Australia's Geothermal Research Activities

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The challenges and technology needs of Australia's geothermal energy industry are significant yet achievable. The sector is organised and has a clear pathway through the stages of project development defined in the Development Framework and Technology Roadmap (DRET, 2008). Collaboration is facilitated by the Australian Geothermal Energy Group and its Technical Interest Groups, where research needs are prioritised by the industry and researchers. The capacity and capability to undertake the much needed research work will be met by geothermal research centres which work competitively yet collaboratively, with complementary programs, to achieve research outcomes most efficiently. This paper will provide 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; a summary of current projects; and how to find out more information.

Keywords: Geothermal, research, technology development.

Centres of expertise

The desire to develop Australia's geothermal energy resources to supply secure and environmentally sustainable energy has led to the impressive growth of the Australian geothermal sector. The challenges facing the sector are known, and the research and development needs of the industry as they strive to commercialise the resources are being met by a growing capacity at dedicated research centres, universities and research groups.

Centres for geothermal energy research have formed: at the University of Queensland, with the Queensland Geothermal Energy Centre of Excellence (QGECE); in a joint venture of the University of Western Australia, Curtin University and the CSIRO, the Western Australian Geothermal Centre of Excellence (WAGCOE); and at the University of Adelaide, the South Australian Centre for Geothermal Energy Research (SACGER). Geothermal energy research is also being supported at many universities around Australia, Geoscience Australia and at the CSIRO. The following sections will describe each of these centres and research groups and their capability.

Geoscience Australia

The Australian Government announced the AU$58.9M Onshore Energy Security Initiative in August 2006, and as part of this, Geoscience Australia established a 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 better define and locate geothermal resources;
- uses (heat) source and (thermal) trap modelling to identify potential Hot Rock and Hot Sedimentary Aquifer 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.

For more information see www.ga.gov.au or contact the geothermal energy team: geothermal@ga.gov.au.

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 the university. The centre commenced operations in

January 2009 with a 5 year program. The centre's research programs were developed to fill gaps in the national and international geothermal research effort and have a focus on above ground technologies with the aim of quickening the pace of large-scale utilisation of hot rocks geothermal energy in Australia. QGECE has four research programs:

- 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 in to electricity grid interaction with an emphasis on remote generation infrastructure.

The current major projects include:

- Design and development of small (5-kWe) supercritical turbines for testing in the QGECE laboratory.
- Construction of a 100-kWe mobile geothermal test plant with high-pressure capability to try supercritical turbines.
- Characterisation of the heat-producing granites in Queensland.
- The effect of ambient dust on air-cooled condenser performance and design against dust.
- Investigation of options for connecting remote geothermal power generation to the Queensland grid.

See also 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, 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 centres' 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 research focus is on Hot Sedimentary Aquifers and direct use of the heat produced from these resources, as summarised in the centre's vision statement "To provide geothermal zero-emission desalinated water, air-conditioning and power to our cities".

WAGCOE has three research programs:

- 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.

Current major projects include:

- Research and development activities associated with the direct use geothermal powered supercomputer cooling system that is part of CSIRO's Sustainable Energy for SKA project (see below). This system targets hot sedimentary aquifers of the Perth Basin.
- Design of an additional sensor equipped deep research and monitoring well at the same site for research, education, training and long term monitoring.
- 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 a novel desalination technology with 30% yield boost from low grade geothermal waters of 65°C and less. A containerised m^3/day first generation prototype is sponsored by the Australian Government National Centre of Excellence in Desalination located at Murdoch University.

For more information 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, 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. The University of Adelaide is providing AU$400,000 over the same period.

The SACGER research program will focus 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 research program is under development and will be designed in consultation with the sector.

Current projects at the centre include those which were funded by tied grants from PIRSA:

- Geophysical mapping and monitoring of an enhanced geothermal system using magnetotellurics.
- Rock fracture characterisation for hot dry rock enhanced geothermal systems.
- Building a regional thermal model for the Adelaide rift complex.
- Experimental verification of underground cooling for efficient thermal cycles.
- Optimisation of geothermal energy investments.
- Investigate low temperature thermal processing using geothermal energy.
- Reconnaissance thermal mapping for uranium and geothermal exploration.

For more information see www.adelaide.edu.au/geothermal/
or contact the centre: imer@adelaide.edu.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, well bore stability, rock petrophysics and microseismic monitoring to geothermal projects

Funding from the Education Investment Fund for CSIRO's Sustainable Energy for SKA project was recently announced. 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.

Other projects 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.
- 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 triaxial cell with acoustic emissions monitoring) and the analysis of field data.

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

University of Newcastle (Priority Research Centre for Energy – PRC*f*E)

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 thermo siphon for EGS. 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.

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

The Melbourne Energy Institute is located at the University of Melbourne and has a number of geothermal projects including the Victorian Geothermal Assessment Report, which intends to address critical issues for the successful development of geothermal power capability in Victoria.

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

RMIT

A significant project linking geothermal energy and desalination is underway at RMIT in partnership with Greenearth Energy.

The project involves the development of a prototype system that combines fresh water production with electricity generation using entirely renewable sources. The project is supported by an Australian Research Council Linkage grant and Greenearth Energy.

For more information on this project contact Mark Miller, Managing Director of Greenearth Energy, via email markm@greenearthenergy.com.au or telephone 03 9620 1566.

For the RMIT website see www.rmit.edu.au

AGEG Technical Interest Groups

Collaboration amongst all participants in the sector is enabled through the Australian Geothermal Energy Group (AGEG) and the AGEG Technical Interest Groups (TIGs).

Through linkages to the AGEG and its TIGs, Australia is a member of and contributes to the work of both the International Energy Agency Geothermal Implementing Agreement (IEA-GIA) and the International Partnership for Geothermal Technologies (IPGT). The 105 organisations that are members of the AGEG have nominated research topics of the highest priority to the industry, which are closely aligned with the priorities of both the GIA and the IPGT.

The 12 TIGs are named in Table 1, and described in more detail in the following section. For more information or to join any of the TIGs: see the AGEG website, <www.geothermal.pir.sa.gov.au>, go to AGEG, Technical Interest Groups; or contact the TIG leader. Contact details for all TIG leaders are also provided on the website.

Table 1. 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

TIG 1 water management and environmental sustainability

Following discussions and a decision made at the AGEG AGM in February, the name and focus of TIG 1 has been redefined as water management and environmental sustainability. The scope of the TIG and definition of outputs from the TIG will be developed by the members and will be available on the TIG webpage. The TIG leader is Steven Kennedy from the Victorian Department of Primary Industries.

TIG 2 reserves and resources

The reserves and resources technical interest group is predominantly to provide a forum for AGEG members to contribute to discussion on the Australian Geothermal Reporting Code. The code is developed and reviewed by the joint AGEG and AGEA Australian Geothermal Reporting Code Committee, chaired by Peter Reid from Petratherm. Peter is also the TIG 2 leader, allowing feedback to the committee. *The Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves, The Geothermal Reporting Code* (AGRCC, 2008), was launched in August 2008 at the AGEG and AGEA Australian Geothermal Energy Conference.

TIG 3 induced seismicity

Highlighting the importance of this topic and the need for research in this area, a new technical interest group has been created to focus on induced seismicity. Led by Michael Malavazos and Barry Goldstein from PIRSA, this TIG will build on the work done under the previous TIG 1, which included the release of two reports, *Cooper Basin HDR hazard evaluation: predictive modelling of local stress changes due to HFR geothermal energy operations in South Australia* (Hunt and Morelli, 2006) and *Analysis and management of seismic risks associated with engineered geothermal system operations in South Australia* (Morelli, 2009).

TIG 4 outreach

The scope of TIG 4 is to assist the development of the Australian geothermal industry through coordinated geothermal training courses (in conjunction with IGA) an annual conference (in conjunction with AGEA), improving communications through provision of a dedicated website that provides linkages to geothermal resource material and informing the public through the provision of accessible information. TIG 4 is led by Betina Bendall from PIRSA.

TIG 5 economic modelling and novel use

TIG 5 has been modified to now cover economic modelling as well as novel use applications for geothermal energy including hybrid systems. Stephen Hinchliffe from SKM is the TIG leader.

TIG 6 power plants

The aim of TIG 6 is to achieve substantial improvements in geothermal power plant efficiency through improvements in, for example, the cycle type, cycle fluids, heat exchanger efficiencies and more efficient cooling processes. Currently the focus is on the following areas:

- New cycles and cycle fluids
- Dry cooling
- Supercritical CO_2 geothermal siphon

The work of this TIG mirrors the IEA Geothermal Research Annex VI. Hal Gurgenci from the QGECE and Behdad Moghtaderi from the University of Newcastle are co-leaders of TIG 6.

TIG 7 direct use

Direct use geothermal applications include both circulating hot water & geothermal heat pumps. Direct use geothermal is being pursued through work in this TIG as a highly desirable substitute for electricity use due to:

- Widespread occurrence
- Shallow depths (i.e. lower cost)
- High efficiency (no energy conversion)
- Utilisation of conventional plant and equipment
- Relatively easy set up
- Can be small to industrial scale

The TIG for direct use is led by Klaus Regenauer-Lieb from the WAGCOE and Donald Payne from the University of Melbourne.

TIG 8 data management

TIG 8, led by Anthony Budd from Geoscience Australia, aims to assist the development of the Australian geothermal industry by simplifying data availability, usefulness and exchange through standards, database design, content, ongoing enhancements and development of manipulation and interpretive tools. Some initiatives already completed through the TIG include the development of an extension to 3D GeoModeller to enable prediction of 3D temperature and heat flow from inputs of heat production and thermal conductivity. Future projects planned are to populate a heat flow database with new data, liaise with international parties working on geothermal data management for web interoperability standards and to build a data system within the Onshore Energy and Minerals Division of Geoscience Australia.

TIG 9 geothermal reservoir characterisation and engineering

Agreed terms of reference for this TIG are to facilitate collaboration and information exchange on topics including, but not limited to,

- Reservoir characterisation and modelling including 3D stochastic modelling and the simulation of fracture networks
- Fracture stimulation with emphasis on design and modelling
- Geochemistry, corrosion and scaling covering both the geothermal plant and equipment and the rock-fluid interaction in the reservoir.

Some projects planned by the TIG include to compile and evaluate a list of available numerical models (algorithms) for fracture characterisation, scan for pre-existing geothermal data handbooks and build up to include information learnt from overseas projects and to date from Australian projects, promote international collaboration through exchanges and develop 3D stochastic modelling and simulation of fracture networks and fracture propagation in crystalline rocks. Peter Dowd from the University of Adelaide is the leader of this TIG.

TIG 10 exploration technologies

TIG 10 aims to cooperate in studies to advance geothermal methods and technologies: including the indirect detection of subsurface properties to delineate prospective trends; to develop, collect, improve and disseminate geothermal-related information; to identify opportunities to facilitate the efficient advancement of geothermal energy projects; and to disseminate information on geothermal energy in Australia and internationally by way of workshops, and open interchange of experiences and ideas generated within the Australian community. The group have held a number of successful workshops and have been actively defining the research focus of the TIG. A few topics that are the focus of the group include:

- geophysical and geological methods to reduce exploration risks prior to deep drilling

- investigating the possible use of satellite and airborne systems to measure surface radiation to detect high heat producing granites in the sub-surface
- the use of magneto-telluric survey data to identify and locate conductive fluids in fractured rocks
- collection and processing of micro-seismic data around geothermal projects.

Des Fitzgerald from Intrepid Geophysics leads TIG 10.

TIG 11 drilling and well construction

TIG 11 has been very active and has regular meetings to advance the group's objectives. Topics in scope for the TIG include, but are not limited to:

- Lower Cost Drilling: Investigate techniques and new technologies which may lead to a reduction in costs to drill geothermal wells.
- Zonal Isolation and Packers: Isolation techniques and equipment need to be developed to isolate zones of interest, at extremely high temperatures and possibly pressures, to allow both stimulation and production through different zones.
- Temporary Sealing of Fractures: Develop a non-damaging means of isolating fractures where multiple fractures/ loss zones may be encountered.
- Cutting Exploration Drilling Costs: A number of mechanisms can be developed to reduce costs, such as improving ROP, utilising smaller rigs, smaller hole sizes, correct selection of materials.

The two projects that will be the focus for the coming year are to progress the slimhole drilling group and organise a drilling workshop. TIG 11 is led by Dean Hindle and Melanie Vonthethoff from Geodynamics.

TIG 12 education

TIG 12 was recently formed to work on the topics of education for the geothermal sector and encompasses topics such as defining the education needs for the industry, the development of courses either at tertiary or postgraduate level or short courses for industry. The TIG would coordinate with aligned international programs and facilitate the initiation & promotion of occasional society lunches with guest speakers.

For more information about any of the Technical Interest Groups please see: www.geothermal.pir.sa.gov.au/ageg
or contact pirsa.ageg@sa.gov.au.

References

Department of Resources, Energy and Tourism (DRET), 2008, Australian Geothermal Industry Development Framework, and, Australian Geothermal Industry Technology Roadmap, Commonwealth of Australia, Canberra.

Australian Geothermal Reporting Code Committee (AGRCC), 2008, The Geothermal Reporting Code. Australian Geothermal Energy Group, Adelaide.

Hunt, S.P. and Morelli C.P, 2006, Cooper Basin HDR hazard evaluation: predictive modelling of local stress changes due to HFR geothermal energy operations in South Australia. Report Book 2006/16. Department of Primary Industries and Resources South Australia, Adelaide.

Morelli, C.P., 2009, Analysis and management of seismic risks associated with engineered geothermal system operations in South Australia. Report Book 2009/11. Department of Primary Industries and Resources South Australia, Adelaide.