Queensland Geothermal Energy Centre of Excellence

ANNUAL REPORT 2012-2013

THE UNIVERSITY OF QUEENSLAND

Queensland Government
Mission

To work with equipment manufacturers, geothermal companies, geothermal power station designers and consultants to research, develop and demonstrate new technologies for the geothermal industry and to collaborate with the Queensland State Government and other stakeholders to develop and promote geothermal energy in Queensland and in Australia.

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Foreword by Chair, Advisory Board

Australia has very significant geothermal energy resources, including in Queensland, but despite this potential, there is currently no commercial geothermal energy production for power generation purposes.

The Queensland Geothermal Energy Centre of Excellence (QGECE) was established in 2009 with a grant of $15 million from the Queensland State Government to help accelerate the development of the Queensland and Australian geothermal energy industry through a managed program of strategically targeted research, development and demonstration projects in innovative technologies in close collaboration with the Queensland State Government and other key stakeholders. The global network of collaborators with the QGECE now includes geothermal companies, equipment manufacturers, renewable energy consultants, universities and national and international energy agencies.

The QGECE since its beginning in 2009 has engaged in extensive and on-going discussions with the Australian Geothermal Energy Industry and Commonwealth and State Governments to assess what needs to be done to realise Australia’s geothermal energy potential. The main challenge is the difficulty in bringing hot water to the surface in sufficient quantities to justify the large investment in the geothermal wells. The corollary is the imperative to extract the maximum possible power from that expensive brine before it is injected back into the underground reservoir. As well, all potential future geothermal power generation sites would be located inland in arid country and unless efficient air-cooled condenser technologies can be developed, they would fail to realise up to 20 per cent of their power generation capacity.

With the determination to be ready with solutions for these problems when the geothermal companies start producing power, the QGECE embarked on an ambitious research program to develop new and better methods of transforming the heat resource in geothermal brine to electricity and to do so with minimum use of fresh water.

The QGECE adopted a strategy of addressing the fundamental issues concerning power conversion and air cooled condensers rather than running after quick partial solutions. As a result of our investment over the years in developing the requisite skills and research laboratories, the QGECE is now the only team in Australia with the international reputation and the recognised capability to develop efficient and cost-effective geothermal power technologies.

This strategy has paid off in two ways. Firstly, the QGECE is now in a position to assist an Australian geothermal power developer to produce up to 50 per cent higher power compared what can be supplied by off-the-shelf products. Secondly, the QGECE solutions are applicable not only to geothermal power but to all power generation from renewable heat. This second assertion is supported by over $7.5 million funding QGECE has received in the concentrating solar thermal power generation area that assures the sustainability of the Centre until 2020.

While concentrating on power generation, the Centre did not ignore the fact that, at least for the geothermal investment sites in 2009, the generated power had to be transmitted over large distances. A project investigating the feasibility of bringing that power to the coast was completed earlier this year and a technical report was released at the time of the 2013 Queensland Geothermal Workshop.
A fundamental program examining the nature of the Queensland heat source and searching for areas of geothermal potential closer to potential customers in inland Australia was also undertaken by the QGECE. Prior to this research, it was generally believed that high-heat producing granites were the principal source of geothermal heat in Australia and all exploration was directed according to this paradigm. This research has identified local hot spots in certain areas of Queensland where the crust was thin and the contribution of the mantle heat was as significant as the heat from the hot rocks. Some of these hot spots are in areas where local communities are served by relatively expensive diesel generated electricity providing potentially quicker paths to commercialisation for the geothermal sector.

My thanks is extended to the members of the Advisory Board and the members of the Technical Advisory Committees for their support and guidance to the QGECE over the past year.

The leadership of the Centre by its Director, Professor Hal Gurgenci, has been outstanding and his research and support staff are to be congratulated on their achievements. A very pleasing feature of the Centre is its large cohort of postgraduate research students who in time will add greatly to the capacity of the geothermal industry.

We look forward to your ongoing interest and support of the QGECE in the coming year.

Emeritus Professor Trevor Grigg
Achievement Highlights

Significant advances have been achieved in all QGECE Research Programs and the following are the highlights of the year:

- The Centre took possession of the Pinjarra Hills Renewable Power Generation Laboratory (RPG Lab) and commissioned the high temperature/high pressure power cycle test loop. Using this facility, we can now design and test advanced turbines for geothermal, solar thermal, biogas and waste heat applications. This is a unique facility in Australia and one of the few university-based facilities around the world. The facility was fully designed and built by the QGECE research team. There are already a number of externally-funded projects to use the RPG Lab extending out to 2020. These are industry and Commonwealth-funded projects to design supercritical turbines for geothermal and concentrating solar thermal applications.

- The Renewable Power Generation Laboratory is also the home of the new QGECE Portable Power Plant. This demountable power plant has been developed in collaboration with our turbine research partner, Verdicorp, as a technology development and demonstration platform for low temperature (<150°C) applications. It has the capability of stand-alone operation at remote sites, generating up to 80-kWe of electricity.

- Last year the Centre commenced the refurbishment of The University of Queensland Gatton wind tunnel. The tunnel is now operational with water sprays and full temperature, flow, pressure and flow visualisation instrumentation (PDPA) at air speeds up to 10 m/s in a test section large enough (1.7m x 1.7m) to accommodate commercial heat exchanger bundles.

- The newly-refurbished Gatton wind tunnel will play a vital role in the Centre’s new project concerning solar mirror cleanliness and solar mirror cleaning mechanisms. The tunnel will be used to establish the optimum nozzle parameters and stand-off distances for cleaning of solar mirrors using pressurised sprays by carrying out tests at different wind conditions.

- The contribution of the mantle heat in addition to the radiogenic granites as the main geothermal heat sources in many Queensland areas is causing a rethink of geothermal exploration strategy in our State. As part of this research, the Centre has developed a substantive project proposal to exploit the geothermal resource in Queensland’s Galilee Basin to provide the power for the future development in this area through a supercritical CO₂ geothermal siphon.

- The QGECE Transmission Project exploring options for connecting future Cooper Basin geothermal electricity to the Queensland grid is now complete and a Technical Report was released in August during the 2013 Queensland Geothermal Workshop.
Advisory Board

The Queensland Geothermal Energy Centre of Excellence has an Advisory Board whose role is to set and monitor the strategic direction of the Centre and to monitor its performance.

Emeritus Professor Trevor Grigg
Independent Chair

Ms Karen Masnata  (since 20 July 2012)  Department of Energy and Water Supply
Replacing Ms Sue Ryan who was a member of the Advisory Board until 1 July 2012

Professor Chris Greig  The University of Queensland Energy Initiative

Professor Graham Schaffer
Faculty of Engineering, Architecture, Information Technology & Electrical Engineering
The University of Queensland

Dr Richard Suttill  (resigned in September 2013)  Origin Energy

Mr Tony Pfeiffer  (since November 2013)  EGM Asset Management
Ergon Energy

Dr Adrian Williams  Australian Geothermal Solutions

Mr Brad John  (since 19 November 2012)  Chief Government Geologist
Geological Survey of Queensland (GSQ)

Professor Halim Gurgenci  School of Mechanical & Mining Engineering
Centre Director  The University of Queensland
The Centre conducts research under four program headings: Heat Source Discovery and Characterisation; Power Conversion; Heat Exchangers; and Transmission. The following pages describe progress in these four programs over the Financial Year 2013/2013.

**Heat Source Discovery and Characterisation Program**

*Understanding Queensland Geothermal Resources and Developing New Techniques for Radiogenic Granite Exploration*

**Program leader** Dr Tonguc Uysal  
**Research team** Dr Aleks Atrens, QGECE Research Fellow  
Ms Victoria Marshall, QGECE MPhil Student  
Mr Alexander Middleton, QGECE PhD Student  
Ms Coralie Siegel, QGECE PhD Student  
Ms Ezgi Unal, QGECE PhD Student  
Associate Professor Massimo Gasparon  
Associate Professor Jason Stokes  
Professor Victor Rudolph  
Dr Scott Bryan, Vice Chancellor’s Research Fellow QUT

The QGECE research team has continued its investigation into the sources for the heat anomalies in Queensland. Our earlier research had identified the mantle as a significant contributor to the Queensland geothermal resource along with high-heat producing granites. Therefore, our research has been progressing along two avenues: (a) high heat producing granites; and (b) the heat contribution from the mantle.

Tonguc Uysal, in collaboration with Professor Uwe Ring of Stockholm University, has been investigating the role of neotectonic reactivation of ancient fault systems in permeability creation and mantle degassing in generation of geothermal resources. This work integrates comprehensive geochronology, isotope geochemistry and structural geology by investigating samples from a number of sedimentary basins in central and eastern Australia (Warburton-Cooper Basin, Galilee Basin, Millungera Basin, Eromanga Basin, Surat Basin, Drummond Basin, and Clarence-Moreton Basin). Recent He and C isotope studies of volatiles from artesian waters suggest mantle-derived fluid reservoir contribution to the geothermal resource. The field studies show that pre-existing faults were reactivated neotectonically and controlled the formation of late Quaternary carbonate vein and breccia deposits, which formed as hydro-fractures during CO₂-rich fluid overpressure, analogous to similar deposits in seismically active geothermal systems world. The preliminary results suggest that there are smaller scale, localised geothermal systems in outback Queensland/South Australia affected by Cretaceous tectonics. These are characterised by significantly high temperatures (>250°C) at 5 km depths and distinctive geophysical anomalies. Particularly, the new conceptual model for the Great Artesian basin needs to incorporate individual sub-basins with varying chemistry, flow paths and mixing dynamics and temperature conditions.
Alex Middleton has been investigating the thermal, fluid flow, and tectonic history of the Warburton-Cooper Basin System and the Big Lake Suite granites to provide an understanding on the mechanism and distribution of hydrothermal events being responsible for producing heat producing elements (HPEs) in central QLD and northern SA. To this end, mineralogical, geochemical and geochronological analyses were undertaken on core samples from the Warburton-Cooper Basin sedimentary rocks and the Big Lake Suite granite. Alex is expecting to submit his PhD thesis in early 2014 but some of his results have already been published and three more papers are in the review process. His findings explain how hydrothermal alteration processes have significant implications for exploration of hot rock geothermal resources. The geothermal heat in hot rocks is provided by heat-producing elements found in granitic rocks. These are U, K, Th. It had been known that enrichment of these elements in granitic rocks could occur from an influx of hydrothermal fluids. However, Th was commonly considered as an immobile element in hydrothermal ingressions. Alex’s work has resulted in a new understanding of the hydrothermal mobility of constituent elements, particularly Th. His results have significant implications for exploring future hot rock resources.

Vicki Marshal submitted her MSc thesis on the inheritance and development of heat-producing element enrichment in the Big Lake Suite (BLS) granite in central Australia. She carried out LA-ICP-MS 206Pb/238U dating of ~500 spots in 431 zircons across two plutons to shed new insights into petrogenesis and the relationship between emplacement age and elemental enrichment. Her results indicate that heat-producing element (HPE) enrichments vary from 144–28 ppm Th and 30–8 ppm U between plutons. New emplacement ages were obtained for drill holes Big Lake 1 (299 ± 6 Ma, MSWD 1.6, n=33) and Moomba 1 (324 ± 5 Ma, MSWD 0.71, n=42) in the southwest pluton, and Habanero 1 (315 ± 5, MSWD 1, n=38), Jolokia 1 (319 ± 13, MSWD 0.75, n=5) and McLeod 1 (306 ± 5 Ma, MSWD 1.8, n=74) in the northeast pluton. 206Pb/238U ages suggest protracted magmatism ~325–300 Ma, reinforcing the idea of piecemeal accumulation of granitic bodies. Her results also suggest emplacement-aged magma having undergone a significant degree of differentiation, thereby enriching it in HPE relative to magma compositions.

Aleks Atrens has continued his research into the use of CO₂ replacing water as the heat exchange fluid in a geothermal power plant. Specifically, he has been examining the potential for exploiting the geothermal resource in the Galilee Basin of Queensland using a supercritical CO₂ geothermal siphon. The Galilee Basin is considered prospective as a high quality geothermal resource that has not been previously seriously examined for power plant development. It has been neglected due to the perception that Australian geothermal resources are only present in areas with granites with high heat production from decay of radiogenic elements. Although the Galilee Basin does not host granites with significantly high heat production, QGECE recent research, as described earlier in this section, has shown that mantle heating also plays a critical role in Australian geothermal resource quality. The Galilee Basin is consequently recognised as containing a high potential resource due to the substantial evidence supporting non-radiogenic heating of reservoirs in the region.

The QGECE research explains how hydrothermal alteration processes play a significant role in the enrichment of high-heat producing elements in granitic rocks. This provides new tools for future exploration of hot rock resources in Queensland and Australia.

1 Middleton, et al, 2013, Chemical Geology, 335, 105-117
The availability of high-temperature high-pressure drilling fluids to access the Australian hot rock resources had been identified as a major issue by the QGECE in past dialogue with the geothermal industry professionals. Specifically, stability of drilling fluid components, and the ability of drilling fluid formulations to provide consistent and controllable rheological behaviour across the range of temperatures experienced in the well have been noted as key areas requiring fundamental research. Aleks Atrens has been investigating how the QGECE can help the industry in this area through pursuing rational design of drilling fluid mixtures.

This has included commissioning of a thermal aging reactor and two high temperature rheometers, the Grace M5600 and the Anton Paar MCR502, which are capable of analysing liquid-phase stability and flow behaviours up to 300 °C (they can contain pressures of 200 to 300 atmospheres). The Grace rheometer is an industrial oilfield design, and in conjunction with the laboratory-type Anton Paar rheometer, will allow linking of academic fluid research findings to industry practice. Initial findings have shown that industrially-used measurement geometries can be confounded in measuring true fluid properties due to interfacial slip – whereby gel strengths lower than the real value are measured. These findings were presented at the Australia-Korean Rheology Conference.
Power Conversion Program
Generating More Power from a Geothermal Reservoir

Program leader
Associate Professor Peter Jacobs

Research team
Dr Andrew Rowlands, Research Scientist
Dr Carlos Ventura, Research Scientist
Dr Rajinesh Singh, Research Scientist
Dr Paul Petrie-Repar, Research Scientist
Mr Jason Czapla, QGECE PhD student
Mr Braden Twomey, QGECE PhD student
Ms Jie Zhang, QGECE PhD student
Mr Mostafa Odabaee, QGECE PhD Student
Mr Qin Kan, QGECE PhD Student

2012/2013 saw significant advances being demonstrated in Enhanced Geothermal Systems (EGS) technology. The US company AltaRock reported multi zone stimulation success earlier in 2013. Geodynamics in Australia not only had a successful trial of its Innamincka pilot plant but it also appears that the success is repeatable with the company engineers declaring that they are now able to complete a well like Habanero-4 at a cost of $14-15m and make it produce 40 kg/s².

QGECE Research Scientists Drs Andrew Rowlands and Rajinesh Singh working with the High-Pressure Test Loop. This is a facility unique in Australia and gives the QGECE the capability to verify and expand our thermodynamic and aerodynamic models of subcritical, transcritical and supercritical power cycles and turbines at pressures as high as 20 MPa.

When these advances are combined with the power plant technologies the QGECE has been developing over the past five years, it should now be possible to generate power in Cooper Basin at levelised costs less than 20 cents/kWh. This is a cost much below the stand-alone costs of diesel generators and makes geothermal power a commercial option for remote area power generation in Australia.

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The two QGECE technologies that make higher power conversion rates possible are supercritical refrigerant cycles; and natural draft dry cooling towers. They have been developed under the two QGECE program headings of Power Conversion and Heat Exchangers.

The QGECE will continue working in the area of supercritical cycles and supercritical turbines using the new Renewable Power Generation Laboratory. This is a new laboratory built last year in Pinjarra Hills. The laboratory has experimental facilities to verify and expand our thermodynamic and aerodynamic models of supercritical power cycles and turbines. It is an oil-free system designed to operate at pressures up to 20 MPa and at temperatures up to 250°C. It will be used to test both recuperated and non-recuperated cycles using a variety of working fluids, simulate turbines of various efficiency via a dedicated controllable expansion valve and cooler, investigate control strategies for supercritical cycles such as addition/removal of mass, as well as provide a test platform for small test turbines of various styles up to 15 kW in power.

The QGECE has a suit of computer-aided design (CAD) and computational fluid dynamics (CFD) tools to develop new generation power plant equipment, including supercritical turbines and advanced condensers. This photo shows the QGECE Research Scientist Dr Paul Petrie-Repar and Mr Daniel Lay working on the CO$_2$ equation-of-state for their radial machine flow simulations.

Work on our local capability in CFD analysis has reached another milestone, with the locally developed code, Eilmer3, being used for classwork in semester 1, 2013. The OpenFOAM simulation was also used in the classwork and its use for dense-gas turbomachinery calculations has been investigated via undergraduate student projects supervised by Dr Paul Petrie-Repar (pictured above).

The past year has seen Carlos Ventura and Rajinesh Singh completing their PhDs. Carlos’ project has grown into a complete radial inflow turbine/power cycle performance optimisation software that the QGECE has registered as TOPGEN$^\text{®}$. This provides QGECE with a unique set of tools to quickly design the best cycle for any geothermal and renewable heat application. Rajinesh investigated dynamic modeling and control of supercritical power cycles, with particular emphasis on carbon dioxide as a working fluid. The “extremum seeking” control algorithm he developed will be useful in making it possible to control future supercritical renewable thermal power plants the QGECE is planning to build in future years.$^3,4$

Two students approaching completion of their PhD studies are Jason Czapla and Braden Twomey. Jason has

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built and evaluated a small impulse turbine, learning much about the design and construction of a real machine along the way. Braden has concentrated on the dynamic of a complete ORC plant (using the QGECE portable power plant mentioned below as the case study)\(^5\).

New QGECE PhD student, Mr Mostafa Odabaee, started this year his PhD project to design, build and experimentally characterise a lab-scale supercritical refrigerant turbine and a supercritical cycle optimised for geothermal fluid temperatures and ambient conditions specific to geothermal power projects in Cooper Basin. He will be able to test this turbine using the new Renewable Power Generation Laboratory.

**The QGECE Portable Power Plant**

The QGECE portable power plant has been developed in collaboration with the US manufacturer, Verdicorp, as a technology development platform. It consists of containerised modules: a control and office module; the Organic Rankine Cycle (ORC) generator module; and the air-cooled condenser module. The system takes a heat stream (from any source, e.g. waste heat, geothermal or solar) and converts it into useful electrical energy. The portable plant was commissioned this year and it will be used to test and refine turbine designs currently under development at QGECE for various organic Rankine cycle (ORC) power systems, both at our new Pinjarra Hills Renewable Power Laboratory and in the field.

In its current form, the system is an oil-free ORC that utilises a radial-inflow turbine and 1,1,1,3,3-pentafluoropropane (R245fa) as a working fluid. The system generates approximately 75 kWe from the turbine with a waste heat source temperature of 150°C flowing at approximately 8 kg/s. This produces a net output of ~45-65 kWe depending on if the system is operated in air-cooled or water-cooled mode.

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Heat Exchangers Program
Advanced Heat Exchanger Technologies and Natural Draft Dry Cooling Towers

Program leader Dr Kamel Hooman

Research team
Dr Zhiqiang Guan, Research Scientist
Dr Ingo Jahn, Lecturer
Dr Morteza Khashehchi, Research Scientist
Dr Anand Veeraragavan, Lecturer
Mr Abdullah Alkhedhair, QGECE PhD student
Mr Iman Ashtiani Abdi, QGECE PhD Student
Mr Ampon Chumpia, QGECE PhD student
Mr Pourya Foroooghi, QGECE PhD student
Mr Suoying He, QGECE PhD student
Mr Yuanshen Lu, QGECE PhD student
Mr Hosein Sadafi, QGECE PhD student
Mr Mehryar Sakhaei, QGECE PhD student
Mr Zheng Zou, QGECE PhD student

Every 1-MWe of geothermal electricity generation will produce 5-6 MW of waste heat at the condensers. If this heat is disposed by using wet cooling towers, the annual water consumption would be about 70 ML for each MW of generation capacity. In many target sites, such quantities of water are simply not available and air cooling is the only option.

Enhancing dry cooling tower performance through evaporative cooling of inlet air on the hottest days of the year will increase geothermal plant revenues substantially at relatively low water consumption levels. QGECE student Suoying He working in the QGECE advanced air-cooled condenser facility. The wind tunnel in this facility is equipped with state-of-the-art instrumentation including Position Image Velocimetry (PIV) and 3D Phase Doppler Particle Analyser (PDPA) to characterize nozzles and to track droplet trajectories at air velocities similar to those in real power plant condensers.

Air cooling works by forcing air across a heat exchanger array either using electrical fans or the buoyancy-driven updraft through a tall tower. The disadvantage of using fans is their high parasitic consumption. For example, a future geothermal power plant in Queensland outback could waste up to 15% of its output to drive its fans, more on hot days. On the other hand, natural draft tower technology is capital intensive and not a commercial alternative for geothermal power plants based on the current design alternatives, all originally developed for coal-fired power plants.

The aim of the QGECE heat exchangers program is development of advanced cooling tower designs and heat exchanger technologies to reduce parasitic losses in forced-draft cooling towers and to increase the commercial attractiveness of natural draft dry cooling tower technology for future geothermal power plants in Australia.
Key activities of this program include:

- Design small natural cooling towers for remote area power generators
- Development of solar enhanced natural draft cooling tower
- Nozzle and wet media characterisation for hybrid cooling
- Numerical/experimental studies of advanced heat exchangers

The QGECE focus on small natural draft cooling towers is important for the future development of Australian geothermal industry. Most the planned projects are in arid places and they will need air cooling. Furthermore, at least in the early years, the future geothermal plants sizes will be relatively small at sizes below 10 MWe. The existing natural draft dry cooling tower technology was developed for large fossil-fuel plants and is not suitable for relatively small renewable thermal power generators. QGECE PhD student Yuanshen Lu has been developing short cooling tower technologies in his Thesis project suitable for small and medium renewable power plants. He has demonstrated that the use of wind breaks at the tower inlet address the main challenge facing the short towers, the cross wind effects. Mr Lu demonstrated⁶ that the use of wind breaks convert the challenge into an opportunity, making the towers perform even better at high cross wind speeds.

The first-generation Australian geothermal plants are likely to be smaller than 10-MWe. The QGECE student Yuanshen Lu is developing novel cooling towers for such small power plants. On the right, Lu working with his experimental rig at the QGECE’s Gatton air-cooled condenser test facility. Below is the 3D PDPA system he uses to characterize the flow in his tests.

Another challenge with dry cooling is the reduced power plant performance at high ambient temperatures. QGECE students have been addressing this challenge. Zheng Zou introduced a novel way of using the sun to enhance dry cooling tower performance⁷, developed design guidelines for the placement of heat exchanger bundles in this concept⁸, and demonstrated that this could offer significant revenue to remote area renewable thermal power generators through increased power generation on hot days⁹.

QGECE PhD students Abdullah Alkhedhair, Suoying He, and Hosein Sadafi have been approaching the challenge of high ambient temperature from another angle. Through numerical analysis, Suoying demonstrated that the use of wet media has the potential to improve natural draft dry cooling tower performance by cooling the inlet air temperature¹⁰. Alkhedhair has been investigating another way of pre-

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cooling inlet air to the tower by using nozzle sprays\textsuperscript{11}. Hosein Sadafi is exploring the use of highly saline water in this function by examining the evaporation of salty water droplets. The QGECE’s Gatton wind tunnel is used extensively by Abdullah Alkhedhair and Suoying He for the hybrid cooling with the help of advanced flow visualisation equipment of Phase Doppler Particle Analyzer (PDPA) and Position Image Velocimetry (PIV).

In another stream of work in the Heat Exchangers program. QGECE PhD student Pourya Forooghi has been investigating the heat transfer mechanisms for supercritical fluids flowing in horizontal and inclined pipes\textsuperscript{12}. His findings are relevant across a range of applications including geothermal and concentrating solar thermal (CST).


Transmission Program

Connecting geothermal energy sources to the national electricity grid

Program leader  Professor Tapan Saha

Research team  Dr Mehdi Eghbal, Research Fellow  Mr Kazi Nazmul Hasan, QGECE PhD student  Ms Huong Mai Nguyen, QGECE PhD student

The aim of the transmission research program is to investigate the technical aspects of connecting remote geothermal power plants to the high voltage transmission network of the Australian National Grid. Two PhD projects focussed respectively on stability and reliability issues of long transmission lines connecting remote geothermal plants to the national grid using both HVAC and HVDC technologies. Several scenarios representing possible output ranges for prospective geothermal power plants are defined. Then, comprehensive power system analyses are conducted to determine the most efficient transmission option for each scenario taking into account the optimum voltage level, stability and reliability standards.

Both PhD students have completed their studies. QGECE PhD student Kazi Hasan reviewed the technical options for long-distance transmission of renewable power and examined the possible mechanisms to enhance regulatory policies and associated planning frameworks to be more efficient and justifiable for renewable power integration paradigm.13

A QGECE technical report specifically investigating the technical options for connecting a large power generator in the Cooper basin to the Queensland grid was released at the 2013 Queensland Geothermal Workshop and can be accessed at the QGECE web site.14 The best option to bring Cooper Basin generation to the Queensland grid depends on the future ramp-up scenarios for Cooper Basin generation capacity. But, based on the experience in overseas examples, the unit cost per transmitted kilowatt is not significant provided the transmission line is used to transmit large amounts of power.

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Industry Engagement

The Centre is engaged with the industry through the following mechanisms:

- Stakeholders Workshops
- Technical Advisory Committees
- Australian Geothermal Energy Group
- Australian Geothermal Energy Association

QGECE Stakeholders Workshop, August 2013

On 1 August 2013, the Queensland Geothermal Energy Centre of Excellence held its fifth Stakeholders Workshop. The workshop was not only an occasion for the QGECE to report to its stakeholders on the progress in its research programs but also an opportunity for the leaders of the Australian geothermal sector to get together and discuss the current development status in current projects, and future prospects in Queensland and elsewhere.

The Workshop was well-attended as in the previous years. About 50% of 72 registrations were from geothermal and service industries; 40% from researchers and academia; and 10% from Queensland and Commonwealth Governments. The following is a list of presentations to the Workshop:

- Hal Gurgenci, QGECE, The Future of Geothermal Energy and QGECE
- Aleks Atrens, QGECE, Progress towards a Supercritical CO2 Geothermal Power Plant in Galilee Basin
- Tapan Saha, QGECE, Integrating Large Scale Geothermal Power into Queensland’s Network
- Geoff Ward, Geodynamics, Habanero Project Update - 1 MW Pilot Plant Trial
- Terry Kallis, Paralana Geothermal Energy Project Summary Information
- Cameron Huddlestone-Holmes, CSIRO, Technology and Commercial Readiness Levels

All presentations were posted on the QGECE web site and can be accessed from the following link: [http://www.geothermal.uq.edu.au/workshop2013report](http://www.geothermal.uq.edu.au/workshop2013report)

The feedback from the delegates to the QGECE Research Reports was positive. High expectations were expressed and the industry was almost unanimously enthusiastic about the Centre. In particular, there was a great deal of interest in the Galilee Basin Supercritical CO2 Project. This area was seen by the Workshop participants as one that could deliver a quantum increment in the commercial viability of geothermal power generation in Australia. There was also discussion about the new Drilling Fluids project and the QGECE was advised to keep a sharp focus and build upon its existing UQ strengths.
**Australian Geothermal Energy Group (AGEG)**

The Australian Geothermal Energy Group (AGEG) is a national association of individuals and companies with interest in geothermal energy. In 2009, AGEG incorporated and subsequently became an affiliate organisation with the International Geothermal Association. QGECE is an active member of the AGEG. The QGECE Director is a member of the AGEG Executive Committee, chairs the AGEG Technical Interest Group on Power Conversion (TIG 6), and has been serving as the Chair or Co-chair for the past three Australian Geothermal Energy Conferences.

**Australian Geothermal Energy Association (AGEA)**

The Australian Geothermal Energy Association (AGEA) is the national industry association for the Australian Geothermal Energy Industry. Since its establishment in 2007, AGEA has focused on building positive relationships with the Federal and State Governments and sought to ensure that geothermal energy is promoted as an important and viable solution to Australia’s future energy security and to the reduction in greenhouse gas emissions.

Australia’s leading geothermal energy companies and service providers are members of the AGEA. The Queensland Geothermal Energy Centre of Excellence is an Associate Member of the AGEA. The QGECE Advisory Board member, Dr Adrian Williams, and the QGECE Director, Professor Hal Gurgenci, were elected to the AGEA Executive Board in November 2012.

**QGECE Technical Advisory Committees (TAC)**

Technical Advisory Committees (TAC) have been established in broad program areas. The role of a TAC is to provide advice to the Director about the conduct of the Centre in a particular research area or a research project. The members of the TAC are persons with relevant expertise nominated by the Director and approved by the Board. The TAC's meetings are minuted and these Minutes are presented to the QGECE Board.

<table>
<thead>
<tr>
<th>Committee Area</th>
<th>Membership</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Source Discovery and</td>
<td>Richard Suttill, Origin Energy (to August 2013)</td>
</tr>
<tr>
<td>Characterisation</td>
<td>Behnam Talebi, Queensland Geological Surveys</td>
</tr>
<tr>
<td></td>
<td>Doone Wyborn, Geodynamics Limited</td>
</tr>
<tr>
<td></td>
<td>David Champion, Geoscience Australia</td>
</tr>
<tr>
<td></td>
<td>Graeme Beardsmore, Hot Dry Rocks Pty Ltd</td>
</tr>
<tr>
<td></td>
<td>Scott Bryan, QUT</td>
</tr>
<tr>
<td></td>
<td>Tonguc Uysal, QGECE</td>
</tr>
<tr>
<td></td>
<td>Massimo Gasparon, QGECE</td>
</tr>
<tr>
<td></td>
<td>Sue Golding, QGECE</td>
</tr>
<tr>
<td></td>
<td>Kurt Knesel, QGECE</td>
</tr>
<tr>
<td>Power Conversion</td>
<td>Allan Curtis, Principal Engineer - Thermal Generation, Parsons Brinckerhoff</td>
</tr>
<tr>
<td></td>
<td>Stephen Hinchliffe, Sinclair Knight Merz</td>
</tr>
<tr>
<td></td>
<td>Tony Roe, Geodynamics Limited</td>
</tr>
<tr>
<td></td>
<td>Sam Button, Origin Energy</td>
</tr>
<tr>
<td></td>
<td>Peter Jacobs, QGECE</td>
</tr>
<tr>
<td></td>
<td>Kamel Hooman, QGECE</td>
</tr>
<tr>
<td></td>
<td>Zhiqiang Guan, QGECE</td>
</tr>
<tr>
<td></td>
<td>Andrew Rowlands, QGECE</td>
</tr>
<tr>
<td>Transmission</td>
<td>Terry Miller, Manager Network Development, Powerlink Queensland</td>
</tr>
<tr>
<td></td>
<td>Luke Falla, Senior Engineer, Australian Energy Market Operator Ltd</td>
</tr>
<tr>
<td></td>
<td>Tapan Saha, QGECE</td>
</tr>
<tr>
<td></td>
<td>Mehdi Eghbal, QGECE</td>
</tr>
</tbody>
</table>

Technical Advisory Committees of the QGECE
Education

The Centre is actively involved in providing a geothermal energy education option for undergraduate and postgraduate students at The University of Queensland.

**Undergraduate & coursework programs**

- **Thesis Projects** – Engineering students take a project course in their final year at The University of Queensland. Over ten such thesis projects were supervised last year by Centre staff.
- **Earth sciences coursework** – one student undertaking a graduate diploma in mineral resources was supervised and supported by the Centre in research activities.
- **Visiting lectures** – The Centre staff is invited to energy-related undergraduate courses to deliver lectures on geothermal energy.

The above activities help the university graduate engineers and scientists with exposure to the geothermal energy sector and understanding of the issues involved in geothermal energy utilisation.

**QGEC weekly seminar program**

The QGEC holds weekly public seminars to keep all research staff informed about what is happening across the Centre, and to provide an opportunity for students and staff from outside the centre, as well as visitors, to hear about current research.

<table>
<thead>
<tr>
<th>Date</th>
<th>Seminar</th>
</tr>
</thead>
<tbody>
<tr>
<td>17-Jul-12</td>
<td>Abdullah Alkhedhair - Characterisation and Placement of Nozzles for Pre-Cooling Inlet Air in Dry Cooling Towers (Confirmation Review Seminar)</td>
</tr>
<tr>
<td>24-Jul-12</td>
<td>Ingo Jahn - Update from the ASME Turbo Expo Conference in Copenhagen</td>
</tr>
<tr>
<td>31-Jul-12</td>
<td>Anand Veeraragavan - Solar thermal power conversion using nanofluids</td>
</tr>
<tr>
<td>07-Aug-12</td>
<td>Ampon Chumpia - Performance test of metal foam heat exchangers – Results of single tubes</td>
</tr>
<tr>
<td>14-Aug-12</td>
<td>Kamel Hooman - Cooling Towers, Foam-wrapped Heat Exchangers, and Dust</td>
</tr>
<tr>
<td>28-Aug-12</td>
<td>Suoying He - Wet media for Inlet Air Cooling in Dry Cooling Towers (Confirmation Seminar)</td>
</tr>
<tr>
<td>11-Sept-12</td>
<td>Alex Middleton - Integrated geochronology from the Warburton-Cooper Basin: Deciphering a thermal history</td>
</tr>
<tr>
<td>18-Sept-12</td>
<td>Hugh Russell - The use of shallow aquifers to assist dry cooling of condensers in geothermal power plants</td>
</tr>
</tbody>
</table>
## Education

### Table 2: QGECE weekly seminars (continued)

<table>
<thead>
<tr>
<th>Date</th>
<th>Seminar</th>
</tr>
</thead>
<tbody>
<tr>
<td>25-Sept-12</td>
<td>Kazi Hasan - Progress on Study of Large Scale Remote Renewable Power Integration into the Australian Grid</td>
</tr>
<tr>
<td>02-Oct-12</td>
<td>Jason Czapla - Impulse Turbine Update</td>
</tr>
<tr>
<td>09-Oct-12</td>
<td>Yuanshen Lu - CFD simulations on small natural draft dry cooling towers</td>
</tr>
<tr>
<td>16-Oct-12</td>
<td>Iman Ashtiani - PIV Analysis of the Wake behind a Single Tube and a one Row Tube Bundle: Foamed and Finned Tubes</td>
</tr>
<tr>
<td>30-Oct-12</td>
<td>Pourya Forooghi - Numerical modeling of SC heat transfer</td>
</tr>
<tr>
<td>19-Mar-13</td>
<td>H Gurgenci - New Directions for QGECE</td>
</tr>
<tr>
<td>09-Apr-13</td>
<td>Aleks Atrens - Rheology of drilling fluids at High Pressures and High Temperatures for EGS</td>
</tr>
<tr>
<td>16-Apr-13</td>
<td>Ezgi Unal - CO2-degassing, seismicity and climate change</td>
</tr>
<tr>
<td>23-Apr-13</td>
<td>Braden Twomey - Dynamic modelling of the QGECE Portable Plant</td>
</tr>
<tr>
<td>30-April-13</td>
<td>Coralie Siegel – Re-evaluating the geothermal potential in SW Queensland, a thermal modelling approach</td>
</tr>
<tr>
<td>07-May-13</td>
<td>Professor Andrew Garnett - Coal Seam Gas Issues and the University of Queensland</td>
</tr>
<tr>
<td>14-May-13</td>
<td>Zheng Zou - Solar Enhanced Natural Draft Dry Cooling Tower Design Optimisation</td>
</tr>
<tr>
<td>28-May-13</td>
<td>Iman Ashtiani Abdi - Separated flow structures, near the wake of a bare, a fin- and a foam-covered circular cylinders</td>
</tr>
<tr>
<td>04-Jun-13</td>
<td>Ampon Chumpia - Thermo-hydraulic Performance of Aluminium Foam Heat Exchanger Arrays</td>
</tr>
</tbody>
</table>

### Postgraduate research students

The main involvement of the Centre in the education area is postgraduate research training. The current list of QGECE PhD students are given in Education Table 3. The Centre's 25 postgraduate research students are a diverse group, comprised of 14 different nationalities. Postgraduate student research is mostly funded externally, typically through competitive scholarships: total postgraduate scholarship funding is 60 per cent external with the QGECE covering the remainder.
**Education**

<table>
<thead>
<tr>
<th>Student</th>
<th>Topic</th>
<th>Commenced</th>
<th>Next Milestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>A M Alkhedhair</td>
<td>Characterisation and placement of nozzles for pre-cooling inlet air in dry cooling towers</td>
<td>Apr-11</td>
<td>Mid-way review</td>
</tr>
<tr>
<td>I Ashtiani Abdi</td>
<td>Wake visualisation behind a rough cylinder in cross-flow</td>
<td>May-12</td>
<td>Confirmation</td>
</tr>
<tr>
<td>A D Atrens</td>
<td>Carbon-dioxide based engineered geothermal systems</td>
<td>Mar-08</td>
<td>Completed</td>
</tr>
<tr>
<td>A Chumpia</td>
<td>Improving the performance of air-cooled condensers by using metal foam</td>
<td>Mar-10</td>
<td>Thesis Review</td>
</tr>
<tr>
<td>J Czapla</td>
<td>An investigation of impulse turbines for geothermal power generation</td>
<td>Nov-09</td>
<td>Thesis review</td>
</tr>
<tr>
<td>P Forooghi</td>
<td>Supercritical fluid flows through plate-frame heat exchangers</td>
<td>Aug-10</td>
<td>Thesis review</td>
</tr>
<tr>
<td>K N Hasan</td>
<td>Reliability and cost benefit assessment of transmission options for connecting large-scale power generators from Cooper's Basin to the Australian national electricity grid</td>
<td>Mar-10</td>
<td>Thesis review</td>
</tr>
<tr>
<td>S He</td>
<td>Wetted-medium evaporative pre-cooling for natural draft dry cooling tower performance enhancement</td>
<td>Aug-11</td>
<td>Mid-way review</td>
</tr>
<tr>
<td>Y Lu</td>
<td>The development of small-size natural draft dry cooling tower for geothermal power plants</td>
<td>Oct-10</td>
<td>Mid-way review</td>
</tr>
<tr>
<td>V Marshall</td>
<td>Petrological, geochemical and geochronological characterisation of heat-producing granites</td>
<td>Jan-10</td>
<td>Thesis review</td>
</tr>
<tr>
<td>A Middleton</td>
<td>The geochemistry and timing of fluid flow events as fingerprints in determining geothermal heat anomalies and their sources, Queensland</td>
<td>Jan-10</td>
<td>Thesis review</td>
</tr>
<tr>
<td>H M Nguyen</td>
<td>Power systems stability issues due to long distance transmission</td>
<td>Mar-09</td>
<td>Thesis review</td>
</tr>
<tr>
<td>M Odabaee</td>
<td>Modelling metal foam heat exchangers</td>
<td>May-09</td>
<td>Completed</td>
</tr>
<tr>
<td>H Russell</td>
<td>Groundwater condenser cooling for geothermal power plants in central Australia</td>
<td>Jan-2011</td>
<td>Thesis review</td>
</tr>
<tr>
<td>M Sakhaei</td>
<td>Inclined arrangements of heat exchanger bundles</td>
<td>Mar-10</td>
<td>Thesis review</td>
</tr>
<tr>
<td>C Siegel</td>
<td>Evaluating the potential of granitic rocks in Queensland for hot-dry-rock geothermal resources</td>
<td>Nov-10</td>
<td>Thesis review</td>
</tr>
<tr>
<td>R Singh</td>
<td>Dynamics and control of a closed carbon-dioxide Brayton cycle</td>
<td>May-09</td>
<td>Thesis review</td>
</tr>
<tr>
<td>B Twomey</td>
<td>Development of a mobile 100kW geothermal power system</td>
<td>Apr-10</td>
<td>Thesis review</td>
</tr>
<tr>
<td>E Unal</td>
<td>U-series dating of carbonates along tectonically active zones of Turkey in a relationship between CO₂ degassing, volcanic/paleo-seismic, and climatic events</td>
<td>Aug-11</td>
<td>Mid-way review</td>
</tr>
<tr>
<td>Student</td>
<td>Topic</td>
<td>Commenced</td>
<td>Next Milestone</td>
</tr>
<tr>
<td>---------</td>
<td>----------------------------------------------------------------------</td>
<td>-----------</td>
<td>----------------------</td>
</tr>
<tr>
<td>J Zhang</td>
<td>Mixed-fluid organic Rankine Cycles for low-temperature power conversion</td>
<td>Mar-11</td>
<td>Mid-way review</td>
</tr>
<tr>
<td>Z Zou</td>
<td>Development and optimisation of solar enhanced natural draft dry cooling water</td>
<td>Mar-10</td>
<td>Thesis review</td>
</tr>
</tbody>
</table>
**Key Performance Indicators**

The following table summarises the Centre performance against the Key Performance Indicators established in the Centre Agreement.

<table>
<thead>
<tr>
<th>KPI</th>
<th>Target over five years</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of postgraduate research students</td>
<td>12</td>
<td>19</td>
</tr>
<tr>
<td>Postgraduate Student Completions</td>
<td>n/a</td>
<td>5</td>
</tr>
<tr>
<td>Number of competitive research grants</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Number of projects with industry funding</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Number of refereed publications (from inception)</td>
<td>40</td>
<td>78</td>
</tr>
<tr>
<td>Number of research projects undertaken in Queensland</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

**List of Competitive Grants**

2. $204,000 for V Rudolph and K Hooman. Metal foam heat exchangers for dry cooling. ANLEC R&D Research Grant.
4. $202,000 for K Hooman, A novel air-cooled fuel cell system, ARC DP Grant.
5. Australian Solar Thermal Research Initiative, P Meredith and H Gurgenci, Australian Solar Institute, $6m over eight years ([http://www.uq.edu.au/news/?article=25674](http://www.uq.edu.au/news/?article=25674)).
6. $293,442 for Stokes, Rudolph, Gurgenci, Steel, Atrens, Bansal and Bhandari. Large Equipment Infrastructure Funding (LEIF) Grant for a High Pressure/High Temperature Rheometer.

**Projects with Industry Participation**

1. Birdsville Geothermal Plant Expansion, H Gurgenci providing advice to Ergon Energy on geothermal plant technology.
2. Supercritical turbine and cycle development with Verdicorp.
3. Australian Solar Thermal Research Initiative, P Meredith and H Gurgenci, Australian Solar Institute, $6m over eight years ([http://www.uq.edu.au/news/?article=25674](http://www.uq.edu.au/news/?article=25674)).
4. Collinsville Power Station conversion feasibility study, $2.5m total, $500k for UQ with about $100k for H Gurgenci, ARENA, ([http://www.uq.edu.au/news/?article=25868](http://www.uq.edu.au/news/?article=25868)).
Number of research projects undertaken in Queensland
1. Birdsville Geothermal Plant Expansion, H Gurgenci providing advice to Ergon Energy on geothermal plant technology.
2. Supercritical turbine development with Verdicorp and the Portable Power Generator
3. Advanced Renewable Power Generation and the construction of the Pinjarra Hills Laboratory
4. Characterisation of High Heat Producing granites in Queensland
5. Using alteration minerals and water to discover and characterise Queensland Geothermal Resource
7. Exploring Options for Connecting Cooper Basin Geothermal Power to Queensland Power Grid
8. Collinsville Power Station conversion feasibility study, $2.5m total, $500k for UQ with about $100k for H Gurgenci, ARENA, (http://www.uq.edu.au/news/?article=25868)
Key Performance Indicators

Financial Summary

The cash balance for the Centre at 30 June 2013 was $2,072,405.40. The details of income and expenditure are presented on the following two pages as the Financial Statement prepared by the Contract & Grants Accounting Section of The University of Queensland.

The University of Queensland in-kind contribution to 30 June 2013 has been $6,994,942. This is based on the overheads for the QGECE-funded research staff, the overheads for the QGECE postgraduate students, and the salary and overheads for the other University of Queensland staff contributing to the QGECE projects but not receiving salary compensation.

The calculation for the in-kind contribution is uses the following formula:

$$UQ_{\text{inkind}} = QGECE_{\text{paid staff}} + UQ_{\text{paid staff}} + PhD_{\text{students}}$$

That shows that the UQ in-kind contribution has three components:

<table>
<thead>
<tr>
<th>Item</th>
<th>Method (as approved by the Board on 13/3/2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QGECE-paid staff: overheads only</td>
<td>QGECE Staff Salary Total / 1.26 x 1.5</td>
</tr>
<tr>
<td>UQ-paid staff: salary and overheads</td>
<td>UQ-paid Staff Salary x QGECE-fraction /1.26 x 3</td>
</tr>
<tr>
<td>PhD Student Overheads only</td>
<td>$10,000/student per year x No of students</td>
</tr>
</tbody>
</table>
Publications

Refereed Journal Publications

35 refereed journal publications from Centre staff in 2012 and 2013 (113 since the Centre’s inception) promote the standing of the Centre in the international scientific and engineering community.


Publications


Publications


Conference Presentations

17 Conference presentations in 2012 and 2013 (106 since the Centre's inception) show that the Centre staff are engaged with the international scientific and engineering community at the highest levels.


Chumpia, A. & Hooman, K. (2012). Quantification of contact resistance of metal foam heat exchangers for improved, air-cooled condensers in geothermal power application. In P. A. Brandner, B. W. Pearce (Eds.), 18th Australasian Fluid Mechanics Conference. 18th Australasian Fluid Mechanics Conference, Launceston, Australia. 3-7 December 2012.


Publications


Book Chapter

QGECE Grant Financial Statements
11 February 2010

Deputy Director-General
Stuart Booker
Department of Mines and Energy
Technology, Exploration & Industry Development
Floor 17, 61 Mary Street
BRISBANE QLD 4000

Dear Mr Booker

Re: Annual Financial Statement for the period ended 31 December 2009

Enclosed is the annual financial statement for the following project:

Project Title: Queensland Geothermal Energy Centre of Excellence

Chief Investigator: Gurgenci, Halim
UQ Reference: 007070, 007003, 007004, 007070, 007006, 007007, 007008, 007065
Your Reference: QLD DME

The statement covers the period 01 July 2008 to 31 December 2009.

Please contact Chanchala Adhikary as referenced above if you have any queries regarding this letter.

Yours sincerely,

Ivy Lee
Senior Accountant
Contract & Grants Accounting Section

Enc
Financial Statement for the period ending 31 December 2009

Grantor: Department of Mines and Energy
Project Title: Queensland Geothermal Energy Centre of Excellence
Project Duration: 01 Jul 2008 to 31 Dec 2015
UQ Reference: 007070, 007003, 007004, 007070, 007008, 007007, 007008, 007005
Grantor Reference: QLD DME
Chief Investigator: Gurgenci, Hallim

Cash balance as at 01 July 2008: Nil

<table>
<thead>
<tr>
<th>INCOME:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>12 Jan 2009 - Invoice # 05705795</td>
<td>1,500,000.00</td>
</tr>
<tr>
<td>06 Feb 2009 - Invoice # 3190000002</td>
<td>1,500,000.00</td>
</tr>
<tr>
<td>Total Income Received</td>
<td>$3,000,000.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXPENDITURE:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries &amp; On Costs - Academic</td>
<td>375,831.50</td>
</tr>
<tr>
<td>Salaries &amp; On Costs - General</td>
<td>106,167.20</td>
</tr>
<tr>
<td>Salary Reimbursements</td>
<td>10,295.10</td>
</tr>
<tr>
<td>Staff App Develop &amp; Health Cat</td>
<td>3,206.04</td>
</tr>
<tr>
<td>Consumables</td>
<td>63,523.17</td>
</tr>
<tr>
<td>Services</td>
<td>113,715.16</td>
</tr>
<tr>
<td>Marketing &amp; Advertising</td>
<td>135.00</td>
</tr>
<tr>
<td>Equipment</td>
<td>258,732.55</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>1,940.51</td>
</tr>
<tr>
<td>Travel &amp; Hospitality</td>
<td>54,688.20</td>
</tr>
<tr>
<td>Scholarships &amp; Prizes</td>
<td>75,744.85</td>
</tr>
<tr>
<td>Financial Costs &amp; Taxes</td>
<td>433.85</td>
</tr>
<tr>
<td>Internal Expenses</td>
<td>8,175.40</td>
</tr>
<tr>
<td>Total Expenditure</td>
<td>$1,072,650.03</td>
</tr>
</tbody>
</table>

Cash balance as at 31 December 2009: $1,927,449.37

I certify that the income and expenditure shown in this financial statement have been recorded and reported in accordance with The University of Queensland financial practices and that this project account is included in the University’s grant accounts that are reviewed as part of a risk based audit conducted by the Queensland Audit Office under the supervision of the Auditor-General.

Ivy Lee
Senior Accountant
Contract & Grants Accounting Section

11 February 2010
3 August 2011

Deputy Director-General
Stuart Booker
Dept Environment & Resource Mgt (NRW)
Technology, Exploration & Industry Development
Floor 17, 61 Mary Street
BRISBANE QLD 4000

Dear Sir/Madam

Re: Annual Financial Statement for the period ended 30 June 2011

Enclosed is the annual financial statement for the following project:

Project Title: Queensland Geothermal Energy Centre of Excellence

Chief Investigator: Gurgenci,Halim
UQ Reference: 008296, 007070, 007003, 007004, 007005, 007006, 007007, 007008
Your Reference: QLD DME

The statement covers the period 01 January 2010 to 30 June 2011.

Please contact Heather Despasquale as referenced above if you have any queries regarding this letter.

Yours faithfully,

Megan Baker
Senior Accountant
Contract & Grants Accounting Section
Enc
Financial Statement for the period ending 30 June 2011

Grantor: Dept Environment & Resource Mgt (NRW)

Project Title: Queensland Geothermal Energy Centre of Excellence

Project Duration: 01 Jul 2008 to 31 Dec 2015
UQ Reference: 008296, 007070, 007003, 007004, 007005, 007006, 007007, 007008

Grantor Reference: QLD DME
Chief Investigator: Gurgenci, Halim

$ 

Cash balance as at 01 January 2010 1,927,449.37

INCOME:

14 Jan 20'0 - Invoice # 3190001716 2,000,000.00
21 Jun 20'0 - Invoice # 319003140 2,000,000.00
11 Oct 2010 - Invoice # 3190004682 1,750,000.00
16 Feb 2011 - Invoice # 3190005855 1,750,000.00

Total Income Received 7,500,000.00

Funds Available 9,427,449.37

EXPENDITURE:

Salaries - Academic 1,281,137.75
Salaries - Academic Casual 2,449.75
Salaries - General 120,645.35
Salaries - General Casual 103,853.49
Salary Reimbursements 0.00
Staff App Develop & Health Cst 5,590.83
Consumables 182,556.74
Services 209,943.59
Marketing & Advertising 525.09
Equipment 810,067.74
Telecommunications 440.04
Travel & Hospitality 188,804.04
Scholarships & Prizes 362,096.49
Collaborative Projects 2,740.00
Financial Costs & Taxes 10,911.91
Internal Expenses 15,347.00
Depn Amortisation & Impairment 0.00

Total Expenditure 3,296,309.81

Cash balance as at 30 June 2011 6,130,539.55

I certify that the income and expenditure shown in this financial statement have been recorded and reported in accordance with The University of Queensland financial practices and that this project account is included in the University's grant accounts that are reviewed as part of a risk based audit conducted by the Queensland Audit Office under the supervision of the Auditor-General.

Megan Baker
Senior Accountant
Contract & Grants Accounting Section

3 August 2011
18 October 2012

Deputy Director-General
Stuart Booker
Dept Environment & Resource Mgt (NRW)
Technology, Exploration & Industry Development
Floor 17, 61 Mary Street
BRISBANE QLD 4000

Dear Sir/Madam

Re: Annual Financial Statement for the period ended 30 June 2012

Enclosed is the annual financial statement for the following project:

Project Title: Queensland Geothermal Energy Centre of Excellence

Chief Investigator: Surgenci, Halim
UQ Reference: 007008, 007007, 007004, 007005, 007006, 007070, 007003, 008296
Your Reference: QLD DME

The statement covers the period 01 July 2011 to 30 June 2012.

Please accept my apologies for any inconvenience the delay in sending the financial statement may have caused. For further queries, please do not hesitate to contact Saurang Lonagata as referenced above.

Yours faithfully,

[Signature]

Ivy Lee
Senior Accountant
Contract & Grants Accounting Section
Enc
Financial Statement for the period ending 30 June 2012

Grantor: Dept Environment & Resource Mgt (NRW)

Project Title: Queensland Geothermal Energy Centre of Excellence

Project Duration: 01 Jul 2008 to 31 Dec 2015
UQ Reference: 007008,007007,007004,007005,007006,007070,007003,008296
Grantor Reference: QLD DME
Chief Investigator: Gurgenci, Halim

$  

Cash balance as at 01 July 2011 6,130,539.58

INCOME:

Total Income Received $0.00

Funds Available 6,130,539.56

EXPENDITURE:

Salaries - Academic 822,992.64
Salaries - General 69,442.47
Salaries - General Casual 36,051.29
Salary Reimbursements 228,189.04
Staff App Develop & Health Cst 4,996.04
Consumables 166,508.94
Services 335,236.75
Marketing & Advertising 345.00
Equipment 1,597,095.82
Telecommunications 589.97
Travel & Hospitality 221,140.74
Properties & Insurances 33.90
Scholarships & Prizes 270,766.31
Collaborative Projects 20,000.00
Financial Costs & Taxes 1,147.39
Total Expenditure 3,775,138.30

Cash balance as at 30 June 2012 $2,355,401.26

I certify that the income and expenditure shown in this financial statement have been recorded and reported in accordance with The University of Queensland financial practices and that this project account is included in the University's grant accounts that are reviewed as part of a risk based audit conducted by the Queensland Audit Office under the supervision of the Auditor-General.

[Signature]

Ivy Lee
Senior Accountant
Contract & Grants Accounting Section

18 October 2012
18 July 2013

Deputy Director-General
Stuart Booker
Dept Environment & Resource Mgt (NRW)
Technology, Exploration & Industry Development
Floor 17, 61 Mary Street
BRISBANE QLD 4000

Dear Sir/Madam

Re: Annual Financial Statement for the period ended 30 June 2013

Enclosed is the annual financial statement for the following project:

Project Title: Queensland Geothermal Energy Centre of Excellence

Chief Investigator: Gurgenci, Helim
UQ Reference: 008296,007070,007008,007007,007006,007005,007004,007003
Your Reference: QLD DME

The statement covers the period 01 July 2012 to 30 June 2013.

Please contact Amaranath Jayakody as referenced above if you have any queries regarding this letter.

Yours faithfully,

Megan Baker, CPA
Senior Accountant
Contract & Grants Accounting Section

Enc
Financial Statement for the period ending 30 June 2013

Grantor: Dept Environment & Resource Mgt (NRW)
Project Title: Queensland Geothermal Energy Centre of Excellence
Project Duration: 01 Jul 2008 to 31 Dec 2015
UQ Reference: 008296,007070,007009,007007,007006,007005,007004,007003
Grantor Reference: QLD DME
Chief Investigator: Gurgenci, Halim

$  

Cash balance as at 01 July 2012 2,355,401.26

INCOME:

Total Income Received $0.00

Funds Available 2,355,401.26

EXPENDITURE:

Salaries - Academic 534,463.63
Salaries - General 161,531.32
Salaries - General Casual 21,688.47
Salary Reimbursements 157,226.00
Staff App Develop & Health Cst (12,699.40)
Consumables 15,008.37
Services (121,940.95)
Marketing & Advertising (55.00)
Equipment (794,483.60)
Telecommunications (1,063.82)
Travel & Hospitality 119,565.70
Properties & Insurances 4,462.84
Scholarships & Prizes 198,867.31
Collaborative Projects 0.00
Financial Costs & Taxes 464.99
Total Expenditure $282,955.86

Cash balance as at 30 June 2013 $2,072,405.40

I certify that the income and expenditure shown in this financial statement have been recorded and reported in accordance with The University of Queensland financial practices and that this project account is included in the University's grant accounts that are reviewed as part of a risk based audit conducted by the Queensland Audit

Megan Baker, CPA
Senior Accountant
Contract & Grants Accounting Section

18 July 2013
Loan Account Financial Statement
19 September 2012

Stuart Bucker
Deputy Director - General
Dept Environment & Resource Mgt (NRW)
Technology, Exploration & Industry Development
Floor 17, 61 Mary Street
BRISBANE QLD 4000

Dear Sir/Madam

Re: Final Financial Statement for the period ended 30 September 2012

Enclosed is the final financial statement for the following project:

Project Title: Queensland Geothermal Energy Centre of Excellence

Chief Investigator: Gurgenci, Halim
UQ Reference: 007070
Your Reference: QLD DME

The statement covers the period 01 July 2008 to 30 September 2012.

Please contact Saurang Lonagata as referenced above if you have any queries regarding this letter and thank you for your continued support of research at The University of Queensland.

Yours faithfully,

Ivy Lee
Senior Accountant
Contract & Grants Accounting Section

Enc
## Financial Statement for the period ending 30 September 2012

**Grantor:** Dept Environment & Resource Mgt (NRW)  
**Project Title:** Queensland Geothermal Energy Centre of Excellence  
**Project Duration:** 01 Jul 2008 to 30 Dec 2015  
**UQ Reference:** 007070  
**Grantor Reference:** QLD DME  
**Chief Investigator:** Gurgenci, Halim

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### Cash balance as at 01 July 2008

<table>
<thead>
<tr>
<th>Date</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00</td>
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</tbody>
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### INCOME:

<table>
<thead>
<tr>
<th>Date</th>
<th>Invoice #</th>
<th>Amount</th>
</tr>
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<tbody>
<tr>
<td>12 Jan 2009</td>
<td>05785795</td>
<td>1,500,000.00</td>
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<td>36 Feb 2009</td>
<td>3190000002</td>
<td>1,500,000.00</td>
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<tr>
<td><strong>Total Income Received</strong></td>
<td></td>
<td><strong>$3,000,000.00</strong></td>
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</tbody>
</table>

### Funds Available

<table>
<thead>
<tr>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,000,000.00</td>
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</table>

### EXPENDITURE:

<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salaries - Academic</td>
<td>35,288.58</td>
</tr>
<tr>
<td>Salaries - General</td>
<td>4,363.57</td>
</tr>
<tr>
<td>Salaries - General Casual</td>
<td>17,083.01</td>
</tr>
<tr>
<td>Staff App Develop &amp; Health Cst</td>
<td>17,088.34</td>
</tr>
<tr>
<td>Consumables</td>
<td>278,218.76</td>
</tr>
<tr>
<td>Services</td>
<td>370,118.26</td>
</tr>
<tr>
<td>Marketing &amp; Advertising</td>
<td>95.00</td>
</tr>
<tr>
<td>Equipment</td>
<td>2,230,366.06</td>
</tr>
<tr>
<td>Telecommunications</td>
<td>1,884.80</td>
</tr>
<tr>
<td>Travel &amp; Hospitality</td>
<td>29,753.64</td>
</tr>
<tr>
<td>Properties &amp; Insurances</td>
<td>0.38</td>
</tr>
<tr>
<td>Scholarships &amp; Prizes</td>
<td>14,444.06</td>
</tr>
<tr>
<td>Financial Costs &amp; Taxes</td>
<td>1,295.54</td>
</tr>
<tr>
<td><strong>Total Expenditure</strong></td>
<td><strong>$3,000,000.00</strong></td>
</tr>
</tbody>
</table>

### Cash balance as at 30 September 2012

<table>
<thead>
<tr>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
</tr>
</tbody>
</table>

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I certify that the income and expenditure shown in this financial statement have been recorded and reported in accordance with The University of Queensland financial practices and that this project account is included in the University’s grant accounts that are reviewed as part of a risk based audit conducted by the Queensland Audit Office under the supervision of the Auditor-General.

Ivy Lee  
Senior Accountant  
Contract & Grants Accounting Section  
19 September 2012
Photos from the front cover (clockwise from the top):
Successful steam flow at Geodynamics' Habanero 4 during clean-up operations. (Courtesy of Geodynamics Limited)
In the lab, from the left R Singh and A Rowlands.
The new advanced air-cooled condenser test facility at Gatton.
From the left: S He, J Czapla, C Siegel, C Ventura, I Jahn, E Unal, Y Lu, P Forooghi