives intensive lectures and laboratory sessions in thermodynamics and energy engineering at the University of Valladolid (UVa).
- Stage 2: The EG academic staff receives intensive lectures and laboratory sessions in geology at the University of Zagreb (UNIZG).
- Stage 3: The EG partners receive intensive lectures and laboratory sessions in the basics of geothermal energy at the University of Bologna (UNIBO) with the invitation for the Professors of the EU universities to participate in this stage. Here, there will be a technical visit of the EG partners to the educational/laboratory pilot plant of UNIBO.
- Stage 4: A series of technical visits and training sessions will be conducted for the EG staff at several industrial geothermal plants. These plants are located in southern Europe and the visits will be divided into two categories: The first will address the heating and cooling technology via geothermal energy, which will be provided by the EU associated partners; while the other will address the power generation technologies, which will be provided via subcontracting.

After that, in phase 2, the EU universities will do teaching mobilities in EG through intensive lectures in specific geothermal energy topics. The objective of this phase is to assure that the EG academic staff will be able to contribute to the design of the geothermal energy diploma structure and to teach geothermal energy modules. Building the geothermal energy educational pilot plant in Egypt

(CU) will be carried out at this stage. The EU universities will contribute greatly to the building of the educational pilot plant. The EG staff will be involved in the site characterization, design, and implantation processes of the pilot plant in order to build up their practical knowledge. The pilot plant will be an important part of the diploma teaching activities of the diploma modules.

Parallel to phases 1 and 2, the purchase of the equipment necessary for teaching the geothermal energy diploma and for the sustainable beneficiary in the EG HEIs will be done. The necessary geothermal equipment and software packages will be assigned to the EG HEIs in such a way as to be compatible with the diploma modules in whose development they will participate, considering the available scientific background of the EG staff and departments involved in the project activities, and, in some cases, the available equipment (applied geology and thermodynamics) in the EG HEIs. The modules each EG HEI develops will be added to study programs belonging to the participating HEIs after the end of the project. The main strategy in the selection of equipment and software packages is to build geothermal energy centers in each EG HEI and to form a major center of geothermal energy in Egypt based on the integration/connection between the centers in each EG HEI. This will allow us to include a wide range of geothermal energy applications (power generation, cooling, and heating) to be covered by the purchased equipment and software packages in the geothermal energy teaching and training activities in the Egyptian HEIs.

Activities and methodologies to achieve Milestone 2:

- Design of modules, accreditation, and publicity of the graduate diploma should be done before the end of the first 18 months of the project. Then, student enrolment in the diploma will start and teaching activities will end before the project's duration finishes.

- EU universities will manage and contribute to the design of the diploma modules and structure. The diploma modules will be based on the European Credit Transfer System (ECTS). Each module in the diploma is planned to be 6 ECTS, and 18 ECTS for the graduation project.

CU will clearly define the responsibilities of each partner/staff member within the project and guarantee the dialogue among partners in order to discuss the outcomes of the project. Consortium semi-annual meetings will be held to discuss, plan, and document the activities of the different stages of the project. Minutes of each meeting will be prepared by the project coordinator. Furthermore, the continuous communication between partners on differenet levels (i.e., EG-EU, EG-EG, EU-EU and within each partner), as well as urgent meetings, would help in devleoping mitigation for any potential risks. The number of participants in the workshops, seminars and other events will also be documented. The project's website and web platform will track the number of visitors and the number of downloads of materials therein published.

The teaching activities will be mainly at CU by the trained EG staff, but students will move between the EG HEIs in order to use the purchased equipment/software packages and any other available equipment needed for the laboratory classes of the diploma modules (students' movement between EG HEIs will be coordinated by the project website). The diploma targets students from different backgrounds classified into two categories: category A and category B. Group A refers to graduate students from mining engineering, petroleum engineering, civil engineering and geosciences programs; whilst group B refers to graduate students from mechanical and electrical engineering programs. The diploma structure (Figure 3) will satisfy four main stages:

1) Prerequisites filling, one module (First Semester)

This stage contains two modules: (i) Introduction to Thermofluids Engineering (only for category A) (ii) Principles of Geology and Geoengineering (only for category B)

(2) Two general modules in geothermal energy (First Semester)

Two modules for students of both categories A and B, in the basics of geothermal energy: (i) Geothermal Resources, and (ii) Basics of Geothermal Engineering.

(3) Specialization, three modules/track (Second Semester)

After finishing the first semester, students will select one geothermal energy specialization from the three following tracks:

Track I_Exploration and Evaluation of Geothermal Resources

1-Site investigation

2-Reservoir Modeling and Simulation

3-Elective Module

Track II_Geothermal System Design

1-Geothermal Well Design and Drilling Technologies

2-Shallow and Deep Geothermal Systems

3-Elective Module

Track III_Engineering Geothermal Project Management

1-Life Cycle Assessment

2-Risk Assessment and Management

3-Elective Module

Elective Modules:

1-Techno-economic Assessment

2-Process Control and Optimization

3-Geothermal Energy for Power Generation

4-Geothermal Energy for HVAC applications

5-Safety in Geothermal Systems

6-Environmental Impact Assessment of Geothermal Projects

7-Operation and Maintenance of Geothermal Plants

8-Oil and Gas Wells Redeployment for Geothermal Energy

9-Design of Geothermal Heat Storage

(4) Graduation Project (4 months, after the second semester)

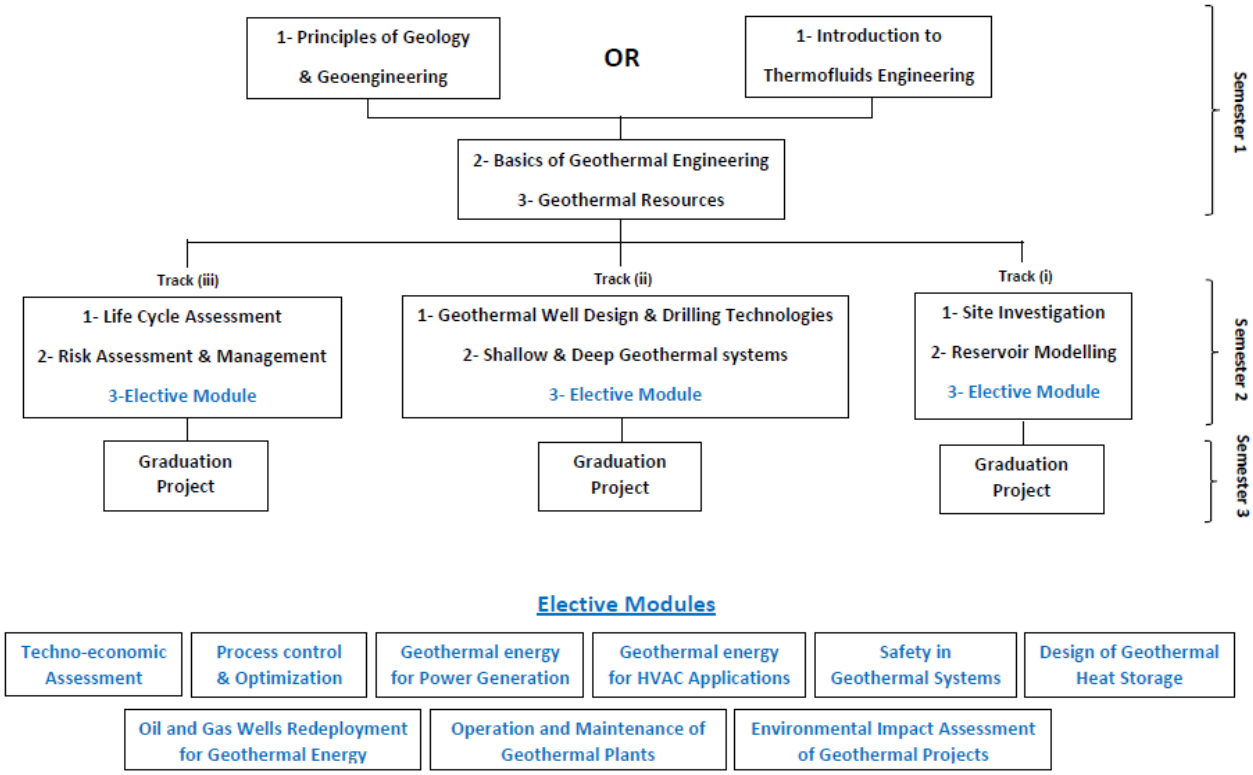

Figure 3: The new geothermal energy engineering diploma structure

Students will have two options: a graduation project in Egypt or at UNIBO. An agreement in this context will be signed between CU and UNIBO. The graduation projects in this case will be supervised by both the Italian and Egyptian academic staff. GEB will cover 3 training/learning mobilities, for 3 months, at UNIBO for 3 EG students under the activities of the graduation project.

Activities and methodologies to achieve Milestone 3:

Geothermal energy centers, represented by the trained EG staff and well-equipped labs (to be purchased) in each Egyptian HEI, would be developed. These centers would be responsible for carrying out the teaching and practical training activities in the diploma and, in general, ensure the sustainability of the project outcomes. These centers would also be responsible for the teaching and training activities of new geothermal energy modules, from the to-be-developed diploma, to be included in each participating EG HEI (after the project's duration). These centers would form the direct link between the Egyptian HEIs, forming a geothermal energy network. They would also represent the scientific and managerial board of the Egyptian Society of Geothermal Energy (to be developed).

Additionally, geothermal energy centers at the EG HEIs would represent a qualified reference, for training and consultancy, to local enterprises and national decision makers and organize technical visits to the educational pilot plants. Furthermore, the Egyptian Society of Geothermal Energy, with members of national decision makers, such as NREA and Ganope, would help in the endorsement of laws that encourage investments in the field of geothermal energy.

The EG HEIs suffer from two main challenges in the field of geothermal energy. The adopted methodology addresses these two challenges in addition to establishing a foundation stone for the geothermal energy implementation on a national level. The choice of the EU HEIs and associated partners is based on their expertise in geothermal energy applications, especially for heating and cooling purposes. These applications are very similar to the cooling application which is generally required in Egypt.

The first challenge to be faced is the knowledge gap between the staff of the EG HEIs and that of the EU HEIs. To overcome the challenge, a series of activities (first phase of development) have been created to fill this gap, in addition to increasing the competences of the staff of the EG HEIs. These activities are mainly Mobilities, intensive short courses, and technical training on both lab equipment at the EU partner HEIs and several geothermal sites established and managed by the EU associated partners, in addition to technical training on the pilot plant at UNIBO. Furthermore, the EU associated partner will offer continuous technical support throughout the duration of the project.

The second challenge that must be faced is how to improve the EG HEIs' capacity in terms of equipment and facilities. Therefore, the necessary educational equipment for the EG HEIs' labs would be purchased (Second phase of development). This will be conducted along with the implementation of the first educational geothermal pilot plant at CU. This pilot plant will be designed by the EU HEIs with the collaboration of the staff from the EG HEIs in order to gain the designing experience. In addition, the first graduate diploma in the field of geothermal energy will be established in Egypt, considering the European Credit Transfer System (ECTS), and a graduation project agreement between CU and UNIBO.

Finally, with the aim of disseminating the project work, a series of activities is contemplated, including public seminars and workshops that would take place in several Egyptian regions (Cairo, Aswan, and Alexandria). The staff of the EU HEIs and EG partner will participate in such activities. In addition, the first Egyptian scociety group in the field of geothermal energy will be established, a new government approved entity where all the planned dissemination activities will be organized during and after the project's time schedule.

The activities of the project will produce a quality control system for the different stages, resulting in annual feedback reports from both technical and financial points of view. In addition, an educational quality control system will be established for the graduate diploma to ensure a quality educational system.

The dissemination and exploitation of the project consider:

i) A website that is designed to produce public information about the project. GEB will create open online platforms for the laboratories established at the five partner Egyptian Universities (geothermal centers). The website will have details of the installed educational equipment and will facilitate access to information on running experiments to all registered students in the EG partner HEIs who fulfill the teaching activities in the diploma modules. The website will also host the Egyptian Society of Geothermal Energy, which will serve as a hub for all geothermal energy stakeholders in Egypt, including the regulator, academia and industry. The website will also host an online platform showing the details of experiments taking place at the educational pilot plant based at CU, upon completion of its installation. The website will also host an online discussion forum for continuous feedback about the quality of project activities. Moreover, an online (on the project website) library of relevant textbooks would be available for diploma students.

ii) Several public seminars and workshops (Cairo, Aswan, and Alexandria) in the field of geothermal energy, addressing the matter socially and governmentally, along with technical visits to the educational pilot plant at CU. The diploma students will participate in the implementation of the dissemination seminars. The decision makers will be involved in these seminars and workshops in order to direct attention to the field of geothermal energy as a great energy alternative.

iii) Establishing the first Egyptian society in the field of geothermal energy that considers technical, social, and research activities in the future.

CONCLUSION

Egypt has a proven resource of geothermal energy. However, unlocking this resource needs capable and well-informed concept developers, engineers, scientists, geologists and technicians. This also needs mechanisms that establish public awareness and understanding of such a new technology in Egypt, despite being deployed in many countries across the globe. A number of EU and Egyptian Universities had attracted European funding to build a human-centered and market-oriented capacity on geothermal energy education, research and deployment in Egypt. Project GEB is designed to channel knowledge transfer between five Egyptian Universities and their expert EU counterparts, taking the forms of: academic staff training, continuous development of learning curricula and the establishment of geothermal energy centers equipped by state-of-the-art characterization and modeling facilities. Project GEB establishes Egypt's first specialized diploma on geothermal energy with three integrated tracks. GEB also installs Egypt's first pilot plant, which will be essential for the expansion of this technology in Egypt. While the diploma should guarantee the successful training of specialized graduate engineers, the geothermal energy centers would sustain market-oriented training, applied research and an informed and aware society in Egypt.

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