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Postgraduate geothermal energy education worldwide and the New Zealand experience

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ABSTRACT

Postgraduate (PG) geothermal energy education is a highly specialised area offered by very few universities around the world. History have witness the demise of several geothermal education programs when their funding was withdrawn.

In this investigation we will give an overview of the global geothermal education programmes. The background, course structure, teaching philosophy, student cohort and funding for the PG geothermal energy course at the University of Auckland is provided. A vision going forward is required given the recent decline in the number of students attending the course and the drop in oil prices which is affecting the global geothermal energy industry.

1. Introduction

Geothermal energy is a clean renewable energy source that has been used for thousands of years. Geothermal energy is simply heat from the ground. It can occur naturally in different geological settings, but is mainly located along tectonic plate boundaries in areas with high volcanic and seismic activities. Geothermal energy can be utilised for electrical power generation as well as a heat source for direct use applications (for example space heating, aquiculture, green houses, industrial processes). Power generation from geothermal energy has been proven to offer reliable base load at low cost (Bertani, 2016; Zarrouk and Moon, 2015). Many countries have recognised geothermal energy as a means of helping to achieve energy independence. Geothermal power is known for its high availability compared with other renewables (e.g. wind and solar) (e.g. Zarrouk and Moon, 2014, 2015). Geothermal energy, however, has higher upfront cost and risk associated with exploration drilling and longer development time when compared with other renewable energy resources. Geothermal power production was started in Italy in 1913 to power the local railway network. New Zealand was the second country to produce electricity from geothermal energy in 1958 with the commissioning of the Wairakei power plant (Bertani, 2016).

In mid-2008 oil price reached a maximum of $US147/barrel (Fig. 1). Climate change is becoming accepted as a reality and expanding the use of renewable energy has become a mainstream idea. The growing awareness of the potential of geothermal resources and engineered geothermal systems (EGS) led to increasing interest in geothermal technology in the United States (MIT, 2006). The interest in the potential of conventional geothermal energy on every continent has continued despite the world financial problems of 2008 (Newson et al., 2010).

Currently more than 12,635 MWe of electricity are generated from geothermal energy in 26 countries, it accounts to a saving of 1000 million ton of CO_2 emission to the environment per year compared to fossil fuelled power (Bertani, 2016). Fig. 1 shows the worldwide history of geothermal power development since 1950. The forecast for the year 2020 shows a target of 21,443 MWe of possible installed capacity in 51 countries (Bertani, 2016). If this is realised a boom in geothermal developments will trigger significant demand for trained geothermal engineers and scientists.

Not surprisingly Fig. 1 shows that development of geothermal energy is strongly affected by the price of oil. Installed capacity grew very little between 1950 and 1970, when the average price of oil was less than 25 $US/barrel. This was followed by significant increase in installed capacity in the late seventies and early eighties in response to the 1973 and 1980 oil crises. Then growth was moderate between 1985 and 2005 when oil averaged about 20 $US/barrel. While more recently the increase from 2005 up to 2015 has resulted from the surge in oil price. However, the data in Fig. 1 which came from countries forecasts from 2014 (Bertani, 2016) did not consider the drop in oil prices in late 2014, which will likely result in lower investment in geothermal power development and lower installed capacity by 2020 than predicted in Fig. 1. Geothermal power development is also being challenged by the drop in the price of photovoltaic solar energy panels in the past ten years (EIA, 2017). However, geothermal energy development will continue in many countries as a reliable renewable energy source and

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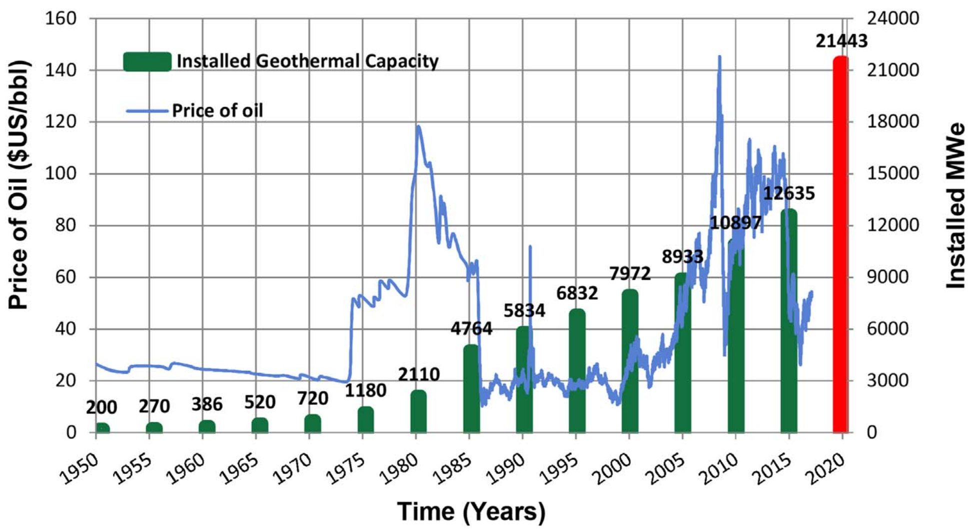

Fig. 1. World geothermal power plant installed capacity in MWe (Bertani, 2016) and the price of Oil (http://www.macrotrends.net/1369/crude-oil-price-history-chart).

as fossil fuel fired thermal and nuclear plants are phased out with time.

In this work, we will give an overview and assessment of the geothermal energy education programmes worldwide, then focus on the Post Graduate Certificate in Geothermal Energy Technology (PGCertGeothermTech) taught at the University of Auckland, New Zealand.

2. Geothermal energy education

Geothermal energy education is a very specialized discipline with only a few courses currently running around the world. It is concerned with understanding the natural setting of the geothermal systems and the technology applied to harness and utilise this energy. Geothermal developments are very man-power intensive. SKM (2005) gave estimates of the man-power requirements for an expansion of the geothermal capacity in New Zealand by 50 MWe/year as follows: 23.5 geoscientists, 43 engineers and 17 managers. This indicates that for the projected optimistic increase in installed capacity by about 41% between 2015 and 2020 (Bertani, 2016), a major increase of about 14,710 in trained man-power is needed worldwide.

3. Geothermal energy education worldwide

Several papers document the history of geothermal energy education since 1970 (Dickson and Fanelli, 1995, 1998; Hochstein, 2005; Fridleifsson, 2005; Newson, et. al., 2010: Zarrouk, 2012; Georgsson et al., 2015; Zarrouk, 2016). By 2003 the United Nations University (UNU) course in Iceland was the only remaining post graduate level geothermal course (see Table 1). The international (taught in English) courses listed in Table 1 had one main theme in common, that they were designed to bring together graduates from different disciplines in science and engineering and cover all aspects of geothermal energy technology.

Specialized education and training in geothermal energy resources and their application is very challenging because "*the market at national level is normally too small to justify investment and running costs"* (Popovski and Vasilevsks, 2004). Therefore, only international courses can potentially run viably (with some additional support).

History has witnessed the end of several geothermal courses around the world when their external funding stopped (Table 1).

Currently, there are only two "established" geothermal institutions specialising in taught geothermal energy training around the world. These two institutions are the United Nations University Geothermal Training Programme (UNU-GTP) in Iceland (Georgsson et al., 2015) and the Geothermal Institute (GI) at the University of Auckland in New Zealand (Zarrouk, 2016).

The UNU-GTP, Iceland is by far the most active and out reaching geothermal education/training programme in the world. It is the only geothermal course that did not stop since it was started in 1979 (Fridleifsson, 2005; Georgsson et al., 2015). The UNU-GTP receives substantial funding from the Icelandic Government, but it is also financed through funds from international cooperation partners with an estimated total annual budget of $US2.8 million to $US3.0 million) (Private communications with Mr. Lúdvík Georgsson, UNU-GTP). The funding allows for the running of the six months (April-October) geothermal training programme in Iceland and several subsidized/free short courses in Africa (Mwangi, 2003), Asia (Benito and Reyes, 2003), South America (Martínez, 2003; Georgsson et al., 2015) and Europe (Fridleifsson and Geogsson, 2004). The funding also covers scholarships for MSc and PhD in Iceland carried out in cooperation with Icelandic

Table 1
History of post graduate geothermal programmes around the world (updated from Hochstein, 2005 and Zarrouk, 2012).

Institution	Country	Year Started	Year Stopped	Duration (months)	Funding support
International Institute for Geothermal Research, CRN in Pisa,	Italy	1970	1985	9	United Nations Development Program (UNDP).
		1985	1992	8	UNESCO
Kyushu University	Japan	1970	2001	2–4	The government of Japan (JICA)
		2016	Continuing	6	
Auckland University	New Zealand	1978	2002	9	UNDP and MFAT Scholarships (varying number over the years)
		2007	Continuing	4	Employer-funded students Self-supported students
UNU-GTP Reykjavik	Iceland	1979	Continuing	6	The government of Iceland and UNU (until 2007) Employer-funded students

Universities.

Building on the success of the UNU-GTP course, an 18 month taught Masters in renewable/sustainable energy was started at Reykjavik University with more of a commercial focus targeting international self and employer funded students. Reykjavik University also runs professional development courses and short summer course (Logadóttir and Perkin, 2015).

In June 2016, Kyushu University, Japan, has restarted its six months geothermal education programme after 15 years from termination (Table 1). The course is fully funded by the government of Japan through the Japan International Cooperation Agency (JICA) with guaranteed funding for the next ten years with scholarships for 15 international students per year (private communications with Prof. Ryuichi Itoi, Kyushu University).

The International Institute for Geothermal Research, Pisa, Italy, started a post graduate course in geothermics in 1970 (Table 1). This course ran for eight months from November to June until 1992. The course trained 324 students from 68 countries with more focus on students from Latin-America and Asia. It was stopped in 1992 when the external UNESCO funding ceased. The education programme was effectively overshadowed a few years later with the creation of a large research centre covering geothermal energy amongst other research interests in earth science and engineering.

In 2011, the Great Basin Centre for Geothermal Energy (GBCGE), University of Nevada, USA started a two months geothermal summer school course fully funded by the US Department of Energy (DoE). It was reduced to one month in 2013 and since 2014 it has been running as a commercial 1–2 weeks training short course (Zarrouk and Newson, 2015) when the DoE funding stopped.

In 2010, a five months post graduate Diploma course taught in Spanish was started at the University of El Salvador with the support of geothermal energy company LaGeo, targeting students from Latin America. Between 25 and 30 students attend the course every year with twenty scholarships offered annually, 10 to international (from Latin America mainly) students and 10 to local students. Between 2010 and 2012 the course was financially supported by the Italian government and in 2013–2015 by the IDB a Nordic Development Fund (NDF). In 2016–2017 NDF and UNU-GTP have supported the course (Private communications with Mr. Lúdvík Georgsson, UNU-GTP).

There are also several other geothermal training programmes in China (Hochstein, 2005; private communications with Prof. Xinli Lu, Tianjin University), Chile (IGA, 2017), Croatia (IGA, 2017), El Salvador (Hochstein, 2005), Germany-Netherlands (Hruska and Clauser 2015), Hungary (Praczki, 2013), Indonesia, (Saptadji, 2010; Utami, 2015), Japan (IGA, 2017), Kenya (Mariita, 2015), Philippines (Aligan, 2010, 2015), Poland (Kepinksa and Nagel, 1997; Popovaki and Vasileveks, 2004), Switzerland, Turkey (Hochstein, 2005; Mertoglu et al., 2016), Romania (Rosca and Antal, 2003), Mexico (Carlos and Jesus, 1995), South Korea (Baek et al., 2010) and the USA (IGA, 2017) with full or partial geothermal focus offered at undergraduate and postgraduate level within different education programs (geology, geophysics, environmental science, petroleum engineering and mechanical engineering). Some of these courses are taught in the local language (not English) which means that they are mainly attended by domestic students.

Experience has shown that it is difficult to sustainably run geothermal energy education programmes as a stand-alone and self-supporting program without external funding. This is due to the high overhead and running costs, changing demand for graduates, limited employment opportunities, limited number of interested students as well as the fact that most interested students come from developing countries where they do not have access to funding.

Several universities and research institutions offer geothermal energy research (not taught) at Masters (MSc) and PhD levels. However, from our experience, MSc and PhD graduates will not grasp the full picture of geothermal energy resources and technology from carrying focused research only, due to the interdisciplinary nature of this industry. We feel, it is those mainly taught courses discussed above that are crucial for the full understanding of this industry and the technology involved. Students attending these taught courses will be better equipped to work in the geothermal industry and/or carry further postgraduate study and research. Our approach to Masters and PhD level applications is to insure that, the student should have geothermal post graduate education qualification before being admitted into these programs. The UNU-GTP has similar criteria before students are admitted into their Masters and PhD programs (Private communications with Mr. Lúdvík Georgsson, UNU-GTP).

Several studies can also be found in literature on outreach, public awareness and education programmes on geothermal energy, visitor centres and tourism/education parks. These studies target the promotion of geothermal energy as an alternative and sustainable energy source to school students and the wider public (Beck, 1991; Kepinksa and Nagel, 1997; Albertsson and Jonsson, 2010; Dobson et al., 2012; Praczki, 2013; Hendrarsakti 2013; Utami, 2015; Camu, 2015).

4. Geothermal energy education in New Zealand

The Geothermal Institute (GI), the University of Auckland, ran a Post Graduate Diploma in Geothermal Energy Technology (PGDipGeothermTech) from 1978, it has 655 alumni (595 from developing countries) from 36 countries (Hochstein, 2005) most of whom are now in senior positions in their home countries. They still maintain a close relation with the New Zealand geothermal industry (providing links and potential contracts). The GI also trained most New Zealand geothermal experts and kept New Zealand at the forefront of geothermal research, knowledge and practice worldwide.

Unfortunately, support from the New Zealand government for the GI was withdrawn at the end of 2002 (Newson et al., 2010). This was despite the growing concern among professionals in the geothermal industry over the loss of momentum in geothermal research and training in New Zealand, and a potential shortage of geothermal professionals (SKM, 2005).

The GI was fully funded by the UNDP from 1978 till 1989 which was later funded by the New Zealand government through the Ministry of Foreign Affairs and Trade (MFAT) up to 2003. It had seven fulltime academic staff (three in geothermal engineering and four geoscientists) plus three administration staff (manager, secretary and technician) and ran the 10 months (two-semesters) PGDipGeothermTech with an average of 25–30 students/year. There were also 84 Masters and 24 PhD students undertaking geothermal research in both earth sciences and engineering up to 2003 (Hochstein, 2005).

Most (> 85%) of the students attending the course were funded by UNDP and later New Zealand government scholarships. Therefore, in 2003 when the New Zealand government stopped funding the running overhead, the course was abandoned by the university and most of the academic staff retired or were made redundant. The fate of the GI is not different from that of the geothermal courses in Italy and Japan (Table 1) and also USA, where these courses were also fully reliant on government/external funding or scholarship programmes. This can serve as an example for similar programmes because as governments change their education funding or aid programs, it puts these academic courses at risk. With that in mind, when restarting the new post graduate certificate PGCert in geothermal energy technology (PGCertGeothermTech) in 2007 significant emphasis was given to making the course self-sustaining.

The PGCertGeothermTech is designed to accelerate the development of geothermal expertise amongst young graduates and professional engineers and scientists. Thus it supports them in starting and/or advancing their career in the geothermal industry. It has been designed in a block structured high-quality postgraduate qualification for professionals with an engineering or science background.

The curriculum of the PGCertGeothermTech programme consists of two compulsory lecture courses (papers), followed by an advanced elective course. Field trips are an integral component of these lecture courses. The PGCertGeothermTech is completed with a short research project.

There are two field trips (five days long each) to the Taupo Volcanic Zone in the central North Island of New Zealand. There are also several day trips to visit geothermal companies and sites of geological or geothermal importance. The field trips (20% of the course time) are integrated with the academic teaching. They are designed to build the student's confidence in understanding the assessment, development and utilization of geothermal systems.

4.1. Teaching and assessment

There is a strong focus on application, field studies, case studies and project-based learning throughout the courses. The teaching periods are compressed into six week blocks of four hours per day, often with additional two hours of tutorials in the afternoon. These teaching methods are designed to be similar (although possibly slightly more intense) to a typical professional workday. This is in terms of the concentration and number of tasks required. It appears to suit a cohort of students with prior practical industry experience. For students that have job commitments, the intensive teaching schedule minimizes time away from their jobs.

The entire courses are 100% internally assessed. This increases the assessment load on staff, but provides the students with prompt and accurate feedback on their progress. This is much appreciated by the students and reflects in their feedback. The assessment involves 40% course work (including: 10% on field-study reports, 10% for seminars and 20% on three different assignments). There are two tests, a 20% short test (90 min) and 40% final test (three hours). These tests are conducted under official university exam conditions.

Formal and informal student feedback is received on an ongoing basis during the programme, individual courses and project. It has been predominantly positive (Fig. 2).

All of the students are given a ten minute individual meeting with the course co-ordinator to provide the students with feedback and direction. Well-performing students are encouraged to continue to develop and improve. For students that are not performing at an acceptable level; they are asked how they feel about their performance in the programme and what they expect to gain from doing the programme. This approach seems to trigger self-motivation without humiliation. Poorly performing students are also engaged through encouragement, direction and offer of help (additional tutorials) if needed. The academic head is also notified early in the programme of any student performing below standard.

PGCertGeothermTech is a very technical and concept rich programme with long lecture hours. This has an effect on the student's attention levels throughout the lectures and it normally drops as expected by the end of lecture. Student's attention is regained through the use of short technical movies, relevant stories from field experience and interesting incidents that took place in the industry. Students are asked to comment and possibly share similar stories from their experience. Models of equipment, rock samples and damaged/broken parts of equipment (turbine blades, heat exchangers, drill bits etc.) are used to regain attention, interest and engagement. The students find these additions to the lectures very interesting as it directly relates to their field of work.

Based on the nature of the PGCertGeothermTech programme and the type of students as discussed above, the human resource requirements for administrative and academic support and pastoral care are relatively high compared to other programmes.

4.2. Lecture component

The first part of the lectures comprises of a fixed set of compulsory courses in both Geothermal Engineering (course GEOTHERM 602) and Geothermal Earth Science (course GEOTHERM 601) to the value of 30 academic credit points. These courses have been designed to provide a comprehensive and broad overview of the geothermal systems, development and energy technology at postgraduate level. Given the diversity of student academic background, the first two weeks of these courses are dedicated to bridging the knowledge gap and bring the students to a common ground. This is when the engineers learn more about earth science (geology, geochemistry, geophysics, environmental science) while the earth scientists learn the engineering fundamentals (thermodynamics, fluid mechanics, heat transfer). Regulatory policies on geothermal energy use and geothermal system management are introduced at this stage. This period also serves as a refresher for returning students who have been outside academia for sometime.

Most of the classroom teaching is done by academic staff. Introduction to different aspects of geothermal development is provided by other New Zealand geothermal experts.

These companies and individuals donate their time and expertise because they believe in the strength of the New Zealand industry and want to share their knowledge and experience with the students. The

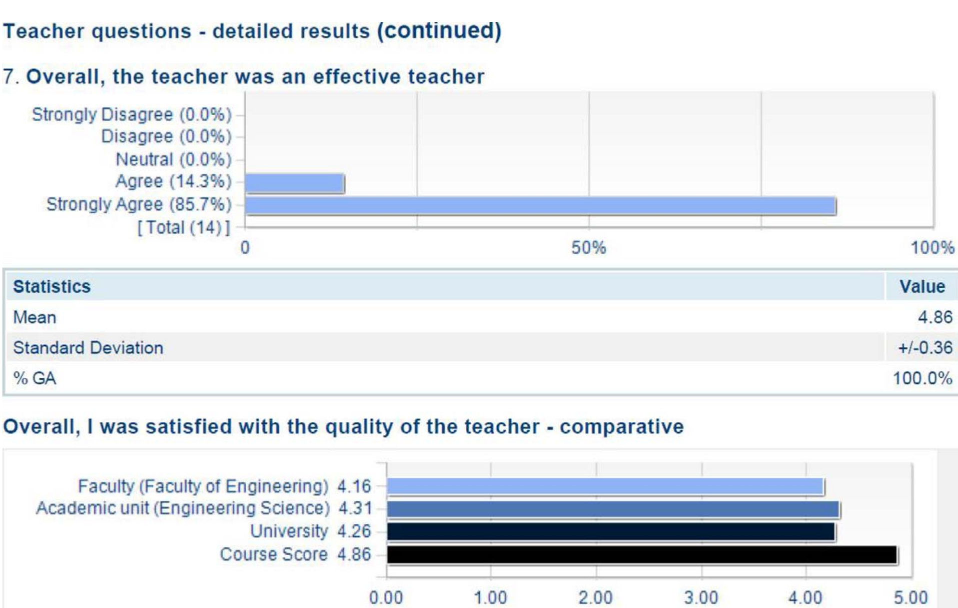

Fig. 2. A screen copy of the bar chart students feedback in 2016 (above) on the geothermal course teaching effectiveness, (below) is a compression of the level of satisfaction compared with the university wide, faculty of engineering and the academic unit (engineering science).

organizers of the PGCertGeothermTech welcome their participation as it gives depth, variety and interest to the course.

In the second part of the programme, the students have the option to learn more about either Geothermal Engineering (GEOTHERM 620) or Geothermal Geoscience (GEOTHERM 603). Again, most of the teaching is done by academic staff. However, some experts from outside the University may join the lecture program for specialist subjects such as geochemistry, geophysics, advanced drilling, power plant maintenance and pipeline design.

There is no scope for the students to select additional electives outside this range of courses due to the block structure of the courses and highly specialized nature. However, some students choose to take the credit (points) from doing the individual course (papers) into other degrees from both the engineering and science faculties. The PGCertGeothermTech programme does not include distance learning courses. This is because of its integrated field based and lecture based education structure. This is made very clear on the programme webpage and information pack.

4.3. Field component

Field-based education is very common in applied sciences (mainly in geology, biology and environmental sciences) and is also applied to some business and engineering courses. Many universities have established undergraduate and postgraduate courses that are taught fully in the field. Many of these universities have permanent field stations or field camps dedicated to this type of applied education (Douglas et al., 2009; Puckette and Suneson, 2009).

The PGCertGeothermTech combines both field-based and class-based teaching. The field trips (20% of the course time) are integrated with the academic teaching to build the students confidence in understanding the framework of geothermal fields, assessment, development and utilization.

There are two field trips (five days each) to the Taupo Volcanic Zone in the central North Island of New Zealand. The first field trip takes place during the GEOTHERM 601 and GEOTHERM 602 courses in the first part of the semester. It is designed to give an overview of geothermal energy. This is to ensure that all students learn a basic level of geothermal surface features, geology, steam-fields, power stations, drilling and direct use. The second field trip is during GEOTHERM 603 and GEOTHERM 620 papers in the second part of the semester. It addresses problems of increasing complexity and students are required to work in groups to record and share data for their field trip reports. Field exercises provide the basis for cementing the concepts and problem solving techniques introduced in the lectures. Students have to complete a 3000–4000 word technical report, recording their observations and applying the techniques they learned during the lectures after each field trip. There are also several day trips to visit geothermal companies and sites of geological or geothermal importance.

By the end of this programme, the students will have visited five different geothermal power stations, three geothermal drilling rigs sites, four steam fields, eight examples of the direct use of geothermal energy and five different natural geothermal systems.

Natural geothermal areas are among the most dangerous natural environments on earth. Key hazards are hot steam and water, unstable and thin ground, potential for toxic fumes heavy machinery and cold weather. The ground can be 100 °C at 10 cm depth and may be covered with a weak and breakable crust. Pools can be boiling or even erupting and splashing boiling water. Gas (CO_2 and H_2S) is also hazardous. Industrial geothermal plant may also have all these hazards, as well as hot equipment, trip, noise, and height hazards. In addition, many geothermal areas are protected environmental sites due to the botanical and geological uniqueness.

Hence, student safety and environmental protection during the field trips are a top priority and we develop a health and safety plan for each field trip. Since the start of the PGCertGeothermTech programme in 2007, there have been no accidents or injuries and we are proud of our zero harm (to human or nature) policy. One of the limiting factors for student numbers in the course is the ability to safely supervise them (10 students/staff member) while in the field. Experience has demonstrated that the supervisors (lecturers and tutors) are comfortable with up to 35 students on field trips (effectively one bus load).

Running the field trips normally requires significant investment due to the high costs associated with travel, food, accommodation and for access to some sites. The regulations at the University of Auckland do not permit charging the students for field trips in addition to the standard course fees. This puts significant pressure on the course budget and viability. At the same time it is not possible to increase student numbers as most geothermal companies/operators put a maximum limit of 30–35 visitors (students and staff) during site visits at any one time. It is also not possible to run these field trips multiple times a year due the logistics, cost and limited staff. In 2014 the faculty of engineering has introduced an added fee of $NZ1000/paper for all international students. This is to cover the field trip costs and consumables.

4.4. Research component

In the final four weeks of the course, the students carry out a geothermal research project (GEOTHERM 689). This project allows students to develop and apply their new skills gained through the programme. The research project should demonstrate how relevant literature, theoretical criteria and considerations, models or concepts learned in the course or through a literature review are used to address a geothermal problem.

Therefore, concepts or models relevant to each analysis should be reviewed and the most appropriate chosen for application in the project setting. The research therefore covers the theories and the methodologies used in conducting the study as well as the main conclusions. It must be written to a standard suitable for publication in an academic journal or conference. Its length should normally not exceed 6,000-8000 words including References

For students with industry experience, the geothermal project provides them with the opportunity to apply the scientific and engineering concepts and tools they have learned during their study. Their research project often includes data collected from their current workplace, thus providing a positive benefit for employers. A project report containing confidential information is not made publicly available.

Emphasis is made on the development of high-level but practice related knowledge with practical computer and field skills. However, to date, 49 out of 238 PGCertGeothermTech graduates have chosen to continue their academic studies at Masters and PhD levels both in New Zealand and in other universities. Building on the success of the PGCertGeothermTech a 12 months taught Master of Energy programme was started in 2011 at the University of Auckland. This is similar to the taught Masters programme in Reykjavik University, Iceland (Logadóttir and Perkin, 2015).

5. Students

In 2007 (the inaugural year) there were nine students enrolled in the course (Fig. 3). Numbers have varied since then. However, 2014 had the highest numbers of students to date, with 48 students enrolled in all or part of the course. International students are generally in full-time employment and some choose to do the programme over two years due to their employment commitments, hence the block structure of the courses. This is a reason why some are only enrolled in part of the course for any given year. In the first three years (2007–2009) of the course, students were allowed to attend the lectures as short courses and charged at a commercial rate. However, this practice was discontinued for administrative reasons. Fig. 3 also show the total number of individual paper enrolment per year. It is clear that there is a

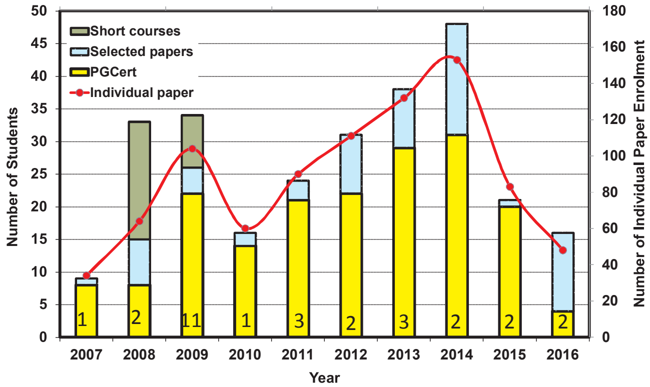

Fig. 3. Annual number of student's enrolment in the PGCertGeothermTech, selected papers, short courses and the number individual paper enrolment. The numbers within the yellow bar indicate the number of domestic students attending the full PGCertGeothermTech course each year. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

significant drop in student numbers by more than 40% per year in the past two years.

To date, students from thirty two countries have attended the course (Fig. 4). The largest percentage is from Indonesia (29.15%) and the Philippines (22.67%), followed by New Zealand (10.93%) and Kenya (8.91%). The combination of nationalities adds a lot of human interest to social interactions within the group. The most common practical problem from a teaching point of view is language.

There is a wide range of student ages (Fig. 5). The youngest age group is 20–24 years, and the oldest is 65–69 years. The most commonly occurring range is 30–34 years. We suggest that there are two reasons for the dominance of this relatively mature age group. One is that many of the students, particularly those from the Philippines, are fully funded by their employer. Philippines employers consider the training, to be ‘professional development’ and also desirable to maintain the strength of the Philippines geothermal industry. The other reason is that domestic (Australian and New Zealand) students are often those who have work experience, but are making a conscious change to a renewable-energy and environmentally-friendly professional career.

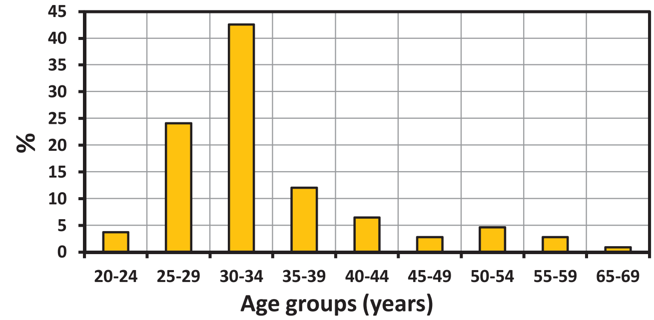

Fig. 5. Students age distribution (years) for the PGCertGeothermTech course.

There have always been more male students than female students in this course with an average of 24% female students from 2007 to 2016. Fig. 6 shows that the highest proportion of female students was in 2009, when there were nine females out of a total of thirty four students (26%). However, the gender distribution is similar to that of all engineering students at the University of Auckland from 2007 to 2016, which is 22% female student on average.

6. Financial support

In 2007 and 2008, there were four industry sponsored scholarships

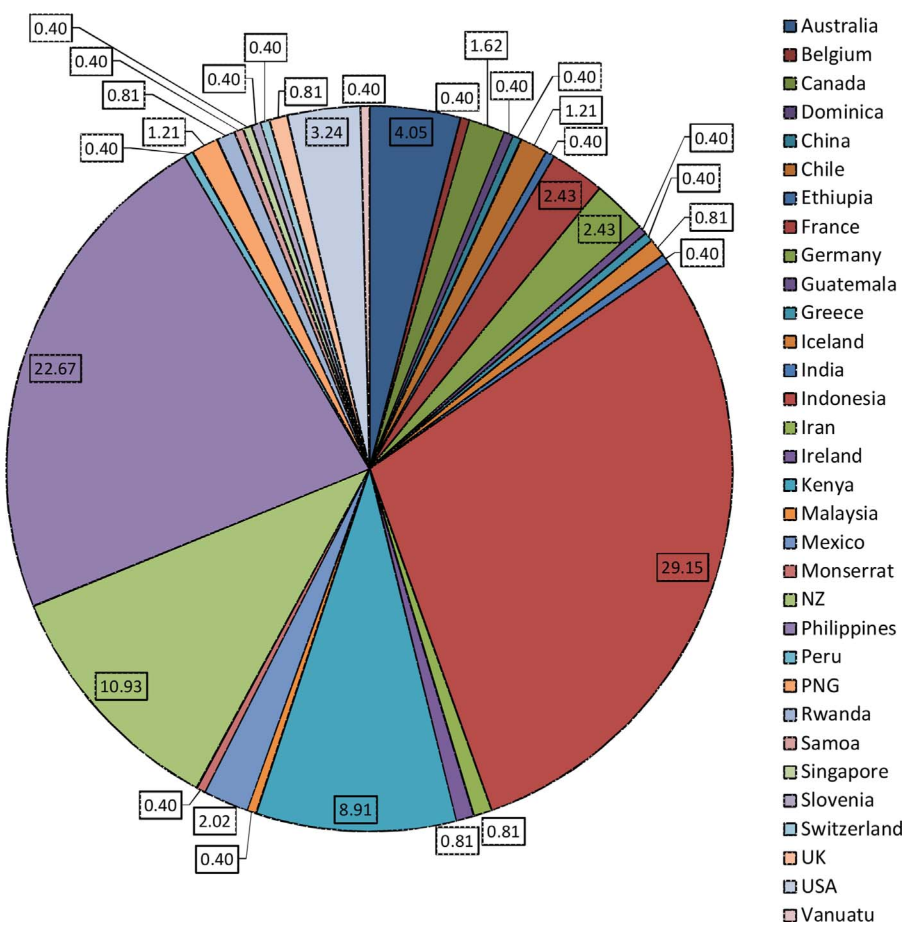

Fig. 4. Total student's proportion (%) by country for the past ten years (2007–2016).

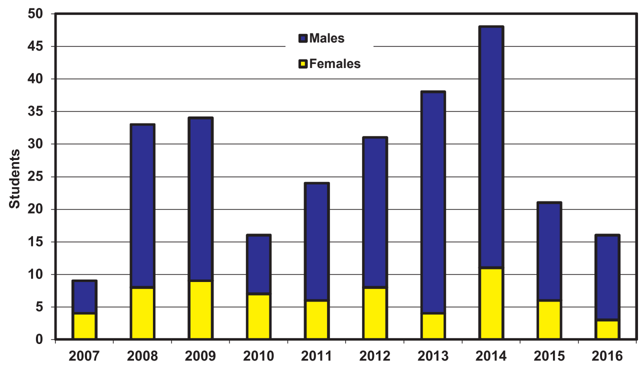

Fig. 6. Annual gender distribution for the PGCertGeothermTech course.

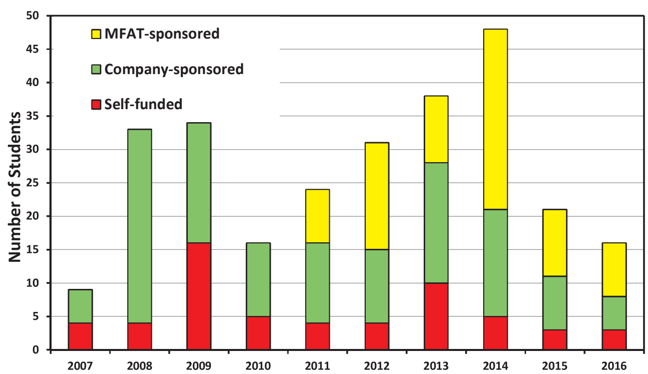

Fig. 7. Financial support for students to attend the PGCertGeothermTech between 2007 and 2016.

per year (one from MBCentury Ltd. and three from Contact Energy Ltd.) for international students. These four scholarships helped to establish the PGCertGeothermTech course.

Fig. 7 shows the categories of support for students and the number of students under each category from 2007 to 2016. The categories we define are: self-supported where no official specific funding to attend the course; company sponsored, whereby the student is supported by their employer to attend the course and scholarship funding, where the student has a scholarship from an organisation other than their employer. For the PGCertGeothermTech this is typically a New Zealand government scholarship. Although Maori Trusts have also offered scholarships, there is a shortage of eligible science or engineering graduates to take up such opportunities.

In 2009 and 2010 the course had only self-supported students and company sponsored students.

Since 2011 there has been several scholarships offered by the New Zealand Ministry of Foreign Affairs and Trade (MFAT) for the geothermal PGCertGeothermTech programme. Students who enquire about these scholarships are directed to the local New Zealand Embassy/High Commission in their home countries, which administer/award these scholarships. MFAT has a list of receiving/eligible countries for these scholarships and this list can change annually. Since 2011, 29.2% of the students have been supported by MFAT scholarships. It is anticipated that this ratio will increase with time.

The majority (49.5%) of our students are sponsored by the companies that employ them. Most of these students are from the Philippines (Fig. 4). In the Philippines, geothermal companies believe that investing in their employees professional development is the way to build a strong local geothermal industry.

From 2007 to 2016, only 21.4% of the students were self-supported. In all years, except 2009, the average number of self-supported students was 4.3 per year. It is doubtful that the course would survive in its present form with this small number of self-supported students, which demonstrates the dependence of the course on external scholarships and sponsored students. The year 2009 had the highest number of self-funded students (47%), which we suspect is anomalous due to the global financial crisis and high level of unemployment. Anecdotal evidence is that at such times professional people may decide, at their own expense, to gain an extra qualification in order to be available and competitive on the job market when the economy improves.

The fee for the 2017 academic year stands at $NZ 27,393.4 for international students and $NZ 5346 for domestic students. Since more than 88% of our students have been international students, the course is reliant on international students. As mentioned previously, from 2014 the tuition fee has been increased by $NZ1000 per course for international students. This possibly has affected (reduced) the number of students enrolled in the course (Fig. 5).

The number of students with geological background is dropping with seven students in 2015 and only three in 2016. This drop in number of enrolments meant the advanced paper on Geothermal Geology (GEOTHERM 603) can be offered every other year if needed to reduce overheads until the number of applications with geological background increases.

7. Conclusion

Geothermal energy is a renewable resource with many industrial applications. Geothermal power development is highly affected by the price of oil over the past seventy years and more recently by the reducing cost of solar energy installations.

Based on our experience and the experience of other similar courses from around the world, given the fluctuation in the energy market and the volatile oil prices; it is not possible to run a financially self-sustaining geothermal course. This is without ongoing financial support either directly (through funding overhead) or indirectly (through student scholarships). This explains the demise of several geothermal education programs when their funding stopped.

History has shown that several geothermal education programmes have ceased to exist when their funding stopped (New Zealand, Japan, Italy, USA). Some of the running geothermal energy training programmes (New Zealand and Japan) were started through UNDP funding or UNU funding (Iceland). They then continued to varying extent through the support of the local governments (Japan, New Zealand and Iceland). The course in Iceland is the most outreaching programme and the only course in the world that did not stop since it was started in 1979.

The PGCertGeothermTech has been taught for ten years, from 2007 to 2016. It will continue to be offered in the second semester of every year at the University of Auckland.

The course is much specialised, with an integrated approach between class-based and field-based education. The course is industry oriented with a strong cross-disciplinary approach to ensure that all students have a grounding of all geothermal-related topics.

The success of this approach requires research and field experience on the part of the lecturers and close co-operation between the course organiser and the New Zealand geothermal industry. It is anticipated that the current worldwide slowdown in the geothermal industry is reflected in the declining number of students in the past two years mainly the self-funded and company sponsored students. It is anticipated the numbers of students will increase in 2017 mainly due to the increase in applications from self-funded students. However, measures are in place to run one of the elective courses every other year to reduce overhead if the demand continues to fluctuate in the future.

As long as most of the teaching is carried out by the course's academic staff, it will remain sustainable and viable to run despite the ever evolving energy market.

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