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AUSTRALIAN GEOTHERMAL RESEARCH 2011

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ABSTRACT

Australia is amongst the forefront of Enhanced Geothermal System (EGS) and Hot Sedimentary Aquifer (HSA) ventures. With no active extensional regimes generating high-permeability systems of fluid-borne crustal heat, commercially-viable geothermal systems in Australia depend on trapping heat from radiogenic decay.

In principle the EGS and HSA concepts are simple. Recent outcomes of Australia's geothermal deep-drilling projects have, however, indicated that extracting heat at sufficient rates from these unconventional geothermal resources is still a challenge. The Australian research community is aiming to overcome these challenges through activities that focus on: characterising the geothermal resources in Australia; understanding the nature of *in situ* permeability; developing methods to target areas of high *in situ* permeability; developing methods to enhance *in situ* permeability; and, developing technologies to increase the efficiency of heat use/ conversion.

The Australian geothermal research community includes the three dedicated geothermal research centres in Queensland, South Australia and Western Australia, that have been established with complementary programs to achieve research outcomes most efficiently. These centres have significantly increased the geothermal research capacity and capability in Australia, augmenting the geothermal programs at Geoscience Australia, the CSIRO and selected Universities in Australia and New Zealand. These research organisations have established the Geothermal Research Initiative (GRI) to provide a mechanism for coordinating research activities and a focal point for industry and government to access research services

Geothermal energy development in Australia will be best advanced through a combined effort by all participants in the sector, working collaboratively to overcome the challenges and technology needs of the industry. This collaboration is facilitated by the Australian Geothermal Energy Group (AGEG) and its Technical Interest Groups (TIG), where research needs are prioritised by the industry and researchers, and collaboration and communication across the sector is enabled.

This paper provides a guide to the research activities in Australia, outlining the programs and areas of expertise of the key research groups working in the geothermal arena, and provides contacts and sources for more information. We also discuss the role that AGEG plays in facilitating collaboration between researchers, industry and government.

OVERVIEW OF RESEARCH ACTIVITY

The benefits of sustained, reliable and continuous zero-emission geothermal energy are driving researchers and commercial energy developers to work through the challenges presented by Australia's frontier geothermal resources of non-magmatic EGS and HSA plays.

Research priorities identified within Australia are aligned with international partnerships where common interests join. International collaboration is facilitated by the International Partnership for Geothermal Technologies (IPGT), of which Australia is a founding member. The IPGT is a forum for government and industry to coordinate their efforts and collaborate on projects. Through the sharing of results and best practices, determining the global status of knowledge and avoiding duplication, IPGT partners aim to efficiently advance geothermal technologies. Working groups are developing white papers and research plans for seven EGS/HSA topics:

- reservoir characterisation and modelling
- exploration technologies
- stimulation procedures
- zonal isolation/packers
- high temperature wellbore tools
- lower cost drilling.
- induced seismicity

The Geothermal Industry Technology Roadmap and Development Framework developed by the Australian Government's Department of Resources, Energy and Tourism recommended the continuation of nationwide discussion and setting of priorities through meetings of the AGEG, its TIGs and the annual AGEG and AGEA (Australian Geothermal Energy Association) Geothermal Energy Conference.

Research activities determined by AGEG and GRI include:

Exploration Technologies
- Precompetitive geoscience data
- Understanding geothermal systems (HSA and EGS)
- Exploration techniques (geophysics)

Drilling and Well Construction
- Drilling cost reduction (ROP, Time on Bottom)
- Well construction (Casing design, cementing)

Reservoir Characterisation and Modelling
- Reservoir properties
- Measurement, monitoring and modelling tools

Reservoir Engineering
- Reservoir stimulation - flow
- Production - monitoring and management of fields

Power Conversion
- Power station design
- Direct use technologies
- National grid interaction

Environment and Community Engagement
- Environmental impact – water use, induced seismicity

The strengths and key focus areas of the research centres are described in more detail below.

KEY RESEARCH ISSUES

Geothermal power-plants at (extensional-tectonic) hydrothermal systems establish a commercial floor for fluid-borne heat energy transfer from crustal volumes. To produce ~ 1MW of electrical power, geothermal production wellbores have to deliver on the order of 25ℓ/s of water that can be processed for $\Delta T \sim 100^{o}$C of heat energy,

$$1\text{MW}_{\text{elec}} \sim \varphi\ \text{MW}_{\text{therm}} \sim \varphi\rho C Q \Delta T, \qquad (1)$$

for,
$\varphi \sim 10\%$ = efficiency of thermal-to-mechanical heat conversion,
$\rho \sim 1000\text{kg/m}^3$ = mass density of water,
$C \sim 4200\text{J/kg/}^{o}C$ = specific heat of water,
$Q \sim 25$ ℓ/s = volume flow of wellbore water, and
$\Delta T \sim 100^{o}$C = temperature drop associated with conversion to mechanical energy.

Given the economics of a 1MW_{elec} gross well, the 25ℓ/s = volume flow of wellbore water is a minimum. Outcomes of some geothermal deep-drilling projects have, however, indicated that extracting heat at the required flow rates from the unconventional geothermal resources targeted in Australia may need further development.

Within crustal volumes, *in situ* permeability varies on all spatial scale lengths, often by orders of magnitude within short distances; such spatial variations are largely unpredictable and are not usefully handled by statistical averaging over small scale samples. This is particularly the case where fracture permeability dominates. Experience with oil/gas and hydrothermal reservoir flow models reveals the difficulties posed by local *in situ* permeability heterogeneity.

The Australian geothermal sector will require the challenges associated with *in situ* permeability to be overcome. Research is required that focuses on the characterisation of the geology of geothermal resources in Australia, including an understanding of the nature of *in situ* permeability and its variability. We know very little about the nature of the crust at depths of 3 to 5 km with the exception of some of Australia's deeper petroleum bearing basins. We need to know more about the lithologies, structures, *in situ* stresses, fluid saturation and chemistry as well as the *in situ* permeabilities.

This understanding will lead to the development of methods to target areas of high heat and high *in situ* permeability as well as methods to enhance the *in situ* permeability. Research and development of technologies that increase the efficiency of heat use and conversion will also be critical in improving the viability of low enthalpy geothermal resources. These improvements may be in the efficiency of electricity generation or by developing direct use applications for that heat.

GEOTHERMAL RESEARCH INITIATIVE

In response to a perceived need for redirection of Australia's geothermal energy development, a number of research organisations, described below, have agreed to work more collaboratively within the

Geothermal Research Initiative. The GRI agreement aims to combine research activities to more effectively identify and address knowledge and technology hurdles, and endeavours to do so in cooperation with industry. By networking state-based university centres, industry bodies and national agencies, GRI is a focal point for industry and government when seeking to build on research advances as they emerge. The GRI will also build international linkages.

A prototype GRI project, which began before the formal GRI agreement, presently involves three GRI parties. The Pawsey Geothermal Supercomputer Cooling Project Research Well based in Perth, WA, centres on designing a geothermal exploration well and two follow-on production wells to provide direct use geothermal cooling for the Pawsey High-Performance Computing Centre. Funding of approximately AU$20M from the sustainability round of the Federal Education Investment Fund enables exploration well drilling to start circa mid-2011. The exploration well will accommodate downhole temperature, seismic and strain sensors, and fluid sampling equipment, and gives facility for long term monitoring of the crustal flow volume as it is invested by production wells.

RESEARCH CENTRES

The following sections describe the research groups participating in the GRI. The research centres, based in Australian states and New Zealand, work on local, interstate and international projects. Table 1 summarises the research capabilities of the centres.

For each group, the research program is described, with detail provided for one or two key projects. A number of papers on different topics will be presented by representatives of these centres at the 2011 Stanford Geothermal Workshop.

Queensland Geothermal Energy Centre of Excellence (QGECE)

The Queensland Geothermal Energy Centre of Excellence is based at the University of Queensland and was established with an AU$15M grant from the Queensland Government and AU$3.3M of in-kind support from Queensland University. The centre commenced operations in January 2009 with a 5 year program. Three of the centre's four research programs focus on above ground technologies.

Power Conversion: developing technologies to enable production of 50% more electricity from binary plants using the same subsurface investment;

Heat Exchangers: development of natural draft dry cooling towers and other cooling solutions to increase by up to 15% the net output of geothermal plants that use air-cooled condensers;

Reservoir Geology: establish a geochemical/isotopic and geochronological database and improve understanding of geothermal resources in Queensland and develop routine exploration tools for hot rock geothermal systems; and,

Transmission: research on electricity grid interaction with an emphasis on remote generation infrastructure.

The centre has direct input from 16 academics and 18 postgraduate students, equivalent to a total effort of 12 full time staff. The following are examples of current projects.

Design and development of small supercritical turbines

The viability of geothermal power generation for Australian EGS and HSA plays assume a reliance on a combination of sufficient heat and flow. A new four year project at the University of Queensland with US-based power plant and turbine manufacturer Verdicorp will aim to develop supercritical turbines and cycle equipment, heat exchangers, air cooled

Table 1: Research capabilities of the research centres

	QGECE	WAGCoE	SACGER	GA	CSIRO	IESE	PRCfE	MEI
Exploration Technologies	★★	★★★	★★★	★★★	★★	★★★		★★★
Drilling			★		★★★			
Reservoir Characterisation		★★★	★★★	★	★★★	★★★		★★
Reservoir Engineering		★★	★★★		★★★	★★★		
Power Conversion	★★★	★★★	★				★★★	
Community Engagement				★	★★★	★★		

condensers, and new cycle fluids or fluid mixtures which would be suitable for supercritical cycles. If successful the new technology would significantly increase the conversion efficiency of geothermal power generation, which has the potential to make geothermal power in Australia comparable to gas fired power generation. An initial stage of this project will be to build a high-pressure supercritical turbine and cycle testing facility on the Pinjarra Hills campus of the University of Queensland. The facility will include a portable test plant for testing and demonstrating the benefits of the new power plant technologies at remote geothermal sites.

CO_2 based EGS

The idea of CO_2 based EGS has been developed by many researchers over the last 10 years, with the various positive attributes but also technical challenges enunciated. Current work at the University of Queensland is determining the most appropriate reservoir conditions for a CO_2-based EGS, considering interactions and properties of the reservoir rock, *in situ* fluid and CO_2.

For more information on the centre or these and other projects see www.uq.edu.au/geothermal or contact the centre Director, Professor Hal Gurgenci: h.gurgenci@uq.edu.au.

Western Australian Geothermal Centre of Excellence (WAGCoE)

The Western Australian Geothermal Centre of Excellence is an unincorporated joint venture between the Commonwealth Science and Industry Research Organisation (CSIRO), the University of Western Australia (UWA), and Curtin University. The centre was established in February 2009 with an AU$2.3M grant over three years from the Western Australian government and substantial in-kind and cash contributions from the centre's members. The centre is providing a scientific focus to the development of the geothermal industry in Western Australia, concentrating on the Perth Basin, and building educational programs around geothermal energy. The centre's three research programs focus on HSA geothermal plays and direct use of the heat produced from these resources.

Perth Basin Assessment: Develop a rigorous scientific understanding of the geothermal resource in the Perth Basin;

Above Ground Technologies: Identify and demonstrate innovative applications of HSA geothermal energy; and

Deep Resources: Provide a scientific framework for the potential exploitation of deep geothermal resources.

The centre has input from 34 academics and 11 postgraduate students, equivalent to a total effort of over 17 full time staff. The following are examples of current projects.

UWA campus cooling project

Research and development activities associated with the direct geothermally driven MW_{th} scale campus cooling project at UWA run by the leaseholders Green Rock Energy and UWA.

Development of geothermal desalination technology

Development of a novel desalination technology with 30% yield boost from low grade geothermal waters of 65°C and less. A containerised $4m^3$/day first generation prototype is sponsored by the Australian Government National Centre of Excellence in Desalination located at Murdoch University.

For more information on the centre or these and other projects see www.geothermal.org or contact the centre business manager, Sean Webb: sean.webb@geothermal.org.au.

South Australian Centre for Geothermal Energy Research (SACGER)

The South Australian Centre for Geothermal Energy Research is based at the University of Adelaide within the Institute for Minerals and Energy Resources (IMER) www.adelaide.edu.au/imer. The centre was announced by the South Australian Government as the first project to be funded from the South Australian Renewable Energy Fund, established with a grant of AU$1.6M over two years from 1 July 2009 with the centre beginning operation in 2010. The University of Adelaide is providing AU$400k over the same period.

Within IMER the South Australian Centre for Geothermal Energy Research forms part of a broader R&D portfolio on energy that includes the Centre for Energy Technologies (CET) which has a focus that includes the energy conversion and hybrid technologies whose aim is to optimise the geothermal energy delivered to the surface. The SACGER research program focus is on subsurface factors in hot rock and EGS resources such as reservoir characterisation and modelling. This is complementary to the research programs of other centres.

The centre has input from 11 academics and 4 postgraduate students, equivalent to a total effort of 5 full time staff. The following are examples of current projects.

Geophysical mapping and monitoring of enhanced geothermal systems using magnetotellurics

This project aims to develop technologies and methods to enable predictive surface based MT surveys to find fluid filled fractured reservoirs and to monitor flow within fractures. The project will build on field surveys and studies at an EGS site in South Australia where preliminary work has been done leading up to real time MT monitoring to be completed concurrently with microseismic monitoring of a hydraulic stimulation.

Fluid rock interactions and chemical reactivity in geothermal systems

Two programs within the SACGER are focusing on fluid-rock interactions and chemical reactivity both within the reservoir, and following this, implications for the surface equipment. One aim will be to improve 3D models of reservoir flow for EGS – combining improved characterisation of fractures created through hydraulic stimulation and with learnings from laboratory testing of the rock-fluid interaction under reservoir conditions.

For more information on the centre or these and other projects see www.adelaide.edu.au/geothermal/ or contact the centre: imer@adelaide.edu.au.

Newcastle Priority Research Centre for Energy (PRCfE)

Located at the University of Newcastle, the Priority Research Centre for Energy has been working on geothermal energy research projects for a number of years through the research program on Renewable Energy Systems. The University of Newcastle has received AU$30M from the Federal Government through the Education Investment Fund and AU$30M matching funding from other sources to establish the Newcastle Institute for Energy & Resources (NIER). As part of this initiative, significant funding has been allocated for geothermal research, in particular for the establishment of a state of the art facility for pilot-scale experimental research. The focus of geothermal research at the University of Newcastle is on novel power generation cycles and the concept of a CO_2 thermosiphon for EGS.

The PRCfE has input from 10 staff members, and 4 postgraduate students, equivalent to 10 full time staff. The following are examples of current projects.

GRANEX Regenerative Supercritical Power Cycle

The study of power cycles is regarded as one of the key areas for major technological improvements since many of the problems associated with power generation from geothermal sources are underpinned by inefficient and often unsuitable heat exchange processes within power cycles. In recognition of these shortcomings, the University of Newcastle initiated a joint R&D program with Granite Power Ltd in 2006 with the goal of establishing alternative and potentially more efficient ways of generating power from geothermal and other low-grade heat sources, such as industrial waste heat. The result was the creation of the GRANEX Regenerative Supercritical Power Cycle which is now being commercialised.

3D reservoir simulation for Supercritical CO_2 EGS

This project has conducted a sensitivity analysis of CO_2 mass flow and heat extraction rates with the variations of injection temperature, rock permeability, rock porosity and reservoir temperature. The next stage has been to couple wellbore simulation to the 3D reservoir simulation to provide injection and production well bore flow parameters. This refinement of the model allows more in-depth research of geothermal reservoir management and optimisation of operations.

For more information see www.newcastle.edu.au/research-centre/energy or contact the Renewable Energy Systems Program leader, Professor Behdad Moghtaderi: Behdad.Moghtaderi@newcastle.edu.au.

Melbourne Energy Institute (MEI)

The Melbourne Energy Institute represents energy-related research involving more than 150 researchers across seven faculties at the University of Melbourne. It has a priority focus on large-scale sustainable energy systems with active research programs in bioenergy, solar, wind, geothermal and carbon capture and storage (CCS) including system integration, regulatory frameworks, economics and social justice issues. Geothermal projects span fundamental geothermics, deep geothermal resource targeting and direct use geothermal applications. A flagship project is the Victorian geothermal assessment report which will assess Victoria's deep geothermal potential and make recommendations for harnessing this geothermal energy. Other key projects of relevance to deep geothermal energy utilisation are described below.

Geothermal projects at the MEI have input from 7 staff members, and 5 postgraduate students, equivalent to 4 full time staff.

Thermal structure and evolution of Australia project

The Thermal Structure and Evolution of Australia project is a 5-year, AU$850k Australian Research Council-funded project designed to provide a better understanding of the thermal evolution of the Australian continental crust and develop a framework

for integrating geochemical and geophysical data to map its thermal structure. Results will provide insights into the fundamental processes governing crustal differentiation as well as new exploration tools to support Australia's energy future.

The Southern Victorian Geophysical Initiative

With thicknesses of coal locally up to 500 m, Victoria's southern sedimentary basins contain some of the most thermally resistive successions on Earth, locally creating some of the highest geothermal gradients in the country and extreme heat flow refraction effects. However the thick coals sequences also challenge many conventional geophysical imaging methods, hence the Southern Victorian Geophysical Initiative is a collaborative effort between the University of Melbourne, Monash University and Geoscience Victoria designed to better understand the potential of the deeper realms of these sedimentary basins to inform integrated basin management strategies.

The AGOS Subsurface Observatory

Through the MEI, the University of Melbourne is the lead node in the AU$6.7M AuScope Australian Geophysical Observing System Subsurface Observatory component to the federal government AU$23M EIF program for 2011 to 2014. The subsurface observatory provides an infrastructure framework for characterising the physical state (temperature, stress, permeability, seismic anisotropy etc.) of the accessible crust relevant to emerging energy issues such as geothermal. The research infrastructure will include new, cheaper ways of monitoring, imaging and modelling the accessible crust and deliver an integrated observing system across the nation comprising:

- a geospatial observatory
- an earth sounding network
- a subsurface observatory
- a geohistory laboratory
- an inversion laboratory
- a geophysical education observatory

Through co-investment, it will make existing deep boreholes available to the geoscience research community, allowing both direct and indirect probing of the upper 5km of the crust. The project will link more than 100 researchers in 14 partner organisations, including the CSIRO, Geoscience Australia, the University of Melbourne, the University of Queensland, the University of Adelaide and other national geophysics centres.

For more information on AGOS see www.auscope.org.au/content.php/category/id/2 or contact Professor Mike Sandiford, Chair of the AuScope Science Advisory Board, mikes@unimelb.edu.au.

For more information on the MEI see energy.unimelb.edu.au or contact the institute: mei-info@unimelb.edu.au

Institute of Earth Science and Engineering (IESE)

The Institute of Earth Science and Engineering is a Research and Development organisation in the University of Auckland. The Institute works on a range of topics in the areas of energy, hazards, and environment, especially as they relate to the earth between the deepest drill holes and tallest buildings. Accordingly, IESE has a strong focus on geothermal systems, covering areas of geothermal geophysics and geology, reservoir modelling, geothermal geochemistry and mineralogy, and the energy business. Geothermal project sites include the Americas, the Southwest Pacific, Europe, and the Middle East. IESE studies earthquake and volcano hazards, with particular reference to those in Auckland area and along New Zealand's Alpine fault. Similarly, IESE also studies the impact of both natural changes and industrial and cultural activities on geological processes. IESE works with both public and private concerns, seeking to deliver project-relevant research, training, and commercial services.

The IESE has input for its geothermal program from 3 University of Auckland teaching faculty, 9 full time professional research staff, 3 postgraduate students, and 4 IESE-associated geothermal consultants. The following are examples of current projects.

Geophysical-Polarisation Mapping For HSA Permeability

The need to locate zones of high natural permeability for direct or stimulated geothermal power production has become a central issue for Australian HSA resource exploitation. IESE propose to extend electromagnetic- and seismic-signal polarisation methods we have developed elsewhere to permeability mapping for such crustal volumes. The project tasks focus on observing, interpreting, and modelling the direction-dependent electrical and elastic responses of stress oriented, fluid rich, permeable fracture networks in HSA environments. The project is motivated by IESE's successful location of high permeability zones in volcanic and sedimentary prospects in Kenya, Iceland, and the US. The projects will be executed in an AGEG TIG environment, which will be open to interested industry, government, and university participants. The TIG goal will be to identify which predictions of the mapping methods matches the ground truth of a drilled geothermal prospect and provide these to the Australian HSA community at large.

For more information on the IESE geothermal program see www.iese.co.nz or contact IESE Deputy Director, Jess Cherrington: j.cherrington@auckland.ac.nz.

Geoscience Australia

Geoscience Australia is the federal geoscientific agency within the Department of Resources, Energy and Tourism. Activities include providing information to assist onshore and offshore exploration and exploitation of resources including pre-competitive data, the management of resources for sustainable energy supply, environmental protection, emergency management and risk assessment for natural events.

Geoscience Australia's Geothermal Energy Project has input from 7 staff members, equivalent to a total effort of over 5 full time staff.

Geothermal Energy Project

The Australian Government announced the five-year AU$58.9M Onshore Energy Security Initiative in August 2006, and as part of this, Geoscience Australia established the Geothermal Energy Project. The project aims to improve the existing knowledge about the type and location of geothermal resources in Australia on a national scale. It also aims to encourage investment, exploration and exploitation of this energy source through provision of pre-competitive geoscience datasets relevant to geothermal energy. To achieve these objectives, the geothermal project:

- collects new heat flow data across Australia to by thermal gradient logging and thermal conductivity measurements to better define and locate geothermal resources (Figure 1);
- uses modelling to identify potential EGS and HSA systems;
- works to compile national datasets which may be useful to the geothermal industry including groundwater temperatures, borehole temperatures, rock thermal conductivities and granite and sediment chemistry;
- uses these new datasets to produce a revised estimate of Australia's total contained geothermal resource; and
- provides advice to government on geothermal resource issues, including the AU$50M Geothermal Drilling Program.

Outputs of the geothermal energy project to date in addition to the above activities include the release of OZTEMP, an updated dataset and map of predicted temperatures at 5km depth, (www.ga.gov.au/minerals/research/national/geothermal).

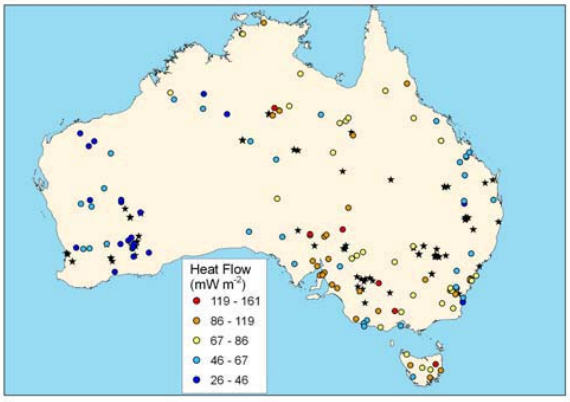

Figure 1: Map of existing heat flow measurements and bores logged for temperature by Geoscience Australia (black stars). (Budd et al., 2010)

For more information on Geoscience Australia or the Geothermal Energy Project see www.ga.gov.au or contact the geothermal energy team: geothermal@ga.gov.au.

CSIRO

CSIRO's research capabilities in the geothermal arena are broad, due to the organisation's research diversity and ability to integrate multidisciplinary skills. The primary focus of CSIRO's activities in geothermal has been through its contribution to WAGCOE. CSIRO's contributions to the centre are mainly in the geological, geophysical, ground water, and reservoir engineering aspects of the Perth Basin Assessment research program. CSIRO is also deploying its research expertise in hydraulic fracturing, reservoir engineering, wellbore stability, rock petrophysics and microseismic monitoring to geothermal projects.

The CSIRO has input for its geothermal program from 15 staff members, equivalent to over 6 full time staff. The following are examples of current projects.

Square Kilometre Array (SKA)

Funding from the Education Investment Fund for CSIRO's Sustainable Energy for SKA project was announced in 2010. A significant component of this project is a 10 MW_{th} direct use geothermal cooling system for the Pawsey High Performance Computing Centre in Perth. The construction of this system will start with the drilling of a research/monitoring well, followed by a production and injection doublet. The heat produced will be used in an adsorption chiller to provide cooling for the supercomputer. CSIRO will work closely with WAGCOE during the development of this project. The geothermal component of the project is led by CSIRO Earth Science and Resource Engineering in collaboration with the leaseholder, Geothermal Power Pty Ltd.

Petroleum and Geothermal Research

The CSIRO has strong capabilities in the areas of reservoir stimulation and modelling, rock physics, wellbore stability and community engagement. Presentations on projects from the Petroleum and Geothermal Energy group within the CSIRO Earth Science and Engineering department will be given at this Workshop and include:

- Development of numerical modelling tools that couple thermal and poro-elastic processes for the assessment of well stability.
- Development of numerical modelling tools and procedures for hydraulic stimulation at high pressures and temperatures, accounting for thermo-poro-elastic effects and interactions with natural fractures.
- Development of numerical modelling tools for fluid flow in fractures.
- Evaluating the application of petrophysical logging techniques to the assessment of thermal conductivity;
- Assessment of waveform characterisation techniques for the interpretation of microseismic monitoring data through laboratory based studies (high pressure high temperature tri-axial cell with acoustic emissions monitoring) and the analysis of field data.

For more information on the CSIRO geothermal stream see www.csiro.au/org/geothermal or contact the CSIRO: geothermal@csiro.au.

AGEG TECHNICAL INTEREST GROUPS

The Australian Geothermal Energy Group is a cooperative whole-of sector representative body whose 105 member organisations are drawn from industry, research and government. The AGEG was formed in 2006 to bring together those with a common interest of advancing geothermal energy development in Australia.

A pivotal aspect of AGEG's mission is to foster research collaboration, information sharing and the transfer of technology at both national and international levels. This is achieved in a practical sense, through the activities of AGEG's 12 TIGs which are focused on addressing a range of key technology challenges faced by the geothermal community at large and have varying levels of activity. The TIGs are linked through their members with the International Energy Agency's Geothermal Implementing Agreement research annexes, and working groups of the IPGT, in order to contribute towards the accelerated development of geothermal energy globally in the most efficient and effective manner. The 12 current TIGs are listed in Table 2.

Table 2: AGEG Technical Interest Groups

TIG	Topic
1	Water management & environmental sustainability
2	Reserves and resources
3	Induced seismicity
4	Outreach
5	Economic modelling and novel use
6	Power plants
7	Direct use
8	Information and data
9	Reservoir development and engineering
10	Exploration and well log technologies
11	Drilling and well construction
12	Education

An exemplary project that has been a joint effort between AGEG and AGEA through the joint geothermal code committee is the development of the Australian Code for the Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves (AGCC, 2008). In 2010 a second edition of the code was released with refinements and improvements (AGRCC, 2010). The vision and first work towards the development of the code was a project from the TIG for reserves and resources, which now provides input to the Code Committee.

For more information on the AGEG or its TIGs see www.pir.sa.gov.au/geothermal/ageg or contact the Technical Interest Group leaders.

CONCLUSION

Australia's geothermal energy research community is developing and formalising arrangements for collaboration and cooperation between dedicated geothermal energy research centres, research groups with geothermal programs, and national research institutes. The research projects will carry forward Australia's goal of securing the benefits of sustained, reliable and continuous zero-emission geothermal energy.

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