Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

An Interdisciplinary Approach to Geothermal Energy Education: The Case of Iceland School of Energy at Reykjavik University

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Keywords: Interdisciplinary approach, geothermal education, graduate studies, Reykjavik University

ABSTRACT

Iceland School of Energy (ISE) has been offering masters programs and short courses in Sustainable Energy Science and Engineering, with a strong focus on geothermal energy, since 2008. The educational programs are operated in close partnership with two leading geothermal companies in Iceland; Iceland Geosurvey and Reykjavik Energy. While technical subjects remain prominent in the curriculum, the education has an interdisciplinary approach including courses in economics, business and law.

This paper outlines how an interdisciplinary approach is achieved with the ISE master's degree programs, specifically by how the program structure combines traditional education with internships, industry-related projects, and research, whilst offering quite substantial flexibility for the choice of elective courses. The industry connections are further elaborated upon, specifically the strategic outreach ISE applies in order to form future connections.

Finally, statistics from 2010 onwards are discussed, in order to evaluate the effectiveness of the ISE's interdisciplinary approach. The program is found to mainly attract non-European applicants, with geothermal energy being the most popular field of study for student research. The interdisciplinary approach is vindicated by the career trajectory examples of ISE graduates, showing that students from varied backgrounds have achieved successful, international careers in the geothermal and sustainable energy sectors.

1. INTRODUCTION

Iceland has utilized geothermal energy since early settlers used the geothermal waters for washing their laundry, and has been a center for geothermal engineering since the Bjarnarflag Power Plant was built in 1969. Iceland satisfies 66% of its primary energy consumption with geothermal energy, according to data from [1], and is home to many world-renowned geothermal companies and organizations.

Similarly, Iceland has been a center for education in geothermal engineering since the establishment of the United Nations University Geothermal Training Program (UNU-GTP) in the year 1978 [2]. Currently there are four geothermal academic programs in Iceland (MSc at ISE, MSc at University of Iceland, UNU-GTP, and Keilir).

The Iceland School of Energy (ISE) is a continuation of Iceland's history of geothermal education, and is built upon the REYST program that was previously offered at Reykjavik University since 2008. ISE is co-owned and operated by Reykjavik University, Reykjavik Energy and Iceland Geosurvey, and accredited by the School of Science and Engineering within Reykjavik University. Two master's degree programs are offered as well as short professional development courses, short courses for international students (RU GREEN), and a two week summer school program. The ISE faculty is also involved in renewable energy research, often in collaboration with the energy industry in Iceland.

The aim of ISE is to provide an opportunity to students and professionals around the world with an opportunity to learn about geothermal and other energy technology from experts in the field, with an interdisciplinary approach. Through this approach the ISE programs aim to arm graduates with a broad understanding of sustainable energy, whilst also providing the opportunity to study their preferred field in greater detail. This is achieved through a set of mandatory fundamental courses, a range of elective courses, an interdisciplinary project, internships, and a master's thesis.

2. PROGRAM OVERVIEW

2.1 Interdisciplinary approach

In the context of geothermal and sustainable energy, the interdisciplinary approach aims to provide students with multiple perspectives on each aspect of energy production and supply. It is important for professionals in the industry to not only understand the technical aspects, but also the social, political, economic, legal and environmental aspects as well. It is also important for students to understand the value of both academia and industry in the field of geothermal energy.

The program is taught mainly at the Reykjavik University (RU) campus in Reykjavik, by RU academic staff and industry professionals; with some subjects being taught at Iceland Geosurvey's headquarters. The course material itself is developed with input from multiple companies within Iceland, including Reykjavik Energy, Iceland Geosurvey, Landsvirkjun, Landsnet, and HS Orka, to name a few.

The master's degrees are structured in a way that provides students with the fundamentals of multiple disciplines, whilst also allowing enough flexibility for students to focus on their interests, and to learn from experience in both industry and academic activities.

2.2 Program structure

As mentioned in the introduction, the following programs are offered by ISE:

- MSc in Sustainable Energy Engineering
- MSc in Sustainable Energy
- Professional Development Courses
- Short Summer Courses
- RU GREEN program

The professional development courses are one off events that cover a range of topics, and generally consist of two to three days of lectures. They cover a broad range of targeted topics, focused mainly on geothermal energy, including maintenance and operation of geothermal power plants.

The short summer course is a two week 6 ECTS program that is offered to students who wish to get an overview of sustainable energy, with a focus on the geothermal energy applications in Iceland. Students who enroll in either of the two masters programs also take part in this summer course, providing a valuable networking opportunity for international students. The summer course is comprised of lectures and multiple field trips to significant sites (e.g. power plants, natural geothermal areas) in south west Iceland.

The two masters programs are largely similar, with the Engineering master's degree requiring applicants to have a bachelor's degree in engineering and to take a minimum of 12 ECTS of elective courses in engineering, with at least one engineering design course. The non-engineering master's degree allows students with alternate backgrounds to also broaden their knowledge in sustainable energy, and allows greater flexibility for students to choose courses that suit their interests.

The interdisciplinary approach is realized by combining the coursework with internships, an interdisciplinary project, thesis and field trips to local geothermal and hydropower sites. The structure of both degrees, in terms of ECTS, is described below in Table 1, with the geothermal specific elective courses listed in Table 2. Although the core courses are broad and interdisciplinary in nature, the elective courses, internships, and thesis allow students to achieve a deep understanding in a particular topic (e.g. wind power, district heating, etc.).

Table 1: List of mandatory courses and ECTS distribution for both Masters degrees. The MSc in Sustainable Energy Engineering requires students to take at least 12 ECTS of their elective courses from the School of Engineering, with at least one Engineering Design course.

Mandatory Courses	**ECTS Units**
Introductory Field Trip	6
Introduction to Energy Technology	6
Introduction to Earth Sciences	6
Introduction to Energy Economics	6
Overview of Sustainable Energy Systems	6
Interdisciplinary Project Course	6
Research Thesis	60
Total Mandatory Units	96
Additional Elective Courses	24
MSc Total	**120**

The 'Introductory Field Trip' course runs in conjunction with the Summer Course available to visiting students, and provides the Master's students with a real-world perspective on geothermal energy. Iceland has a large number of valuable field trip opportunities, given the numerous geothermal plants and natural geothermal sites. As stated by [3], "The [Icelandic] power plant complexes are ideal and important interdisciplinary training platforms". Therefore, it is important that the education is put in context by taking students to a number of geothermal and hydropower plants in Iceland, as well as unutilized sites (e.g. hot springs and waterfalls). Most power plants in Iceland have well equipped visitor centers and education facilities, which provide a great service for people who are interested in learning about their operations first hand.

Table 2: The geothermal engineering specific courses that are offered to Masters students at the ISE

Geothermal Engineering Courses	ECTS Units
Introduction to Surface Exploration for Geothermal Resources	6
Geothermal Subsurface Exploration	6
Geothermal Reservoir Engineering	6
Applied Geothermal Subsurface Exploration	6
Applied Geothermal Surface Exploration	6
Applied Geothermal Reservoir Engineering	6

At the end of the two semesters of coursework, and prior to the start of the thesis, student's take part in an interdisciplinary group project. The project is in cooperation with a company within the Icelandic energy sector, and aims to address a real problem that the company is facing. The assignment is generally structured in a way that requires knowledge of multiple overlapping disciplines (for example, evaluating the socio-economic, environmental and political viability of an engineering solution to excess H2S emissions). The aims of the project is to give students practice in combining the different disciplines covered in the courses, to provide experience working on a real-world issue, as well as experience working in a multi-discipline team of peers.

Short Internships are also available as an elective course to students in the master's program, and are offered on a rolling basis. This gives students the opportunity to have direct industry experience in the field of their choice, and allows them the opportunity to grow their professional network with industry professionals. The internship program began in 2013, and students have already had successful internships with several Icelandic companies, including Fafnir Offshore, Landsvirkjun, Arion Bank, and Reykjavik Energy.

All students are required to complete a 60 ECTS master's research thesis on a topic of interest related to their studies. The thesis allows students to pursue independent, focused learning on a topic of interest, and a taste of academia and research in the field of sustainable energy. It is common for students to work on a project relevant to an Icelandic company, such that their work is of definite value and to provide them with additional access to supervision, expertise, tools and data. Recently, students have worked on their theses with assistance from companies such as Landsvirkjun, Reykjavik Energy, Iceland Geosurvey, Mannvit, and Strætó and many more.

The overarching expectation of the ISE program is that the coursework will ensure all graduating students have a good understanding of the fundamentals of sustainable energy, to provide the foundation for specialization in a certain field. The research thesis and internships help students gain experience and to further develop their understanding of their field of interest.

3. INDUSTRY CONNECTIONS

By encouraging strong connections of the program with industry partners in Iceland and abroad, ISE provides a talent hunting opportunity for the industry, as well as keeping the program up-to-date for the benefit of students. The masters programs are as much a networking opportunity for students and professionals as it is an educational pursuit. The majority of the geothermal courses taught at ISE are held at Iceland Geosurvey's offices, and taught by Iceland Geosurvey staff.

ISE develops its industry connections through a strategic outreach that can be divided into five separate avenues for cooperation. These are recruitment, formal partnerships, funding, knowledge sharing and marketing, which are described below:

- Recruitment: Provide prospective students with pathways and financing to participate in the masters programs, or parts of, by creating partnerships with other academic institutions or companies in the field.
- Formal partnerships: Partner with educational institutions and companies in order to create opportunities for ISE's students, faculty and staff and to further advance ISE's operations through various different forms of collaborations.
- Knowledge sharing and learning: Informal dialogue with foreign academic institutions to learn from, and share experiences.
- Funding: Reduce the financial barriers of attending ISE programs for applicants of merit and to strengthen research on renewable energy.
- Marketing: Partnerships and direct outreach to increase exposure of the program both domestically and internationally.

4. PROGRAM STATISTICS

4.1 Intake

The number of applicants has increased gradually since the program initiated. The increasing quantity of applications can be attributed to initiatives undertaken by ISE in strategic outreach and by building up a reputation, as defined above. The programs 2014 intake outcome already shows a large increase in the number of both quality and quantity of applications. It is expected that continual efforts in the five fields discussed above will result in a sustained growth in student interest. Also, an increased utilization of geothermal energy in the world, and plans for further development are likely to stimulate interest.

The ISE program is also receiving a majority of its incoming applications from non-Icelandic and non-European students, as shown by Figure 1 below. Again, this is due to number of initiatives undertaken by ISE, but also due to the strong, positive image of Iceland in the geothermal industry and the sustainable energy industry, as well as the high standard of living in the country.

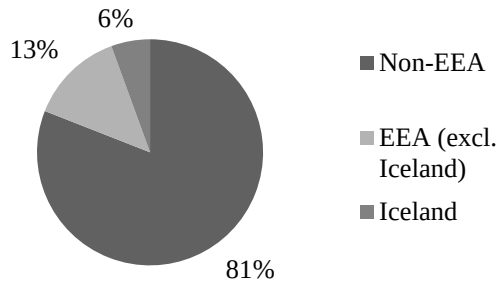

Figure 1: Origin of ISE applicants for the 2014 academic year, showing proportion of total from Iceland, EEA (excluding Iceland) and non-EEA countries (n=126, sourced from internal records)

4.2 During studies

Since 2010, 25 students who commenced the program also completed a research thesis (and hence graduated from the program). The topics discussed in the thesis papers are shown below in Table 3. Of note, 48% of students chose to study topics related to geothermal engineering, suggesting that many students drawn to ISE hold geothermal engineering as their main field of interest. The majority of these topics are supported by the provision of data and supervision by companies such as Reykjavik Energy and Icelandic Geosurvey.

Table 3: Summary of the thesis topics covered by ISE graduates since 2010, showing the obvious bias ISE graduates have had towards topics related to geothermal energy (note that only the main topic of each thesis is counted, and that many papers cover multiple topics)

Topic	Number of Theses
Biofuels	2
Development	1
District Heating	1
Environmental Assessment	1
Geothermal	12
Heat Recovery	1
Natural Gas	1
Nuclear	1
Policy	1
Transport	2
Wind	2
Total	**25**

The willingness and ability of local industry to provide useful data is an invaluable service for students. This is shown by 64% of graduating students having supervision, data, or technical support from industry professionals since 2010. For geothermal studies specifically, the proportion of students who had industry assistance was 58%.

4.3 Graduates

Since 2010, 25 students have graduated from the ISE (and formerly REYST) program. Precise employment statistics are not known currently, but examples of some of the career trajectories of previous graduates are shown below:

- An assistant hotel manager graduated from ISE and now works as the director of project management at a leading Icelandic geothermal engineering firm;
- A construction engineer graduated and went on to undertake research on transmission systems as part of an EU framework project;
- A former purchasing administrator now works as an economist for a leading Scandinavian TSO;
- A student with a background in biology started their own alternative energy vehicle consultancy after graduating;
- A former surveyor now works as a production manager for a carbon recycling firm;

- A student with a background in geology is now the deputy manager of a solar panel producer in South-East Asia.

These examples of success imply the value in the education from the perspective of their employees, and show the willingness of graduates to apply their education at ISE within the field of sustainable energy. They also highlight the value of an interdisciplinary approach, in that students with varying backgrounds can use the ISE program to change their career paths effectively, utilizing the flexibility of the degree to achieve the education that best meets their goals.

5. CONCLUSION

Student feedback and the career paths of ISE graduates suggest the inherent value of the interdisciplinary approach. Increased interest in the ISE program suggest that ISE is well positioned to take advantage of a growing international interest in the field of sustainable energy, and will continue to be a source of geothermal energy professionals in the future. The program is likely to further improve in the future with the continued support and cooperation of local geothermal expertise and infrastructure.

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