



Barry Goldstein
The Australian Geothermal Energy Group
C/o PIRSA, GPO 1671
Adelaide SA 5000

4 April 2008

Dr Ross Garnaut
Garnaut Review
C/o contactus@garnautreview.org.au

Dear Dr Garnaut

THE ROLE OF GEOTHERMAL ENERGY IN THE FUTURE IN AUSTRALIA

I am pleased to provide the Australian Geothermal Energy Group's submission in relation to the Garnaut Review Issues Paper 4: Research and Development: Low Emissions Energy Technologies.

Thank you for the opportunity to comment. Should you want further discussion on any issues relating to our submission, please feel free to contact me:
Yours sincerely

Barry Goldstein
Chair - Australian Geothermal Energy Group
Executive Committee Member – IEA Geothermal Implementing Agreement

ATTACHMENT

AUSTRALIAN GEOTHERMAL ENERGY GROUP SUBMISSION TO THE GARNAUT REVIEW ISSUES PAPER 4: RESEARCH AND DEVELOPMENT: LOW EMISSIONS ENERGY TECHNOLOGIES



Habanero 3 Flow Testing in March 2008, Cooper Basin, SA


AUSTRALIAN GEOTHERMAL ENERGY GROUP SUBMISSION TO THE GARNAUT REVIEW PAPER 4: RESEARCH & DEVELOPMENT: LOW EMISSIONS ENERGY TECHNOLOGIES

INTRODUCTION TO THE AUSTRALIAN GEOTHERMAL ENERGY GROUP

The AGEG is a whole-of-sector representative body for Australia’s geothermal sector, and its members are representatives of 65 organisations (48 companies, 10 Universities and lead agencies (for geothermal) within the Australian Federal, State and NT governments. Most of the companies represented in the AGEG are also members of the Australian Geothermal Energy Association (AGEA – the peak representative Directorate for geothermal industry companies). The AGEG’s vision and membership summarised in Table 1. The AGEG’s terms of reference are:

1. Provide support for Australia’s membership in the IEA’s Geothermal Implementing Agreement (GIA) and facilitate engagement with the international geothermal community.
2. Foster the commercialisation of Australia’s geothermal energy resources. Collectively:
 - Cooperate in research and studies to advance geothermal exploration, proof-of-concept, demonstration and development projects;
 - Cooperate to develop, collect, improve and disseminate geothermal-related information;
 - Identify opportunities to advance geothermal energy projects at maximum pace and minimum cost; and
 - Disseminate information on geothermal energy to decision makers, financiers, researchers and the general public (outreach).

Table 1 – Vision and membership of the Australian Geothermal Energy Group (AGEG)

 Australian Geothermal Energy Group (AGEG) Members http://www.pir.sa.gov.au/geothermal/ageg ASX-Listed (Code)		
AGEG’S VISION: Geothermal resources to provide the lowest cost emissions-free renewable base load energy for centuries to come.		
1. SA Government (Chair) 2. Australian Fed. G'ment RET, GA, CSIRO, AGO/Climate Change) 3. AGEA 4. AAA Energy 5. BurnVair Corporate Finance 6. Callabonna Energy 7. Clean Energy Australasia 8. Curtin University 9. Deep Energy 10. Earth Heat 11. Earthinsite 12. E-Connect 13. Eden Energy (EDE) 14. Electranet 15. Energycore 16. Geodynamics (GDY) ¹ 17. Geogen 18. Geopower 19. GHD 20. Google (RE<C) 21. Gradient Energy	22. Granite Power 23. Greenearth Energy (GER) 24. Greenrock Energy (GRK) 25. Geothermal Resources (GHT) 26. Hot Dry Rocks 27. Hot Rock Ltd (HRL) 28. Hot Rocks Tasmania 29. Hydro Aluminium 30. Inferus Resources 31. Intrepid Geophysics 32. KUTh Energy Ltd (KEN) 33. KPMG 34. Monaro 35. Monash University 36. Near Surface Geothermal Energy 37. New World Energy 38. NSW Government 39. NT Government 40. Origin Energy (ORG) - Diversified Energy Co. 41. Osiris Energy 42. Panax/ Scopenergy (PAX) 43. Petratherm (PTR) ²	44. Pacific Hydro 45. Queensland Government 46. Red Hot Rocks 47. Schlumberger (NYSE) 48. Sinclair, Knight, Merz 49. Snowy Mountain 50. Syncline Energy 51. Stuart Petroleum (STU) – upstream petroleum co. 52. Tasmanian Government 53. Teck Cominco (Toronto Exchange) 54. Torrens Energy (TEY) 55. Tri-Star Energy 56. University of Melbourne 57. University of Adelaide 58. University of Newcastle 59. University of NSW 60. University of Queensland 61. University of South Australia 62. University of West Australia 63. University of Tasmania 64. Victorian Government 65. WA Government
1. Origin & Woodside are cornerstone investors 2. JV with Beach Petroleum		

The AGEA has formed to enable the geothermal industry to focus and amplify a shared message from industry through a single directorate. The AGEG understands the AGEA will lodge a separate submission to the Garnaut Review, as may several AGEG member organisations. This submission has been reviewed by, and reflects the consensus views of the AGEG’s members.

GEOTHERMAL – A NATIONAL OVERVIEW

Australia's vast hydrothermal and Hot Rock energy resources have the potential to become a very significant source of safe, secure, competitively-priced, emission free, renewable baseload power for centuries to come. This potential combined with the evidence of risks posed by climate change is stimulating growth in geothermal energy exploration (drilling) and proof-of-concept (flow tests) and demonstration power generation projects in Australia.

AUSTRALIA'S NATURAL COMPARATIVE ADVANTAGES FOR HOT ROCK DEVELOPMENT

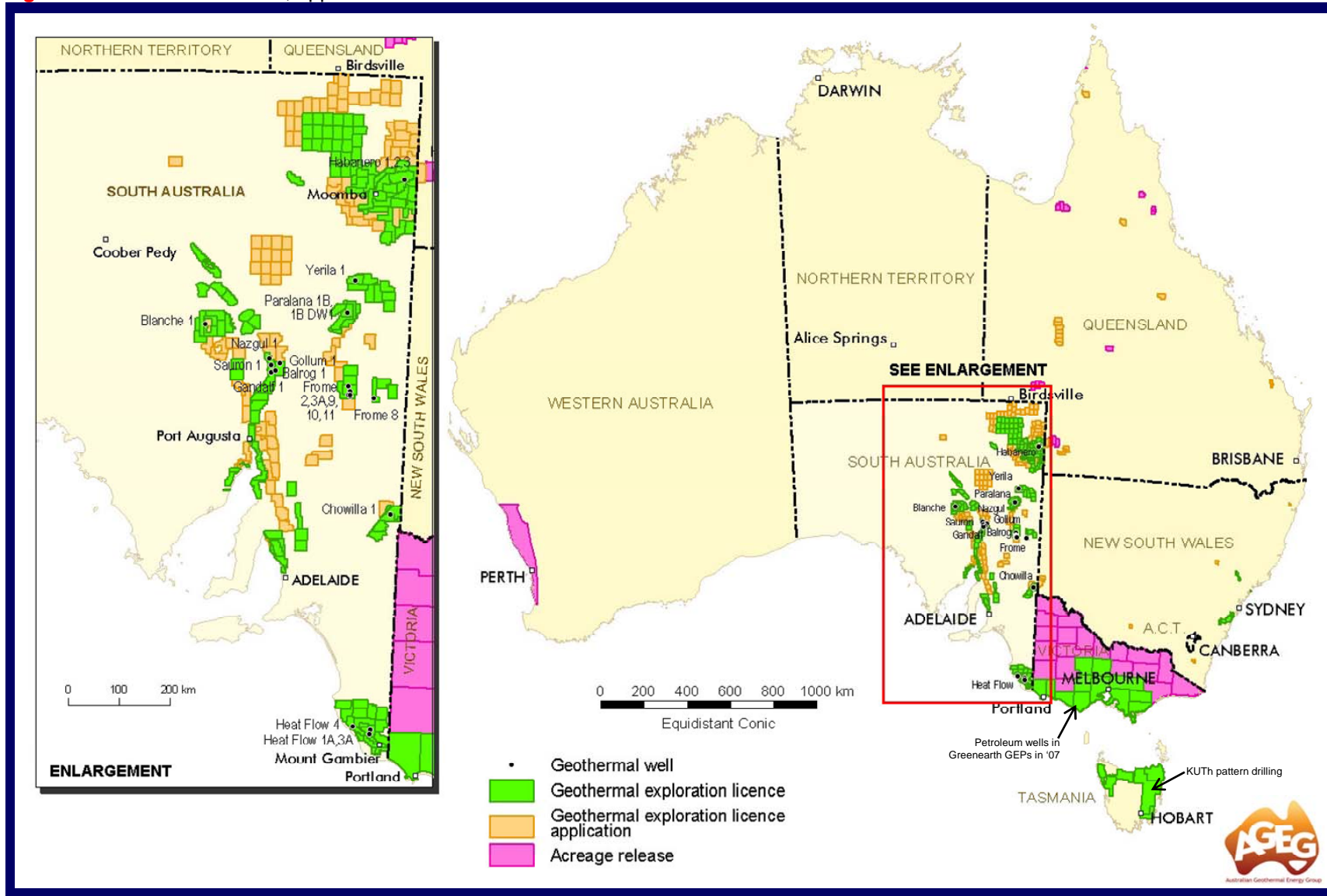
Australia's hot rock and hydrothermal resources have the potential to fuel competitively-priced, emission free, renewable baseload power for centuries to come. This potential and the risks posed by climate change are stimulating geothermal energy exploration projects in Australia.

In 2007 Geoscience Australia produced an estimate of total contained crustal energy for that portion of the Australian continental crust which is shallower than 5km and hotter than 150°C. Converting just 1% of this crustal energy above 5 km (190 million PJ) to electricity would supply around 26,000 years of Australia's primary power usage in 2005, and that neither takes into account the renewable characteristics of hot rocks, nor the resource below 5,000m. It is expected that this estimate will be further refined by Geoscience Australia in 2008 with the addition of both new and existing geothermal data.

Three geological factors distinguish Australia as having world class 'amagmatic', Hot Rock (HR) resources.

- First, Australia is endowed with anomalously radioactive Proterozoic granitoids. The best known examples are located in South Australia where the mean heat flow is $92\pm 10 \mu\text{Wm}^{-2}$ compared to a global average for continents of $51\text{--}54 \mu\text{Wm}^{-2}$. Elsewhere in Australia, radiogenic iron oxides, hydrothermal systems, high-heat producing granites of Archaean and Palaeozoic age, and hot depocentres associated with recent volcanic activity also constitute attractive targets for geothermal energy exploration.
- Second, Australia is converging with Indonesia on a plate scale – giving rise to horizontal compression and common, naturally occurring sub-horizontal fractures and faults. Hence, Australia has extensive volumes of Hot Rocks with pervasive sub-horizontal fractures and faults. The recognition of these comparative advantages has enabled several companies to raise market capital to explore for locations where Hot Fractured Rocks (HFR) underlie insulating sedimentary rocks within drillable depths – and also where the insulating sedimentary cover is prospective for permeable geothermal resource targets. Additionally, naturally fractured rocks tend to be susceptible to hydraulic fracture stimulation to enhance hot rock reservoir properties – and this has been demonstrated in Geodynamics' Habanero wells in the Cooper Basin.
- Third, sedimentary basins occupy a large proportion of the Australian landmass. The world's largest artesian groundwater basin, underlying about 22 % of the Australian continental landmass, is the Great Artesian Basin. Groundwater comes out at wellheads at temperatures ranging from 30°C–100 °C. Basins are an attractive place to explore for geothermal resources as they potentially provide both thermal insulation to trap heat flow from depth, and permeable reservoir formations. When combined in an optimal way, these properties of basins provide potential for warm to hot natural aquifers at economically drillable depths. The natural temperature, porosity and permeability of sedimentary aquifers may be sufficient to provide usable geothermal power without the requirement of stimulation

Figure 1: Geothermal licences, applications and bid blocks



INVESTMENT IN AUSTRALIA'S HOT ROCK PLAYS

Nationally, 33 companies have applied for 282 licences (Figure 1) with work program investment over the term 2002-13 totaling \$832 million, and this forecast excludes up-scaling and deployment projects assumed in the Energy Supply Association of Australia's scenario for 6.8% (about 5.5 GWe) of Australia's base-load power coming from geothermal resources by 2030 (ESAA, 2006¹).

The majority of current and forecast investment to explore for, and demonstrate the potential of, geothermal energy in Australia focused on hot rock enhanced geothermal systems (EGS), but some companies are also exploring for hydrothermal resources in the Great Artesian, Gippsland, Otway and Perth Basins. Most holders of rights to explore-for, demonstrate, develop, deploy and produce geothermal energy are focused on the use of Hot Rock energy to fuel power plants to meet base-load electricity demand. However, other possible applications include niche markets such as pre-heating water for coal- and gas-fired power plants, drying coal, desalinisation, ground source heat pumps (for heating and cooling buildings) and local direct-use for heating.

Many forms of conventional energy generation such as coal and natural gas are currently more cost effective than any renewable energy sources. However, modelling undertaken by MIT² and MMA³ concludes that electricity generated from Hot Rock EGS will be lower cost than any other form of renewable energy and, within decades has the potential to be comparable in cost to coal-fired power without the pricing of greenhouse gas emissions factored into the cost of electricity generation. Hence, government policies that support the learn-while-deploying phase of Hot Rock energy development are also expected to be essential to Australia's capability to attain efficient emissions abatement while also securing 'lowest cost' renewable base load power. Estimates (calculations) of public benefit that influence energy markets and contestability for government grants ought to take account of that prospective character of Hot Rock power.

PROSPECTIVE MATERIALITY OF AUSTRALIA'S HOT ROCK RESOURCES

The potential materiality of Hot Rock project areas remains to be fully demonstrated, but proponents of geothermal energy development believe there is sufficient information to conclude:

- Hot, wet, fractured granites in Geodynamics' South Australian Cooper Basin geothermal tenements (covering 1,983 km²) represent a potentially accessible 270,000 PJ (defined) plus 100,000 PJ (inferred) that may in future be able to support > 10,000 MW of emissions-free power generation;
- Heat exchange within insulator (HEWI) hot rocks covering just 20 km² area by 1 km thick with an average temperature of 200°C in Petrathern's Paralana project area in the northern Flinders Range in South Australia could support the generation of 520 MW of electricity to the National Electricity Market over 25 years; and
- Hot wet sandstones in Panax's Limestone Coast Geothermal Project in the South Australian Otway Basin geothermal tenements (covering 2,674km²) represent a possibly accessible generating potential in excess of 1,500 MWe.

There are just a few of the many prospective Hot Rock project areas across Australia. Key advances in geothermal energy projects scheduled for conclusion in 2008 include:

- (1) drilling and flow test projects by companies;
- (2) a national geothermal resource assessment by Geoscience Australia; and
- (3) the Australian Federal Government's Geothermal Industry Development Framework which will include a roadmap for the deployment of geothermal energy technologies through a joint effort by Australian State and Federal governments (under the CoAG).

¹ Electricity Supply Association of Australia report titled, Energy and emissions study – Stage 2. Emissions Targets and Least Cost Generation Options See: <http://www.esaa.com.au/images/stories//energyandemissionsstudystage2.pdf>

² Tester, et al December 2006, The Future of Geothermal Energy. see: <http://geothermal.inel.gov>

³ McLennan Magasanik Associates, Renewable Energy – A contribution to Australia's Environmental and Economic Sustainability, 6/06. <http://www.rega.com.au/Documents/Publications/J1281%20Final%20Report%20V3%20Exec%20Summary.pdf>

CURRENT USE OF A HYDROTHERMAL RESERVOIR IN AUSTRALIA

The only geothermal power currently being consumed in Australia emanates from a small binary power station located in Birdsville⁴, Queensland (Fig. 1). This development draws from hot (98°C) hydrothermal waters at relatively shallow depths in the Great Artesian (also referred to as the Eromanga) Basin. The gross capacity of the plant, which is run by Ergon Energy, is 120 kW (gross) and exports 80 kW, with the plant operations consuming 40kW. Associated demand ranges from a minimum of ~120 kW to a maximum of ~ 300 kW. Total power generation at Birdsville in 2007 was 1,787,458 kWh of which 522,636 kWh was provided by the geothermal power plant with the remainder provided by auxiliary diesel powered generators. Ergon Energy has commenced a feasibility study into whether it can provide Birdsville's entire power requirements and largely relegate the existing 300 kW LPG and two 300 kW diesel-fuelled generators to peaking.

AUSTRALIAN GEOTHERMAL EXPLORATION AND PROOF-OF-CONCEPT PROJECTS

Since the grant of the first Geothermal Exploration Licence (GEL) in Australia in 2001 through to 2 April 2008, thirty-three companies have joined the hunt for renewable and emissions-free geothermal energy resources in 282 licence application areas covering ~219,000 km² across Australia (Fig. 1). Geothermal legislation promulgated since 2000, calls for licence applications and licence applications will attract considerable investment in geothermal projects in coming years in all Australian states. To 2 April 2008, the combination of supportive investment frameworks and quality geothermal resources have attracted about 80% of geothermal licence applications and forecast national expenditure for the term 2002 through 2013 to South Australia.

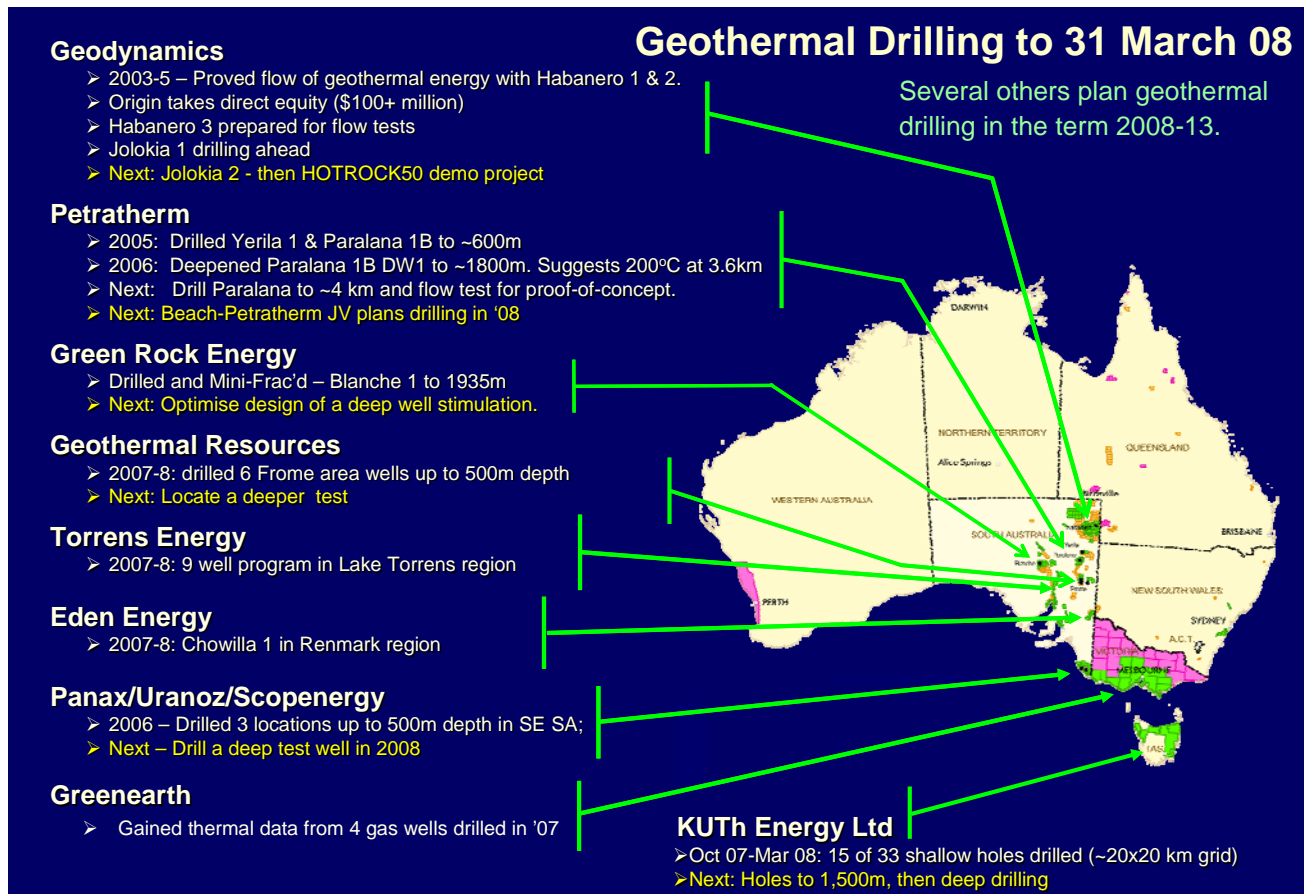


Figure 2: Location of geothermal drilling in Australia to 2 April 2008.

Since the drilling of Habanero 1 in by Geodynamics Limited in 2003 through to 2 April 2008, eight companies (Geodynamics Limited, Petratherm Limited, Green Rock Energy Limited, Geothermal Resources Limited, Scopenegy-Panax, Torrens Energy Limited, Eden Energy and KUTH Energy) have drilled a total of 42 wells to establish the extent of hot rock resources in Australia. In addition, Greenearth recorded temperatures and measured conductivities in cores cut in two petroleum wells drilling within its geothermal licences in 2007, and Pacific Hydro, Torrens Energy and Geothermal

⁴ See: http://www.epa.qld.gov.au/publications/p00834aa.pdf/Birdsville_geothermal_power_station.pdf

Resources undertook temperature surveys of pre-existing water bores and ascertained temperatures in wells drilled for petroleum to define high heat flow targets through end March 2008.

DRILLING TO END MARCH 2008

Geodynamics Limited

The most significant advancement in terms of demonstrating the potential of Hot Fractured Rock (HFR) energy in Australia is Geodynamics' drilling, fracture stimulation and flow testing project near Innamincka in the Cooper Basin in northeast South Australia (Fig. 2). Geodynamics has drilled three, and is drilling a fourth deep well in this project area, including: Habanero 1 (Total Depth: 4,421m), Habanero 2 (total depth: 4,357m), Habanero 3 (Total depth: 4,221m) and Jolokia 1⁵ (Planned total depth of 4,250m). Geodynamics' fourth well in the Cooper Basin, Jolokia 1, commenced drilling in March 2008 and is located 9.2 km WNW of Habanero 1, beyond the extent of the fracture network drilled with Habanero 1, 2 and 3, as defined during seismic monitoring during the stimulation of Habanero 1 and 2. The granites in Jolokia 1 are expected to be about 10°C hotter than at the same depths in the Habanero wells.

The Habanero Project was the first and remains the most advanced Hot Rock 'proof of concept' project in Australia. Flow of geothermally heated formation waters (20,000 ppm Total Dissolved Solids) at a maximum rate of 25 litres/second to surface at (up to) 210°C from Habanero 2 was achieved in 2005. The geothermal reservoir in the Habanero wells is a water-saturated, naturally fractured basement granite (250°C at 4,300 m as reported by Geodynamics) with permeability that was effectively enhanced by fracture stimulation. Two fractured reservoir zones are present in the Habanero wells: a shallower, less permeable zone at 4,200 m; and a deeper, more permeable zone below 4,300 m. Geodynamics' Habanero 3 has an 8 ½ inch hole through its HFR reservoirs (compared to 6 inch through reservoirs in Habanero 1 and 2). At the time of writing this report, Habanero 3 was sustaining production of 208 °C formation water at a rate of 18 kg/second at a flowing pressure of 27.5 MPa (3,990 psi) through a 12.5mm fixed choke. The flow is directed to a steam separator designed for up to 25 kg/second input, the rate achieved with an output temperatures of 210°C from Habanero 2 in 2005. Produced fluids from Habanero 3 flows through a variable choke capable of increasing production is available for trim (finely adjust the flow rate). In one short experiment lasting 3 minutes the variable choke was opened to 100% and production of 40 kg/second was sustained over that period. Productivity is 400% higher than that obtained from Habanero 2 in 2005, where lost down-hole equipment impeded flow and eventually caused blockage from the main fracture zone. During production and shut-in of Habanero 3, the monitored well head pressure at Habanero 1 responded as expected, indicating good communication between the wells at 4,250m depth. The high rates of injectivity into the heat exchanger from Habanero 1 and 2 and pressures measured at Habanero 1 and Habanero 3 during flow testing in March 2008 indicate the presence of a large volume of low impedance, water saturated reservoir where the rock temperature is 250°C (4.3 km). The flow tests of Habanero 1 and 3 will continue for some months in 2008, and will entail tracer injection between Habanero 1 (the injection well) and Habanero 3 (the production well) and closed-loop flow tests as a further step in demonstrating commercial viability

The horizontal extension of stimulated reservoirs at the Cooper Basin site lends itself to multi-well developments. Geodynamics' HOTROCK 50 project entails a proposed 9-well, 50 MWe power station. The 9 wells will be drilled 1km apart at 4km depth. This will entail 4 injection wells and 5 production wells forecast to yield 10MW net per well from flows of 120 kg/sec/well. This will be an important milestone for the demonstration of EGS from HFR in Australia and a stepping stone towards commercialising vast renewable and emissions-free geothermal energy supplies to meet Australia's future baseload energy requirements. Geodynamics believes that a successful flow test between Habanero 1 and 3 will lead to large-scale development of an extensive area of more than 1,000 km² where rock temperatures, stress conditions and rock properties are extensive and favourable for geothermal energy production. Two Australian Stock Exchange (ASX) listed companies with extensive upstream petroleum interests (Origin Energy and Woodside Limited) are cornerstone investors in Geodynamics. In November 2007, Origin agreed to take a 30% equity in the Cooper Basin geothermal licences operated by Geodynamics, while it also retains roughly 10%

⁵ Jolokia is named after the hottest chilli pepper listed in the Guinness Book of World Records

ownership of Geodynamics. Origin Energy's forecast expenditure in Geodynamics' Cooper Basin project is expected to be about \$100 million.

Petratherm Limited

Petratherm drilled two wells to establish thermal gradients down to about 600 m above exceptionally high heat producing granites in South Australia. Results from both wells were encouraging, with the Callabonna and Paralana sites (Fig. 2) respectively exhibiting 68 and 81°C/km thermal gradients. In June 2006, the phase-2 drilling program at Paralana was successfully completed with the geothermal test well being extended to 1,807 m. Temperature logging of the well suggests a world class thermal resource is located at Paralana, with extrapolations indicating 200°C can be expected at a depth of 3,600 m within insulating sedimentary rocks that are predicted to be susceptible to fracture stimulation. Petratherm refers to this play concept as Heat Exchange Within Insulator (HEWI). High heat producing basement rocks are a prerequisite for high quality HEWI plays.

Petratherm plans to create a HEWI system with the circulation of water between the two Paralana project wells to demonstrate hot rock EGS energy production from an initial small scale power plant that will supply up to 7.5 MW to a growing electricity market 10 km away at the Beverley Uranium Mine. This plan is the subject of a Memorandum of Understanding between Petratherm and the owners of the Beverley Mine, Heathgate Resources. An ASX-listed upstream oil and gas company (Beach Petroleum) has taken an equity position in the Paralana project. In November 2007, Petratherm signed a Letter of Intent for Ensign International Energy Services to secure a suitable rig and drill a Paralana well to 4,000 metres in the last half of 2008. Stimulation, flow testing and the drilling of a second well would follow, pending results of the first deep Paralana well.

Green Rock Energy

Green Rock drilled Blanche 1 (Fig. 2) to 1,935 m (718 m of sedimentary rocks and 1,216 m of homogenous hot granite) 8 km from the giant Olympic Dam mine in South Australia in 2005. The target granite is interpreted to persist to depths of 6,000 m over an area of about 400 km² and represents a potential geothermal resource in excess of 1,000 MWe. Cores and wireline logs from Blanche No 1 suggested natural fractures exist. In 1Q 2008, Green Rock undertook a mini-fracture stimulation program in Blanche 1 to inform the design of a deep well stimulation. Thirteen zones were tested and the well bore was imaged with a slim-hole acoustic televiewer to enable the analysis of fractures, post fracture stimulation.

Geothermal Resources Ltd

Geothermal Resources Limited is exploring a gravity low that could be a high heat producing granite associated with hot rock reservoirs predicted to be over 200°C at roughly 4,000m depth in its Frome project area (Fig. 2). Potential hot rock power markets for the Frome project electricity consumers connected to the National Electricity Grid, some 120 kms away (from the Frome area) at the township of Broken Hill. A number of active minerals exploration projects that lie between the Frome Project and Broken Hill are additional, potential future power markets.

Frome 2, 3A, 5 and 9 were each drilled to depths of approximately 500m in 2007, and have provided encouragement to commence a campaign of three shallow holes (Frome. 5, 10 and 11, each to 200–300 m) between Frome 3 and 9 in February 2008. Pending further encouraging results from the shallow drilling in 1Q 2008 and rig availability, Geothermal Resources will drill a Frome well to at least 1,000m in the first half of 2008, and use the information gained to drill a well to at least 3,000m in 2008.

Panax Ltd

Scopenergy was acquired by Uranoz (an ASX-listed company changing its name to Panax) in October 2007. In the first quarter of 2006, Scopenergy drilled 3 slim-hole wells in its Limestone Coast Project located near Millicent and Beachport in southeast South Australia (Fig. 2) to determine geothermal gradients and confirm several large scale heat flow anomalies previously measured in 19 petroleum exploration wells and 26 water wells in the vicinity of its tenements. In mid 2006 the company completed temperature logging of its 3 wells: Heatflow 1A, 3A and 4. Poor recovery of core samples from unconsolidated sediments and highly variable lithology affected the reliability of thermal conductivity measurements and hence, estimates of heat flow. Panax is currently assessing options to secure a rig for drilling a deep geothermal test well and searching for a joint venture partner.

Torrens Energy

Torrens Energy drilled five of its nine well program in its Lake Torrens project area in late 2007 (Fig. 2). Results from drilling those 5 wells to depths ranging 375m to 601m are encouraging, suggesting temperatures of 248°C ($\pm 6^\circ\text{C}$) to 202°C ($\pm 6^\circ\text{C}$) at 5,000m in the Lake Torrens project area. The aim of this program is to delineate heat flow trends as a precedent to locating deep proof-of-concept wells in proximity to the National Electricity Grid and power markets.

Eden Energy

Chowilla 1 was drilled to 512m in the Renmark-Tararra Trough, in the Riverland of South Australia, 40km northeast of Renmark. Chowilla-1 is located to establish geothermal resources in proximity to transmission lines running to Adelaide and Broken Hill.

Pacific Hydro

In the second quarter of 2006, Pacific Hydro conducted downhole temperature measurements on three water bores to a depth of 1,500m to confirm 56.1 °C /km, which suggests temperatures of 133 °C at 2,000m in the target Jurassic-aged Hutton and Poolowanna Formations. Laboratory permeability tests of Hutton core samples and thin section analyses provide further verification of high permeability at target reservoir depths. Two slim holes are planned to be drilled in 2009, in the gravity low (deepest, so hottest Jurassic targets) in the eastern section of Pacific Hydro's GEL. That drilling program will establish potential upside above the 133 °C temperature projected from measurements taken at 1,500m. These wells will drill in a geological setting with benign fluid chemistry, high permeability and lateral continuity. This drilling aims to establish a very large scale hydrothermal resource that could be developed with existing technologies.

Greenearth Energy Ltd

One of the cornerstone investors in Greenearth, Lakes Oil, is the operator of Petroleum Exploration Permits (PEPs) coincident with Greenearth's Geothermal Exploration Permits (GEPs) in the State of Victoria. Lakes Oil NL's Trifon-2 gas exploration well in 2004 (in PEP 157) in a petroleum exploration permit flowed 90° C water to surface from 2,200 metres within one of Greenearth's permits in the State of Victoria. Greenearth will also benefit from information obtained in four additional wells in petroleum permits coincident with its geothermal licences: Hazelwood-1 (PEP 166 - total depth: 2,081m) and Boola Boola-2 (PEP 166 - suspended with a log total depth of 1,715m); Alberton-1 (PEP 158 – total depth: 998m); and Napier High-1 (in an application area for a Petroleum Retention Licence – will be drilled after the grant of the relevant PRL). Greenearth has retained rights to deepen, core and log Boola Boola-2 from depths below 1,715m.

KUTh Energy Ltd

In October 2007, KUTh started its 2007/8 systematic (~20km x 20km), shallow (up to 300m each) 33 well drilling program with up to 2 drill rigs on 3 shifts. To end March 2008, 15 holes had been completed for a total of ~3,500m percussion drilling and coring. This shallow hole program is a precursor to locating holes to 1,500m, and then deep drilling locations.

EXPENDITURE

All Australian geothermal industry field expenditure to date is classed as research and is estimated at \$33 million for the calendar year 2007. This represents a 29% increase of \$7.3 million from the previous year. A 171% increase (to \$89 million) is forecast for 2008. The high level of competition for deep drilling rigs underpinned with high oil prices may be a factor in this forecast being achieved. To date, one company has bought a rig capable of drilling to at least 5,000m e.g. Geodynamics for its Cooper Basin project). A second company has signed a Letter of Intent to secure a rig capable of drilling to at least 4000m in the second half of 2008 e.g. the Petratherm – Beach Paralana Joint Venture. Historical, current and projected expenditure for 2008 are highlighted in Figure 3.

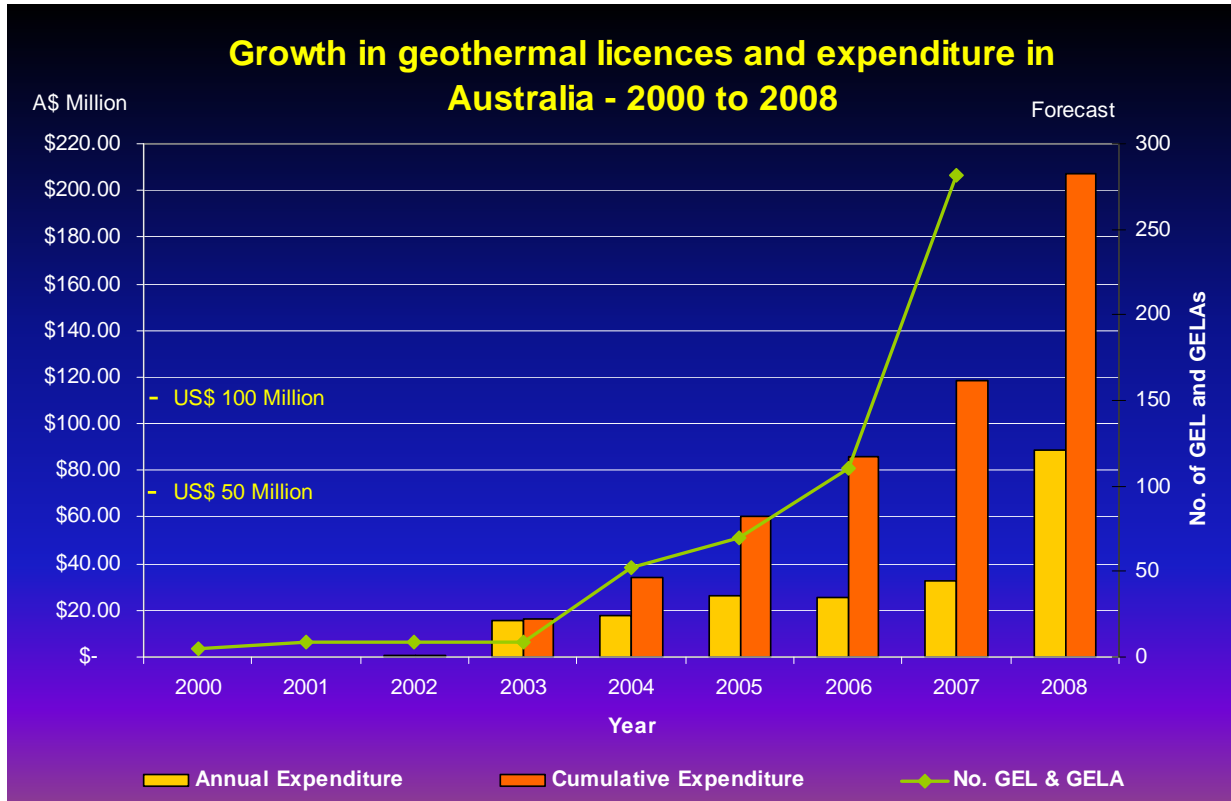


Figure 3: Geothermal Licence applications and exploration expenditure, 2000 to 2008. Source PIRSA

FUTURE COST OF HOT ROCK GEOTHERMAL ELECTRICITY

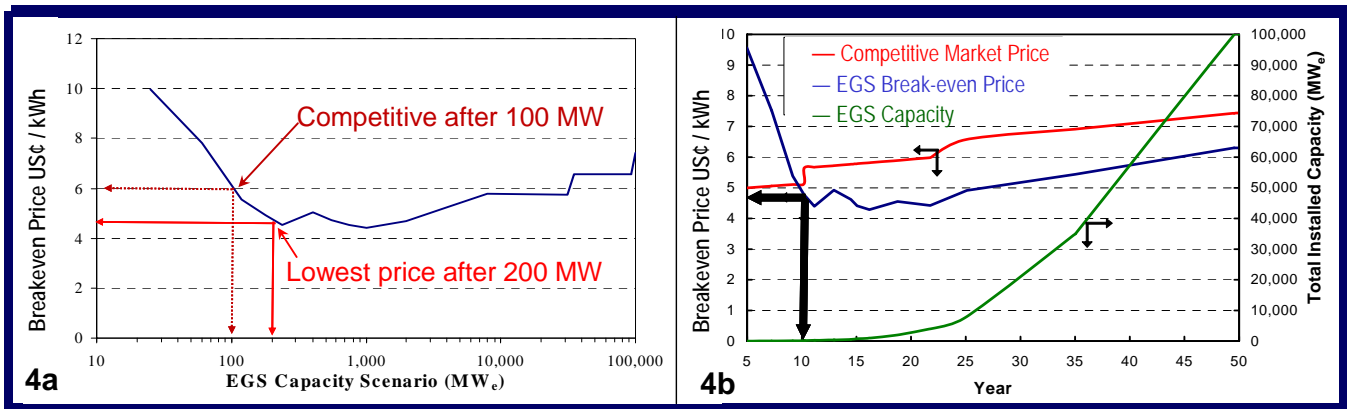
Assuming success in demonstration and proof of concept projects, the Electricity Supply Association of Australia concluded that 6.8% of all Australia's power could come from geothermal energy by 2030 under a "scenario that assumes no nuclear power and (CO₂) emissions reduced to 70% of 2000 levels by 2030" (ESAA, 2006⁶). The forecast 6.8% represents 5.5 GW in generating capacity from EGS. Without appropriate pull from Government and push from industry, the ESAA's (October 2007⁷) view will probably prevail e.g. that geothermal technologies are unlikely to be sufficiently advanced to make a significant contribution to the 20% target geothermal by 2020. At roughly 2% growth, Australia's power demand will grow from approximately 50 GW current generation capacity to approximately 80 GW in 2030.

The vast potential of Australia's Hot Rock resources can plausibly provide a more significant proportion of the nation's energy demand, and with the emergence of hybrid electric vehicles, geothermal energy may fuel a part of transport as well as stationary energy and regional heating and cooling needs. These views are consistent with conclusions reached by the Massachusetts Institute of Technology (MIT, December 2006) in its US Department of Energy commissioned assessment of the potential for Hot Rock geothermal resources to supply competitive electricity supplies into the US energy markets through 2050. Figures 4a

⁶ See: <http://www.esaa.com.au/images/stories/energyandemissionsstudystage2.pdf>

⁷ See http://www.esaa.com.au/media_releases/2006_media_releases/alp_interim_renewable_energy_target.html

and 4b illustrate conclusions drawn by MIT in relation to the development of Hot Rock geothermal resources (in the form of EGS) in the USA.



Figures 4a and 4b – US\$ cost reductions forecast for EGS through its development and deployment to 2050. Costs are expected to fall to levels competitive with coal- and gas-fired electricity without the cost of carbon in the price of coal- and gas-fired power. From Tester, et al (2006) Future of Geothermal Energy available from <http://www.geothermal.inel.gov>

According to South Australia’s Electricity Supply Industry Planning Council’s 2007 Annual Report, Australia’s initial 7.5 to 250 MWe geothermal power plants are forecast to have power generation costs between \$70 and \$130 per MWh with a 90% capacity factor. Proponents of geothermal power supplies (including Geodynamics, Petrathern, and others), industry lobby groups (including REGA and the ESSA) and respected energy sector consultants (including MMA) forecast that the costs of generation from Hot Rock resources will fall to a range of \$60–\$100 per MWh. Figure 5 illustrates the current costs of power generation from alternative fuels, including geothermal, coal, wind, gas and nuclear energy. Without carbon pricing, many forms of conventional energy generation such as coal and natural gas are more cost effective.

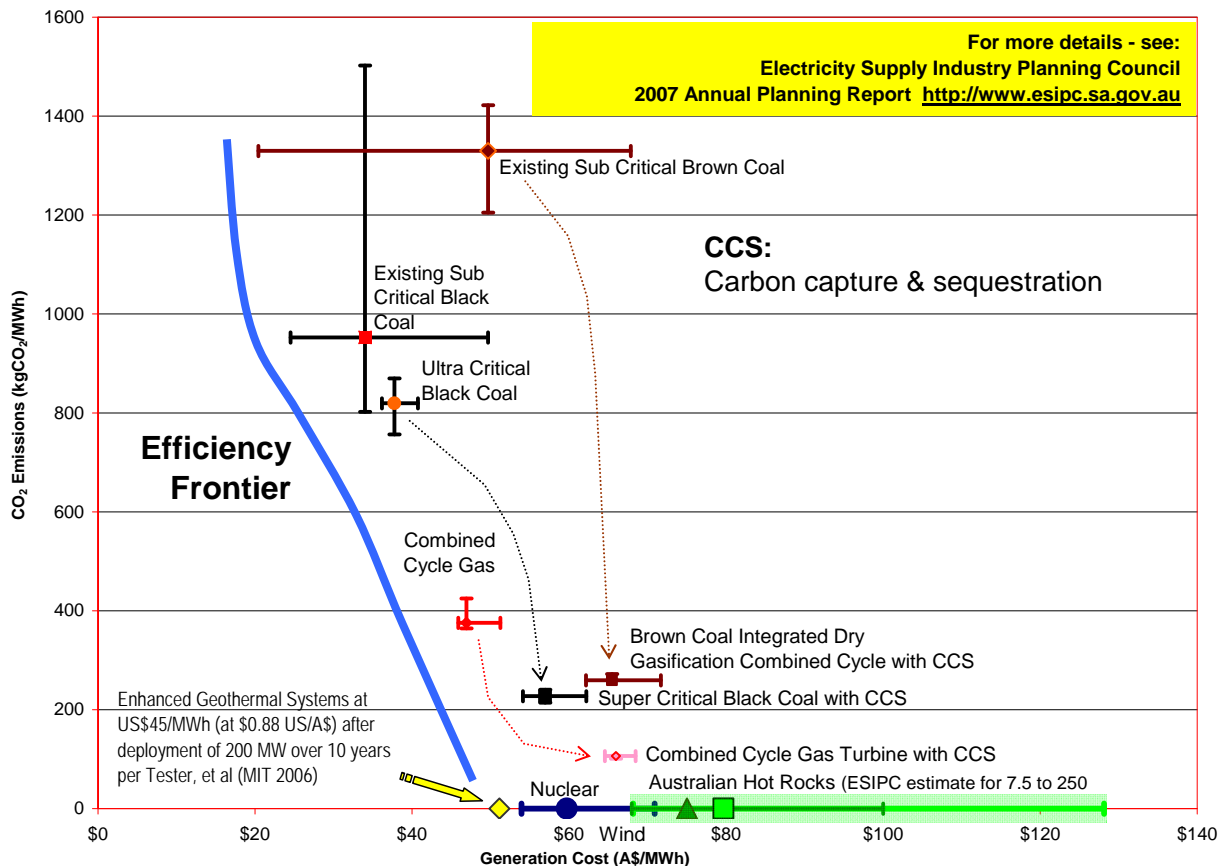


Figure 5: CO₂ emissions (Kg/MWh) on the vertical axis versus A\$ costs to generate electricity power in Australia on the horizontal axis to indicate relative costs and CO₂ emissions from various fuels, with and without carbon capture and storage (geosequestration). Source: Electricity Supply Industry Planning Council 2007 Annual Planning Report.

The Australian Federal Government intends to have a National Emissions Trading Scheme starting in 2011, and has set a target of 60,000 GWh of renewable energy consumption by 2020. That target is about 20% of the total, forecast electricity consumption in 2020. Expeditious and compelling results from Hot Rock demonstration projects in the next 5 years will be drivers for geothermal power taking up a material proportion of that target consumption. The AGEG's vision is for Hot Rock power to fuel at least 10% of Australia's base load power demand by 2050. A greater market share for geothermal power may be feasible, too.

Table 2. The following grants plus government programs that foster exploration and development put government support for the learn-while-doing phase at more than \$100,000,000 since 2000.

Grant	Date	Recipient	Project	A\$ Amount
Fed. RECP	2000	Pacific Power/ANU	Hunter Valley Geothermal Project, NSW	\$ 790,000
Fed. START	2002	Geodynamics	Habanero Project, SA	\$ 5,000,000
Fed. REEF	2002	Geodynamics	Habanero Project, SA	\$ 1,800,000
Fed. GGAP	Mar 05	Geodynamics	Kalina Cycle to produce 13 MW from waste heat at the Mt Keith Nickel Mine in WA	\$ 2,080,000
Fed. REDI	Dec 05	Geodynamics	Habanero Project, Cooper Basin, SA	\$ 5,000,000
Fed. REDI	Dec 05	Scopenergy	Limestone Coast Geothermal Project, SA	\$ 3,982,855
SA PACE	Apr 05	Petratherm	Paralana Geothermal Project, SA	\$ 140,000
SA PACE	Apr 05	Scopenergy	Limestone Coast Geothermal Project, SA	\$ 130,000
SA PACE	Apr 05	Eden Energy	Witchellina Project, SA	\$ 21,000
SA Grant	June 05	U of Adelaide	Induced seismicity – Cooper Basin, SA	\$ 50,000
SA Grant	Dec 05	Geodynamics	Cost: benefit evaluation of developing Australia's hot rocks a study to confirm hot rock development could meet LETDF criteria: 2% national emission savings	\$ 40,000
SA PACE	Dec 05	Geothermal Resources	Curnamona Geothermal Project, SA	\$ 100,000
SA PACE	Dec 05	Green Rock	Olympic Dam Geothermal Project, SA	\$ 68,000
Fed. REDI	July 06	Geothermal Resources	Frome Geothermal Project, SA	\$ 2,400,000
Fed. REDI	Dec 06	Proactive Energy	Adapting supercritical cycles to geothermal power application	\$ 1,224,250
SA PACE	Dec 06	Torrens Energy	Heatflow Exploration in Adelaide Geosyncline, SA	\$ 100,000
SA PACE	Dec 06	Eden Energy	Renmark Geothermal Project, SA	\$ 100,000
SA PACE	Dec 06	Geodynamics	High Temperature Borehole Image logging of Habanero 3, Cooper Basin, SA	\$ 100,000
Fed. REDI	Feb 07	Petratherm Ltd	Paralana Geothermal Project, SA	\$ 5,000,000
SA Grant	May 07	U of Adelaide	Induced seismicity protocols – SA	\$ 50,000
SA Grant	June 07	U of Adelaide	Research posed by the AGEG	\$ 250,000
Fed. REDI	Aug 07	Torrens Energy	3D modelling of hot rock resources, SA	\$ 3,000,000
Qld Grant	Oct 07	U Queensland	Geothermal energy research, Qld	\$15,000,000
SA PACE	Feb 08	Petratherm	Shear wave splitting for Hot Rock exploration, SA	\$ 100,000
SA PACE	Feb 08	Torrens Energy	2D seismic on a Hot Rock play in the Adelaide Plains, SA	\$ 100,000
REDI	Feb 08	KUTh	Geothermal energy from pre-fractured hot granites, Tasmania	\$ 1,800,000
WA Grant	Mar 08	U of WA	WA Geothermal Centre of Excellence, WA	\$ 2,300,000

Grants to end March 2008: \$50,726,105

Minimum grants for meritorious geothermal drilling from the Australian Renewable Energy Fund: \$50,000,000

FUTURE COST OF DIRECT HEAT USE IN HYDROTHERMAL SEDIMENTARY BASINS

Using heat from hydrothermal basins, so prominent in Australia, can significantly broaden the application of geothermal energy exploitation. While direct heat use in farming, fish ponds and balneology, is the oldest form of geothermal energy use, new initiatives that are capable of extracting more than 1 MW thermal power are under development. In Australia such novel concepts are geothermal heat driven desalination, absorption and adsorption air conditioning and refrigeration and industrial preheating and dehumidification. Since no demonstration plant is operating at present it is still early days for estimating costs. The financial scale of these operations will, however, be considerably lower than the Australian hot rock projects. Distributed direct heat use is particularly attractive to develop areas where no infrastructure (water pipelines, power lines) are present. It therefore offers a complimentary low risk entry into geothermal providing comparatively small scale distributed energy sources.

PROGRESS TOWARDS COMMERCIALISATION OF GEOTHERMAL ENERGY

There have been a number of industry and government initiatives to foster investment in geothermal energy exploration, proof-of-concept, and demonstration projects, toward the commercialisation of geothermal energy resources. These initiatives include:

- Stimulating significant exploration and proof-of-concept investment with attractive legislation, policies and programs:
 - Since 2000, the Australian Federal and State Governments have committed more than \$100 million in grants and studies for geothermal exploration and proof-of-concept projects (Table 2). Australian Federal and State Government grants to advance geothermal power development correspond to roughly 25% of industry's investment for Hot Rock exploration in Australia in the term 2000-2007;
 - The direction of part of the \$59 million Federal Government's Onshore Energy Security Program in 2006-2011 towards the provision of precompetitive geoscience data for the advancement of geothermal energy;
 - \$50 million of Australian Federal Government's \$500 million Renewable Energy Fund budget is reserved for the co-funding (with industry) meritorious hot rock drilling projects.
- Membership in the International Energy Agency's Geothermal Implementing Agreement (GIA) Research Cluster;
- In November 2006, the establishment of a whole-of-sector interest group, the Australian Geothermal Energy Group (AGEG – see Table 1), to provide support for Australia's membership in GIA and facilitate engagement with the international geothermal community. The AGEG is a geothermal sector cluster for industry, government and research organisations;
- The Australian Federal Government's Geothermal Energy Development Framework which will also result in the development of a CoAG roadmap for the development of Australia's geothermal energy resources and technologies (due in 2008). and
- In November 2007, corporate members of the AGEG agreed to create a new peak geothermal industry directorate – the Australian Geothermal Energy Association (AGEA). The aim of the AGEA is to provide a unified voice to key stakeholders, notably governments, on matters of policy affecting the geothermal industry. The AGEA has stated its intentions to complement other major geothermal initiatives – notably the Australian Geothermal Energy Group (AGEG) and the Australian Geothermal Industry Development Framework. The AGEA has asked the AGEG to become the Australian affiliate of the International Geothermal Association, and all company members of the AGEA are also members of the AGEG

Australian Geothermal Energy Group (AGEG)

The AGEG formed in late 2006. The AGEG's vision is for geothermal resources to provide the lowest cost emissions-free renewable base load energy for centuries to come. At year-end 2007, a total of 65 organisations have named representatives to the AGEG including representatives from 48 companies (including all Geothermal Exploration Licence holders in Australia), the Australian Federal Government, the governments of all six Australian States and the Northern Territory, the







CEO of the AGEA, and well-respected researchers from 10 academic institutions, with more likely to join hence. Government organisation members in the AGEG include all the agencies with a focus on the investment attraction and/or geothermal energy exploration and production licensing; and key research organisations, including: Geoscience Australia; the CSIRO; the Federal Australian Department of Climate Change (Australian Greenhouse Office); the Department of Resources, Energy & Tourism (including the Federal representatives to the Senior Council of Officials to the Ministerial Councils for Energy, Minerals and Petroleum Resources); SA's PIRSA; Victoria's DPI; WA's DOIR; NSW's DPI; Queensland's DME; NT's DPIFM; Tasmania's DIER; as well as other government agencies keenly interested in the prospects for geothermal energy becoming a major source of emissions-free base load power for Australia. The corporate members of the AGEG have formed an industry directorate – the Australian Geothermal Energy Association (AGEA - to amplify the coordinated voice of Australian geothermal companies.


AGEG – AGEA Technical Interest Groups (TIGs)

To foster the achievement of these objectives, in 2007, the AGEG established ten Technical Interest Groups (TIGs) as outlined in Table 3. The AGEG and the AGEA have since agreed to coordinate research efforts through the AGEG's 10 Technical Interest Groups (TIGs). This will facilitate Australian companies, research experts and government agencies (including regulators) to convey and take note of international best practices for the full-cycle of below-ground and above-ground geothermal energy operations and stewardship;

The industry policy forum under AGEG's TIG 3 has evolved into the AGEA.

The AGEG's TIGs will have active links to the International Energy Agency's (IEA's) research annexes, and will aim to attain strong linkages to all other reputable international geothermal research clusters, to ensure that Australia's comparative advantages in hot rock geothermal resources can be leveraged into international leadership in geothermal technologies, methods and development. On this basis, the AGEG and the AGEA have agreed that the AGEG should become the Australian affiliate for the International Geothermal Association. This will foster links to reputable international research.

 Australian Geothermal Energy Group (AGEG) Technical Interest Groups (TIGs)			
AGEG Technical Interest Group (TIGs)		Purpose –Share Information to Learn-While-Doing with Maximum Effect & Efficiency	TIG Leaders / Members
 1	Land Access Protocols (induced seismicity, emissions, native title, etc)	Management of environmental concerns and potential impacts of geothermal energy and devises protocols to avoid or minimize impacts.	TIG Co-leaders: Mike Malavazos / Barry Goldstein
2	Reserves and Resource (Definitions)	Align with similar International forums	TIG Leader: Adrian Williams, Geodynamics
3	Policy Issues *Industry Forum (AGEA) *Whole-of-Sector Forum (AGEG)	Industry advice to Governments – NOW <u>AUSTRALIAN GEOTHERMAL ENERGY ASSOCIATION</u>	TIG Leader: Susan Jeanes, AGEA
 4	Engineered Geothermal Systems	Investigate technologies for enhancing geothermal reservoirs for commercial heat extraction.	TIG Leader: Doone Wyborn Geodynamics (also IEA Annex III leader).
5	Interconnection with Markets	Transmission, distribution, network, NEM issues	TIG Co-Leaders: Ian Stirling, Electranet and Terry Kallis, Petrathern
 6	Geothermal Power Generation	Develop scenarios as a basis for comparison of cycles, plant performance and availability, economics and environmental impact and mitigation. The output would be a database and guidelines of best practice.	TIG Co-Leaders: Hal Gurgenci, U of Queensland Behdad Moghtaderi, U of Newcastle
 7	Direct Use of Geothermal Energy (including geothermal heat pumps)	Direct use for heating and cooling, with emphasis on improving implementation, reducing costs and enhancing use	TIG Co-Leaders: Klaus Regenauer-Lieb, CSIRO / U WA Don Payne – CoreEnergy/U of Melbourne
8	Outreach (Including Website)	Create informed public through accessible information. Provide educational kits for media, K-12 and university education.	TIG Leader: Tony Hill, PIRSA
9	Data management	Database design, contents and ongoing enhancements.	TIG Leader: Anthony Budd, Geoscience Australia
 10	Wellbore operations	Cover drilling, casing, logging, fracture stimulation, testing, etc	TIG Leader: Cam Selin, Clean Energy Australasia

 Parallels an IEA R&D Annex

Fed Government: \$32,077,000 grants for company projects & University research to end March 07
 SA Government: \$1,350,000 grants for company projects & University research to end March 07
 Qld Government: \$15,000,000 grant to U of Queensland for geothermal research over 5 yrs
 WA Government \$2,300,00 grant to the U of WA for geothermal research

Table 3. The AGEG's Technical Interest Groups

Current AGEG Research Activities

The principal focus topics of current Australian research relate to:

- Identification and targeting of locations with high potential for the development of Hot Rock geothermal;;
- Reserve and resource definitions;
- Assessment of technologies (including numerical simulation techniques) with high potential to minimise costs and maximize efficiencies in the development of Hot Rock geothermal resources;
- Environmental impacts of developing Hot Rock geothermal resources, including potential induced seismicity that can be associated with the fracture stimulation of EGS reservoirs; and
- Modeling future energy supply: demand scenarios.

Government support (in the form of grants for exploration and proof-of-concept projects) has been instrumental in progressing geothermal research... Federal and State grants provided to underpin geothermal company projects and research that addresses both local and sector-wide uncertainties are listed in Table 1.

FEDERAL SUPPORT AUSTRALIAN GEOTHERMAL PROJECTS AND RESEARCH

As detailed in Table 2, to the 2 April 2008, the Federal Government has provided \$32,077,000 in grants for Australian geothermal projects and research. Additional Federal Government support will be crucial to the efficient deployment of geothermal power into Australian energy markets, and significant Federal Government initiatives are underway to define the sensibly efficient and effective means of support. Two key Federal government initiatives are Geoscience Australia's Onshore Energy Security Program and the Geothermal Industry Development Framework as described. The South Australian, Queensland and Western Australian State governments have also implemented programs that support the advancement of geothermal projects and geothermal research. Descriptions of key programs follows.

Australian Federal Government's Geothermal Industry Development Framework

The Australian Federal Government instigated a Geothermal Industry Development Framework in March 2007. Work will be completed in 2008. A series of workshops was held in November and December 2007 on the following topics:

1. Development of a Geothermal Technology Roadmap
2. An assessment of the research, training and skills development infrastructure of the Australian geothermal sector
3. Assessment of the legislative and regulatory framework governing the Australian geothermal sector
4. Analysis of private sector and government financing structures supporting the Australian geothermal sector
5. Identify community concerns regarding geothermal technologies and develop response strategies

The draft framework and roadmap are being developed and will be presented at a final workshop expected to be held in May 2008.

Geoscience Australia (Federal Government) Onshore Energy Security Program

A part of the Australian Federal Government 2006–11, \$58.9 million Onshore Energy Security Program will enable Geoscience Australia to acquire precompetitive data and conduct research in support of geothermal energy exploitation. Key activities will include:

- acquisition of additional, infill (precompetitive) geothermal and cognate data (including new thermal conductivity and heat flow measurements);
- acquisition of new radiometric, seismic, magneto-telluric, gravity and magnetic data;

- construction of an information system for the dissemination of geothermal and associated data, including consolidation of existing geothermal data and development of agreed data interchange formats with State government partners;
- develop play maps that will characterise the key geologic factors that determine the extent of Hot Rock plays;
- assessments leading to a new detailed map of temperature at five kilometers crustal depth with refined gridding techniques, and a national geothermal resource assessment calculated from this; and
- other activities to support the growth of the industry including outreach and education, participation in AGEG Technical Interest Groups and co-funded projects, and provision of advice to government.

Commonwealth Science & Industry Research Organisation (CSIRO)

The Energy Transformed Flagship of the CSIRO will invest \$3.47 Million into the Western Australian Geothermal Centre of Excellence over its lifetime. This initiative is initially incorporated into the Flagship's— Low Emission Distributed Energy Theme. This is a first step in consolidating a number of CSIRO capabilities in the geothermal arena. These areas of expertise include: Geomechanics, Subsurface Heat Exchange, Surface Heat Exchangers/Multi-Phase fluid flow, Permeability Enhancement by Hydraulic Fracturing, Geochemical Thermal History Analysis, Optimal Design of Renewable Systems, Fluid-rock interaction analysis, Novel Low/Medium T Geothermal Uses, Remote Sensing, Exploration geophysics, and Integration of Geothermal Technology with Public Perception and Awareness. In addition to the investments into the WA Geothermal Centre of Excellence, CSIRO plans to respond to and develop geothermal industry relationships and to co-fund research projects. In the longer term CSIRO plans to assist the “hot rock” sector by expanding its geothermal initiatives into the Low Emission Electricity renewable energy stream of the Energy Transformed Flagship.

SOUTH AUSTRALIAN GOVERNMENT SUPPORT FOR GEOTHERMAL RESEARCH

As detailed in Table 1, in the term April 2005 to the 2 April 2008, the South Australian Government has provided \$1,350,000 in grants for Australian geothermal projects and research, and additional support is expected. In 2005, the Primary Industries and Resources South Australia (PIRSA) commissioned research by the Australian School of Petroleum at University of Adelaide to undertake a research study of potential induced seismicity associated with the fracture stimulation of ESG wells in the Cooper Basin. This research was undertaken to underpin PIRSA's approach to the regulation of fracture stimulating Hot Rocks. The results of this study are detailed in Hunt *et al.* (2006)⁸. Key conclusions are:

- The Cooper Basin in South Australia is ideally suited to Hot Rock EGS activities in terms of natural background seismicity levels;
- Reactivation of any basement faults in the region is unlikely in the vicinity of the Habanero Site; and
- Seismic events induced by reservoir stimulation at the Habanero well site in the Cooper Basin were of low magnitude (intensity) and fell below the background level that the government's current building design standards allow-for. The petroleum industry operating in the same area have been using similar reservoir fracture stimulation methods safely for decades.
- The static stress damage zone would not be expected to have any impact on identified local structural features. This is due to the nearby faults being beyond the reach of the induced seismicity associated with reservoir stimulation activity.

Also in 2005, the Department of Primary Industries & Resources – South Australia (PIRSA) agreed to be the Contracting Party to the OECD's International Energy Agency's geothermal research cluster under the auspices of the Geothermal Implementing Agreement (GIA).

⁸ Hunt, et al (2006) can be found at www.iea-gia.org/publications.asp

In early 2006, to foster the commercialisation of Australia's hot rock resources at minimum cost and maximum pace, PIRSA reached out to Australian companies, researchers and government agencies with an interest in the development of Australia's geothermal resources, and in mid 2006, the Australian Geothermal Energy Group (AGEG) formed to provide a sector wide alliance to benefit from, and provides intellectual input into the GIA.

In May - July 2007, PIRSA made two tied grants to the University of Adelaide to foster the emergence of South Australian universities to become the world's hub for excellence in innovative Hot Rock geothermal energy research, demonstration and development projects. These include:

- A \$50,000 tied grant to extend the findings from Hunt, et al. (2006) to the Adelaide Geosyncline. This will enable an analysis of induced seismicity risks associated with geothermal reservoir stimulation operations. This will result in the establishment of peer-reviewed protocols for assessing and managing potential induced seismicity risks arising from these activities. The resulting protocols will also have relevance to induced seismicity risk management for geosequestration operations. The protocols will have direct application to regions identified to be of high Hot Rock potential in Australia. Operators of geothermal energy projects in Australia will then have a credible foundation to develop or their own hazard management strategies to avoid negative impacts from induced seismicity. PIRSA's regulatory aim is two-fold: (1) foster robust risk-management frameworks and (2) sustain widespread, multiple-use land access for geothermal energy projects by attaining stakeholders' confidence that regulated activities undertaken by companies will deliver safe and sustainable operations; and
- A \$250,000 tied-grant to initiate Hot Rock geothermal research in the South Australian context. The tied grant requires project plans to be agreed by the geothermal sector – through the Australian Geothermal Energy Group (AGEG). The framework specified in the relevant Deed between the University of Adelaide and South Australia's Minister for Mineral Resources Development is designed to:
 - Enable and stimulate national and international collaboration in geothermal energy research;
 - Attract in-kind and financial inputs from non-SA Government sources that are a multiple of the SA Government inputs. The Australian geothermal industry, the Federal Government (through Geoscience Australia and the CSIRO) and capable universities both in and outside South Australia (in addition to the University of Adelaide) are expected to welcome and participate strongly in this initiative, and/or complementary initiatives to follow; and
 - Ensure that funded projects are focused on what Industry considers to be high priority research, findings undergo high quality peer review, and final reports of findings are prepared and made freely and openly available.

The criteria for tied grants are designed to:

- Underpin practical, high priority research aligned with the geothermal industry's emerging requirements and endorsed by the AGEG and an AGEG Technical Interest Group Leader;
- Entice at least matching funds from project participants, thus creating leverage for practical, high priority research aligned with the geothermal industry's emerging requirements;
- Foster collaboration between industry and university researchers from across Australia by allowing up to 80% of the funds for any single project (and up to 80% of the \$250,000 tied grant) to be used to bring in expertise from outside the University of Adelaide, thus enabling other capable institutions (in South Australia and elsewhere) to participate in studies relevant to the advancement of geothermal energy development with generic and/or specific application to South Australian geothermal projects.

Australian Geothermal Energy Group Submission to Garnaut Review Issues Paper 4

Table 4. AGE G endorsed research projects supported with joint PIRSA and geothermal sector support.

Theme	Project Name	Summary of key project objectives	Research Partners
AGEG TIG 4 Engineering EGS	Geochemistry, Corrosion and Scaling in HDR Energy Extraction Systems	Determine the effect of variations in geochemical composition of circulating water on clogging of fracture networks in reservoir rock. Budget: \$110,000 (50% from sector participants)	<ul style="list-style-type: none"> ◆ U Adel (Ngothai & O'Neil) ◆ S.A Museum (Brugger) ◆ Ian Warke Inst. U of SA (Pring) ◆ Geodynamics (Wyborn) ◆ Petratherm (Reid) ◆ Eden Energy (Jeffress) ◆ Greenrock (Larking) ◆ Geothermal Resources (Johnson) ◆ PIRSA (Malavazos)
AGEG TIG 4 Engineering EGS	Full life-cycle water requirements for deep geothermal energy developments in South Australia	Water requirements for each step of geothermal through production will be quantified. An atlas of available water resources; processes for accessing these resources; and (possibly) software for calculating water requirements for specific projects will be developed. The aims are to allow individual project managers to manage water availability, and the industry to counter potential community concerns over water use for geothermal projects. Budget: \$33,000 (\$12,375 from PIRSA Tied Grant; balance from sponsor participants)	<ul style="list-style-type: none"> ◆ Hot Dry Rocks Pty Ltd (HDRPL: Beardsmore, Baria, Cordon, Walsh, Waining & Cooper) ◆ PIRSA (Hill) ◆ Panax (de Graaf)
AGEG TIG 6 Engineering Power Generation	Preliminary assessment of the impact of geo-fluid properties on power cycle design	Study the relationship between the effect of non-condensable gas, fouling and corrosion caused by geofluid properties on surface heat exchangers and the heat transfer efficiency of the exchangers. Budget: \$85,729 (\$6,784 from PIRSA Tied Grant; balance from sponsor participants)	<ul style="list-style-type: none"> ◆ U Adel. (Ashman, Gamboa & Nathan) ◆ Petratherm (Reid) ◆ Pac Hydro (Teoh) ◆ Eden Energy (Jeffress) ◆ Greenrock (Larking) ◆ PIRSA (Malavazos)
AGEG TIG 6 Engineering Power Generation	Preliminary assessment of the potential for underground cooling on power cycle design	Test the cost-saving potential of using the thermally cool and stable soil layer to cool surface geothermal exchangers, pipework and plant. Compare different underground cooling systems with air cooling systems in Australian conditions. Budget: \$44,550 (\$22,275 375 from PIRSA Tied Grant; balance from sponsor participants)	<ul style="list-style-type: none"> ◆ U Adel. (Dally, Nathan & Ashman) ◆ Pac Hydro (Teoh) ◆ Petratherm (Reid) ◆ Eden Energy (Jeffress) ◆ Greenrock (Larking) ◆ Geothermal Res (Johnson) ◆ KUTh (Ward) ◆ PIRSA (Malavazos)
AGEG TIG 6 Engineering Power Generation	State of the Art in Power Cycles for geothermal applications and bottoming cycles	Make a detailed comparison of the performance and operating conditions of selected existing geothermal power plants with the range of conditions expected to apply in South Australia. Develop a detailed model of the Kalina cycle using HYSYS and compare with existing models - ORC and SC. Budget: \$83,710 (\$41,855 from PIRSA Tied Grant; balance from sponsor participants)	<ul style="list-style-type: none"> ◆ U of Newcastle (Doroodchi) ◆ U Adel (Nathan & Ashman) ◆ Pac Hydro (Teoh) ◆ Petratherm (Reid) ◆ Eden Energy (Jeffress) ◆ Greenrock (Larking) ◆ PIRSA (Malavazos)
AGEG TIG 6 Engineering Power Generation	Development of a geothermal power plant cost estimator - Stage 1: basic estimates	Develop a model to estimate costs of geothermal power generation (South Australian conditions). The model will provide input options for key variables such as well depth, ambient conditions, geofluid temperature etc. Budget: \$40,979 (\$8,610 from PIRSA Tied Grant; balance from sponsor participants)	<ul style="list-style-type: none"> ◆ U Adel.(Nathan) ◆ Petratherm (Reid) ◆ Eden Energy (Jeffress) ◆ Greenrock (Larking) ◆ PIRSA (Malavazos)
AGEG TIG 4 Geology EGS	Adelaidean reservoir characterisation	Characterise Adelaidean rocks for their potential to serve as heat exchange reservoirs within geothermal insulators and potential for geosequestration reservoirs in the vicinity of coal-fired electricity plants in the Port Augusta region Budget: \$55,000 (\$27,500 from PIRSA Tied Grant; balance from sponsor participants)	<ul style="list-style-type: none"> ◆ U Adel. (Ainsworth) ◆ Petratherm (Reid) ◆ Eden Energy(Jeffress) ◆ Torrens (Matthews) ◆ PIRSA (Hill)
AGEG TIG 9 Geology Data Management	Forward prediction of spatial temperature variation from 3D geology models	Develop model for rapid calculation of spatial variations of temperature from 3D geology. Compare model-derived temperatures with observed to refine model. Demonstrate methodology via a case study of Petratherm's Paralana Project. Budget: \$110,000 (\$27,500 from PIRSA Tied Grant; balance from sponsor participants)	<ul style="list-style-type: none"> ◆ Intrepid (Gibson & Calcagno), ◆ GA (Budd) ◆ Petratherm (Reid) ◆ Eden Energy (Jeffress) ◆ PIRSA (Hill)
AGEG TIG 4 Geology EGS	3D reconstruction of the Adelaide Geosyncline	Produce a geologically and geophysically sound 3D model of the Adelaide Geosyncline from studies of outcrop geology (existing geological maps, satellite images analysis, field work) and potential field data (gravity and magnetic data) interpretation and forward modelling. Budget: \$248,324 (\$27,858 via PIRSA Tied Grant; balance from sponsor participants)	<ul style="list-style-type: none"> ◆ U Adel. (Backe & Giles) ◆ U of Pau (France); ◆ U of Toulouse (France) ◆ HDRPL (Beardsmore) ◆ Torrens (Matthews)
AGEG TIG 2 Geol. / Engin../ Finance Reserve Definitions	Geothermal Reserve and Resource Estimates and Definitions	Establish a trustworthy code and guidelines for estimates of the in-place and extractable geothermal heat energy in hot rock resources. Sustain the draft to international peer review, including comments from the ASX, the JORC Committee, the IEA's GIA, AGE G members, and others. Budget: \$27,500 (50% from sector participants)	<ul style="list-style-type: none"> ◆ SKM (Lawless) ◆ Geodynamics (Williams); ◆ GA (Holgate); ◆ Petratherm (Reid) ◆ Torrens (Matthews) ◆ Greenrock (Larking); ◆ HDRPL (Beardsmore) ◆ Eden (Graham Jeffress) ◆ KUTh (Ward) ◆ Intrepid (Gibson) ◆ PIRSA (Goldstein)

Table 4 summarises the nature of the AGEG endorsed research projects underway under the South Australian Grant to the University of Adelaide. The aggregate budget for these AGEG endorsed research projects is \$ 737,538 (including \$250,000 from PIRSA). The quality and impact of reports on findings and scope of inputs from non-SA Government sources are key performance indicators for this initiative. The findings of these research projects will be made freely available, and the experience gained will inevitably be leveraged into further valuable research and the development of a service sector for the geothermal industry. This initiative will be complementary to any/all other proposals from the Federal Government and other jurisdictions to support geothermal research.

QUEENSLAND GOVERNMENT SUPPORT FOR GEOTHERMAL RESEARCH

In September 2007, the Queensland State Government committed \$15 million to the Queensland Geothermal Energy Centre of Excellence (QGCoE) at the University of Queensland for research towards exploitation of the geothermal reserves of Queensland through: (1) resource management and optimization; (2) optimum power conversion; (3) power plant cooling systems; and (4) long-distance electricity transmission. The Centre will work with other national and international research groups to address challenges that need to be overcome before geothermal energy becomes a proven commercial reality. The specific research plans for the Queensland Geothermal Energy Centre will be finalised by September 2008. It is expected that a major thrust of the Centre will be the supercritical CO₂ geothermosiphon directed towards a field demo project in 2013 as shown in Figure 6. The Centre will also pursue novel power conversion systems for more conventional binary geothermal power plants, air-cooled heat exchangers and long-distance power transmission and electricity market and network modelling.

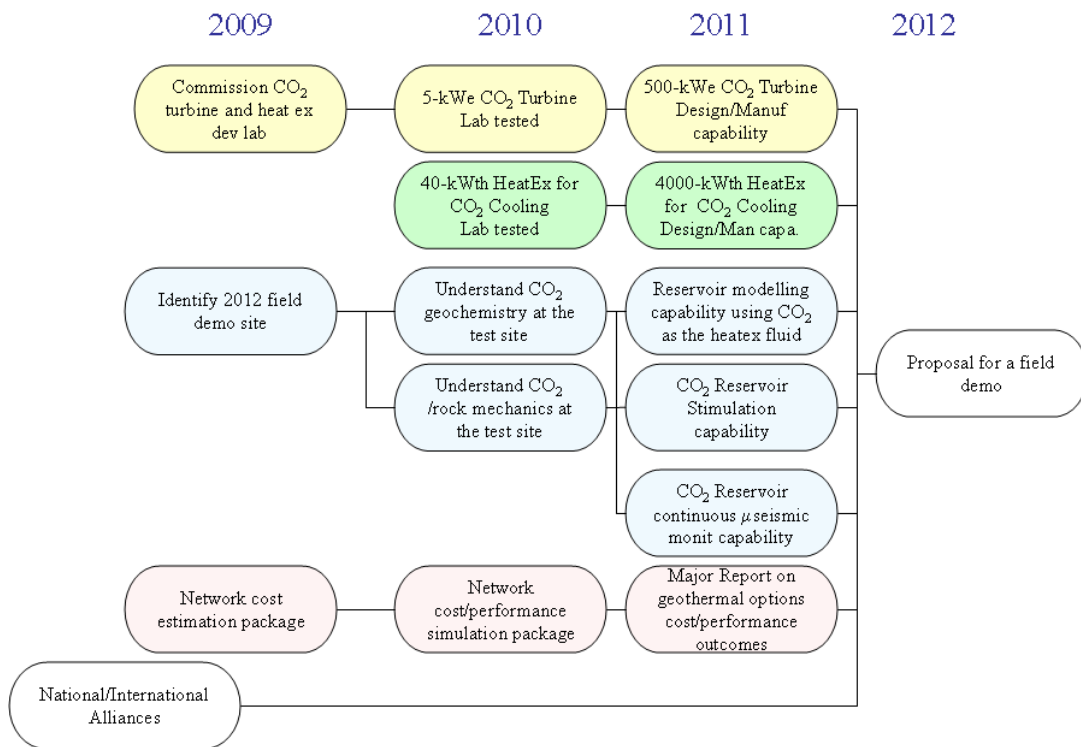


Figure 6. Road map to a field demo project using a supercritical CO₂ geothermosiphon

The centre will also work with other Australian universities to introduce undergraduate and post-graduate programs to develop a skill base, and train postgraduate students. Hal Gurgenci is the inaugural Director of the QGCoC, which is expected to make a submission to the Garnaut Review to elaborate the prospectivity of circulating stored supercritical CO₂ in a closed loop through a hot dry rock reservoir both to yield geothermal power and sequester CO₂ as a by-product.

WEST AUSTRALIAN GOVERNMENT SUPPORT FOR GEOTHERMAL RESEARCH

On the 29th of February 2008, the Western Australian State Government announced a new \$2.3million WA Geothermal Centre of Excellence. The Centre comprises three participants: CSIRO, The University of Western Australia, and Curtin University of Technology. Because of Perth's geological setting, the Centre focuses on direct heat use technologies (e.g. geothermally powered air conditioning and desalination) for use in population centres where there is shallow groundwater of moderate temperature. Geothermal groundwater convection in settings such as the Perth basin provides a natural underground heat exchanger. Owing to the high natural permeability there is no need for artificial hydraulic fracturing. For 3-D modelling of these geothermal systems the Centre will harness the supercomputers now being set up in Perth, and will make it possible to drive geothermal research into computationally intensive directions that had previously been out of reach in Australia. The Centre will also offer geothermal training to students and industry. The research is organised in three interlinked Programs: 1) Assessment of Perth Basin Geothermal Opportunities using presently available data; 2) Optimal use of geothermal resources; 3) Identification of Future Potential by going deeper...

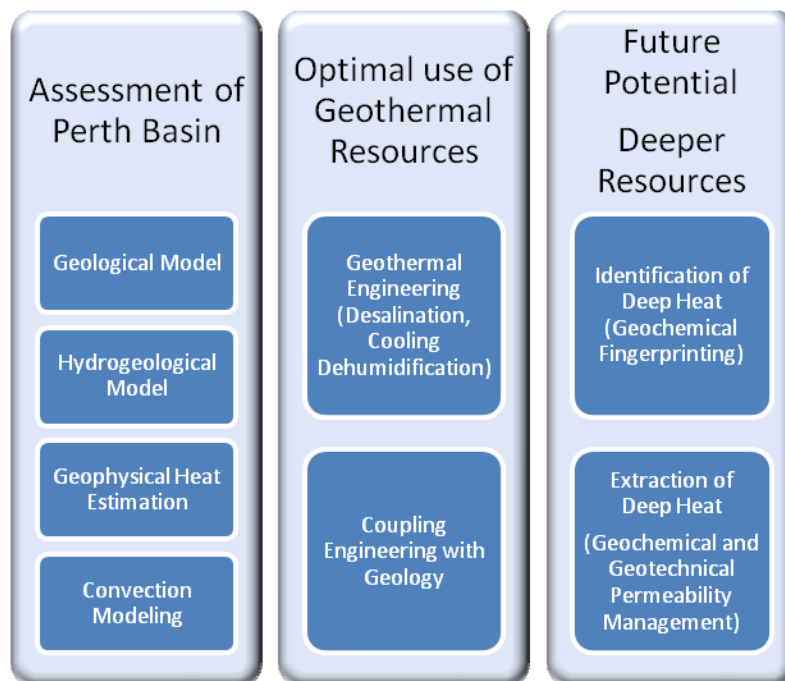


Figure 7. The WA Geothermal Centre of Excellence planned, interlinked approach to foster progress in the development of geothermal energy

KEY STEPS TO DRIVE GEOTHERMAL ENERGY DEVELOPMENT IN AUSTRALIA

- Geothermal exploration, proof-of-concept and demonstration projects (fostered with government grants);
- Attractive, appropriate investment frameworks in all Australian jurisdictions;
- Government and industry support for research and sharing lessons learnt to reduce critical uncertainties (nationally and internationally);
- A national roadmap for geothermal energy to guide the path for Hot Rock geothermal energy to meet a significant part of Australia's power demand by 2030; and
- States and the Northern Territory working cooperatively with Geoscience Australia in the development and delivery of salient maps, enabling data management tools, and a readily assessable national database for geothermal energy information.

FORECAST MILESTONES ON THE ROAD TO HOT ROCK ENERGY DEVELOPMENT

About \$119 million has been invested in Hot Rock projects in Australia in the term January 2002-December 2007. The results to date lead the Australian Geothermal Energy Group (AGEG) to forecast:

- At least 10 successful research (exploration drilling) and proof-of-concept (heat energy is flowed) geothermal projects by end 2012. This will be enabled with government grants and frameworks that stimulate pre-competitive, 'learn-while-doing' investment to pull low emissions and renewable energy technologies through costs-curves, towards market-competitive energy supplies;
- Several geothermal power generation demonstration projects in distinctively different geologic settings in the coming years, and at least three by end 2012, if governments provide sufficient 'pull' for pre-competitive, 'learn-while-doing' investment in the demonstration of low emission and renewable technologies, and Hot Rock geothermal, in particular;
- Compelling success with geothermal power generation demonstration so the investment community is convinced geothermal energy supplies are real by end 2012, again, if governments provide sufficient 'pull' for pre-competitive, 'learn-while-doing' investment in the demonstration of low emission and renewable energy technologies, and Hot Rock geothermal, in particular;
- Realising the vision of safe, secure, reliable, and the lowest-priced renewable and emissions-free base load power from geothermal energy for centuries to come, with at least 7% of base-load demand from Hot Rock power by 2030;
- Enhanced energy security with vast reliable, competitively priced, emissions-free and renewable base load power from geothermal energy for centuries to come; and
- Mitigation of expected negative impacts of greenhouse gas emissions and associated climate change.

MEASURES TO ACHIEVE THE VISION FOR GEOTHERMAL ENERGY

Coherent policies can constructively influence private sector strategies to commercialise vast geothermal plays at maximum pace and minimum cost. Policies that underpin the learn-while-doing phases of Hot Rock resource delineation, demonstration, development and deployment have been, and will remain particularly influential in attracting multiples of private funds into the pre-competitive phase of developing Australia's geothermal resources.

Key standing Government policies that will support efficient investment to develop Australia's vast geothermal resources include:

- Market-based mechanisms that account for the cost of CO₂ gas emissions e. g. an efficient emissions cap and trade scheme with robust targets to reduce emissions by at least 60% by 2050);
- Application of \$50 million of the Australian Renewable Energy Fund (REF) to underpin the drilling of 'proof-of-concept' geothermal wells (e.g. wells drilled to stufiest depths into hot rock target reservoirs to establish prospective flows of geothermally heated fluids), and the availability of further REF grants for meritorious geothermal power demonstration projects on a level, contestable basis with other renewable energy projects;
- Openness to vary National Energy Market definitions to appropriately reflect national benefits in alignment with the aims of attaining emissions abatement targets at lowest costs and to deliver the most competitive spectrum of power supplies by 2030;
- Conclude the Geothermal Industry Development Framework and the CoAG Road map for the deployment of geothermal technologies – with a view to implement associated recommendations; and

- Adding matters relating to investment attraction in, and the regulation of Geothermal Licences to the MCMPR and MCE, with the MCMPR's Upstream Petroleum and Geothermal Subcommittee being the focus for the States, Northern Territory and Federal Governments to devise best practice investment and regulatory regimes in Australia.

Key additional Government policies that will support efficient investment to develop Australia's vast geothermal resources include:

- Sufficient incentives to pull diverse low emission fuels and technologies into markets during the pre-competitive, 'learn-while-doing' phase of bringing costs down to competitive levels; i.e. MLET, Feed-in, etc;
- In addition to the \$50 million of the REF for drilling to hot rock target reservoirs to undertake flow tests, additional Federal and State/Territory-based frameworks to entice early, material and meritorious investment in geothermal exploration, proof-of-concept and demonstration (pre-competitive development) projects, with emphasis on Hot Rock EGS i.e. REDI Commercial – type and PACE-type grants that recognise exploration is research, demonstration is necessary in a number of different geologic settings, and that conditional offers will facilitate funding for pioneer geothermal projects;
- It is hoped that one of the implemented recommendations to flow from the Australian Federal Government's Geothermal Industry Development Framework (GIDF) will be the funding of a national, Australian Geothermal Energy Centre of Excellence (AGECoE), led by a Chief Executive (Director). The constitution for the AGECoE will specify that the incumbent Chief Executive (Director) of the AGECoE will also be named the Executive Director of the AGECoE TIGs, providing strategic coordination for Australian geothermal research. This will enable alignment of Australia's geothermal research with the needs of industry, through an organisational structure linked to government agency representatives to the AGECoE. This could all be transferred to an Australian Geothermal Energy Cooperative Research Centre (CRC), when the sector's companies have greater financial strength to fund at least 50% of such a CRC; A Federal Government grant of \$20 million over 10 years (\$2 million pa) from the Innovation Investment Fund (or budget under the auspices of the Minister for Industry, Innovation and Science) is one proposed option to implement an Australian Geothermal Energy Centre of Excellence.
- Investment in Australian Geothermal Licences should be eligible for the fullest extent of any *flow-through share scheme* implemented by the Federal Government
- Appropriate Government policies to support meshing 1,000 MWe (or more) of Hot Rock power into the National Electricity Market (NEM) by 2020, in a way that is consistent with NEM rules.
- Appropriate refinement of National Electricity Market rules to take account of the 24/7 and low emissions characteristics of geothermal energy in relation to augmenting the national electricity grid with regulated assets;
- Federal support for active participation in selected international geothermal research alliances, including an alliance with a focus on hot hole drilling technologies with the USA and Iceland, at least

Given such support, the geothermal industry can be expected to coordinate efficient mobilisation of equipment between Hot Rock projects, to minimise the cost, and maximise the pace of demonstrating the viability of Hot Rock energy production in a number of geologic settings.

The Australian Geothermal Energy Group (AGEG) thanks the Garnaut Review for the opportunity to make this submission to its Inquiry into the development of non-fossil fuel energy in Australia.

For further discussion contact Barry Goldstein

Phone 08 8463 3200

E-mail goldstein.barry@saugov.sa.gov.au

Enclosure 1 - Attachment 1 Australian Geothermal Licence Holders (Alphabetical Order)

AAA Energy is an unlisted company with 9 licence applications (GELAs 340–348) in the Great Artesian Basin in South Australia. These applications will be determined in 2008. For further information, contact John Palermo - Email: jpalermo@palermo.com.au;

A.B.L.R Joint Venture. This consortium has one licence application (GELA 287) south of Olympic Dam in the Gawler Craton in South Australia. This application will be determined in 2008.

Callabonna Energy is an unlisted company with 6 licence applications (GELAs 296, 304–307 and 350) adjacent to Petrathern's Callabonna Geothermal Project in the Mount Painter area in South Australia. These applications will be determined in 2008. For further information, contact Peter Bull - Email: redstones@optusnet.com.au

Clean Energy Australasia Pty Ltd (CEA). During 2007, CEA has secured 22 tenements in South Australia and 6 in Queensland where prospective hot rocks are located well within conventional drilling depths. The South Australian tenements are located in the Cooper Basin where petroleum and geothermal well data confirms temperature gradients of 50 °C/km depth. The tenements are also located close to modest-in-size local and regional electricity markets, with the nearest points of connections to the national grid at Olympic Dam and Broken Hill being approximately 400km away. The Queensland tenements are located south of the North West Queensland Minerals Province, which include major copper, lead/zinc and silver mines at Mt Isa and Cannington. The Great Artesian Basin overlies and insulates high temperature rocks in this area. During 2007, CEA also commenced significant technical and commercial activities towards demonstration power generation projects. For more information visit: <http://www.cleanenergyaus.com.au>

Deep Energy is an unlisted company with 5 licence applications (GELAs 308 and 311–315) over the western and southern margins of Lake Frome in South Australia. These applications will be determined in 2008. For further information, contact John Risinger - Email: JRisinger@adavaleresources.com.au;

Earth Heat is an unlisted company with 3 licence applications (GELAs 337-339) over the Adelaide Geosyncline in South Australia. These applications will be determined in 2008. For further information, contact, Ray Shaw – Email: vanibe@bigpond.com;

Eden Energy Ltd listed on the Australian Stock Exchange in May 2006 (ASX Code: EDE) and is focused on clean energy technologies, including hydrogen technologies, transport fuel systems, natural gas, and geothermal projects. Eden's four geothermal exploration project areas are located at: (1) Witchellina, northwest of Leigh Creek; (2), north of Renmark, on the Murray River; (3) in the Moomba region in the Cooper Basin, adjacent to Geodynamics' project and at Bollards Lagoon; and (4) Mungeranie, in the southwest Eromanga Basin region on the Birdsville Track. These projects cover a number of different geothermal target types, ranging from the deep hot fractured granite model near Moomba and at Mungeranie; relatively shallow (2-3km) heat sources associated with buried radiogenic iron oxide and granite at Witchellina; and enhanced permeability zones in the Renmark Trough associated with elevated heat flows. If successful, Eden will target electricity markets and hydrogen production. The company completed Chowilla 1 near Renmark in February 2007 to a depth of 512 in mid February 2008 as part of a \$100,000 PACE 4 grant and expects to complete temperature logging by in early 2008. For more information, visit <http://www.edenenergy.com.au>

Geodynamics Ltd listed on the Australian Stock Exchange in 2002 (ASX Code; GDY). Geodynamics has the most advanced geothermal project in Australia. Geodynamics has first mover advantage in Australia with its Habanero-Jolokia project in granites beneath the Cooper Basin in northeast South Australia and is the only proponent with a proven resource in its tenements. Geodynamics "Proof of Concept" project (Habanero) is located where rocks are claimed to be the hottest in the world in a non-volcanic environment (up to 280°C at 5 km depth). The company 'engineered' the world's largest (known) underground heat exchanger by high pressure water injection into water saturated, naturally fractured granites in two stages, in 2003 and 2005. At the time of writing this report, Habanero 3 was sustaining production of 208 °C formation water at a rate of 18 kg/second at a flowing pressure of 27.5 MPa (3,990 psi) through a 12.5mm fixed choke. The flow is directed to a steam separator designed for up to 25 kg/second input, the rate achieved with an output temperatures of 210°C from Habanero 2 in 2005. Produced fluids from Habanero 3 flow through a variable choke capable of increasing production is available for trim (finely adjust the flow rate). In one short experiment lasting 3 minutes the variable choke was opened to 100% and production of 40 kg/second was sustained over that period. Productivity is 400% higher than that obtained from Habanero 2 in 2005 where lost down-hole equipment impeded flow and eventually caused blockage from the main fracture zone. During production and shut-in of Habanero 3, the monitored well head pressure at Habanero 1 responded as expected, indicating good communication between the wells at 4,250m depth. The high rates of injectivity into the heat exchanger from Habanero 1 and 2 and pressures measured at Habanero 1 and Habanero 3 during flow testing in March 2008 indicate the presence of a large volume of low impedance, water saturated reservoir where the rock temperature is 250°C (4.3 km). The potential area of accessible hot rocks in Geodynamics' South Australian geothermal tenements cover 1,983 km², and Geodynamics estimate the Hot Rock resource in these areas is very large, at around 270,000 PJ (defined) plus 100,000 PJ (inferred), and the company believe the defined resources can support > 10,000 MW (power generation). In addition it has applied for exploration licenses in Queensland and has two such licenses in NSW. Consultants' reports prepared for Geodynamics indicate transmission costs of less than 0.8 cents per kilowatt hour to connect Hot Rock electricity generation from Habanero-Jolokia to the National Electricity Market power grid. Geodynamics was the recipient of a \$6.5 million START grant in 2003-4 and a \$5 million REDI grant in 2005. These grants were provided to both underpin the Habanero project and to generally advance the prospects for developing Hot Rocks in Australia. Geodynamics was also granted \$140,000 by the South Australian government for innovative borehole logging and desktop studies to estimate the potential emissions abatement associated with the deployment of Hot Rock power in Australia. The company has stated that to start, it aims to build a 50MWe power station connected to the national grid based on 9 wells by 2012, and then scale up to 500 MWe

based on 90 wells by 2016. Geodynamics owns 25% of a company with geothermal projects in Nicaragua and Germany (named Exorka International) in partnership with Canadian, Icelandic and New Zealand geothermal companies. For more information visit <http://www.geodynamics.com.au>

Geogen Victoria Pty Ltd is an unlisted company that holds the largest contiguous geothermal exploration acreage in Australia. The wholly owned subsidiary of Queensland based Geogen Pty Ltd holds Victorian GEP's 1, 2 and 3 – a total area of 18, 342 km² in the state of largely based in the central highlands of Victoria and including the major regional centres of Ballarat and Bendigo. Geogen Victoria is planning to drill 30 thermal scout holes to 300m depths in Year 2 and Year 3 of the five year exploration program for these GEPs. The GEP's are northwest and within 60 km of Melbourne and include some exploration targets within 1 to 20 kms of the national electricity grid. The highest measured heat flow estimate of 121 mW/m² in Victoria, measured near Castlemaine, is contained within Geogen Victoria's acreage. For more information, see <http://www.geogen.com.au/> or contact Bob Kitch - Email: bob.kitch@geogen.com.au

Geothermal Resources Ltd listed on the Australian Stock Exchange in 2006 (ASX Code; GTH) and has two hot rock geothermal exploration projects: Frome and Crower. Both are in South Australia where there is evidence of prospective "hot" radiogenic granites below a sufficient thickness of insulating sediments. Both projects are well located with respect to existing power grids and even modest-in-size geothermal fields could be quickly brought into production to meet the rising demand in nearby electricity markets. The Frome project lies within the Curnamona Province, which is underlain by some of the most radiogenic Mesoproterozoic granites in Australia, associated with numerous historic uranium occurrences. In the project area a large body of granite, evidenced by a regional gravity low and non-reflective seismic responses, is interpreted to lie beneath 2-4 kilometres thickness of younger sedimentary cover rocks. With the assistance of a Commonwealth government REDI grant of \$2.4 million and a \$100,000 PACE 3 grant by the South Australian government, the Company completed 4 holes to approximately 500 metres depth on its Frome Project during 2007. Temperature logging indicated abnormally high temperatures within the sediments above the interpreted buried granite body, with geothermal gradients comparable to the Cooper Basin, thus vindicating the buried granite heat source model. In the first half of 2008, the Company plans to complete several further shallow holes in order to determine the area of highest heat flow over the granite body and therefore the optimum site to drill the first hole to greater than 1000 metres depth. The Crower project situated in the South East lies along the northern onshore margin of the Otway basin where early Palaeozoic granites of the Padthaway Ridge dip beneath onlapping Jurassic to Cretaceous sediments. Rapid changes in thickness of the sediments caused by basement faulting and rifting at the time of continental break up provide the opportunity for locally elevated geothermal gradients and optimal depths of burial. The results of recently published research work indicate a 40 km long by 15 km wide zone of markedly elevated heat flows within the Crower project area. During 2008 it is proposed to drill several strategically placed holes to depths of greater than 500 metres to better define the heat flow anomaly. For more information please visit: <http://www.geothermal-resources.com.au>

Gradient Energy is an unlisted company with 13 licence applications (GELAs 354–365, 377) over the northern Eromanga (Great Artesian) Basin in South Australia. The northernmost application areas are located 30km to south of the Birdsville geothermal power plant which operates from ~90°C waters from the Great Artesian Basin. In New South Wales, Gradient Energy has two geothermal applications over sedimentary basins settings in proximity to power markets and the national power grid. The company will explore both hot fractured rock basement and hot aquifers in sedimentary settings for power generation and direct heat applications, including desalination. The SA and NSW geothermal applications will be determined in early 2008. For more information, contact Stephen Nano Email: scnano@globalorecovery.com

Granite Power Limited is an unlisted company exploring for hot rocks in two geothermal exploration licence (Victoria GEP 11 and South Australian GEL 207), one licence application in South Australian (GELA 291) and has been named by the Queensland Government as one of three preferred tenderers for a total nine 2006 bid blocks. Granite Power is also developing complementary high efficiency heat exchange and complementary desalination technology with the University of Newcastle. The University of Newcastle and Granite Power (under its former name – Proactive Energy Development) were the recipients of a \$1.2 million REDI grant for adapting supercritical cycles to geothermal power generation. The Company plans to list on the ASX and/or in the UK. For more information contact Stephen de Belle Email: sdebelle@granitepwr.com Phone: 02 8252 6101 or see: <http://www.granitepwr.com/>

Greenearth Energy Limited listed on the Australian Stock Exchange in 2008 (ASX Code; GER). A petroleum exploration well (Trifon-2) drilled in 2004 by one of Greenearth's cornerstone investors (Lakes Oil – an ASX listed company) flowed 90°C water to surface from 2,200 metres. Greenearth subsequently applied-for and was granted three geothermal exploration permits (GEPs) in May 2007 by the Victorian Government covering 18,795 km². The permits are located in the Latrobe Valley/Gippsland Area (GEP12 and 13) and the Otway Basin (GEP 10). Greenearth has formed a 'Coordination Agreement' – to reduce costs where possible – by leveraging on petroleum permit data and exploration programs – including conditional access to petroleum wellbores for geothermal permit operations where Lakes' and Greenearth's licences are coincident. In addition to geothermal power generation, two important possible direct heat applications for the Company include the use of geothermal energy to help dry coal and to pre-heat feed-waters into coal fired power stations. For more information please visit: <http://www.greenearthenergy.com.au>

Green Rock Energy Ltd listed on the Australian Stock Exchange in 2003 (ASX Code; GRK). Greenrock is undertaking the evaluation and development of a hot dry rock ("HDR") geothermal power plant on its geothermal exploration licences in central South Australia in preparation for the construction of power plants with a base load electricity capacity of no less than 400 MW. Green Rock Energy holds a 100% interest in an area of around 3,000 km² next to BHP Billiton's world class Olympic Dam mine in South Australia. In 2005 Green Rock drilled Blanche No 1, its first exploratory diamond geothermal well, to 1,935 m (718 m of sedimentary rocks and 1,216 m of homogenous hot granite) 8 km from the giant Olympic Dam mine and 5 kms from a high voltage power transmission line connected to the national power grid. The target granite is interpreted to persist to depths of 6,000 m over an area of about 400 km² and represents a

potential geothermal resource in excess of 1,000 MWe. Cores and wireline logs from Blanche No 1 suggested natural fractures exist. In 1Q 2008, Green Rock undertook a mini-fracture stimulation program in Blanche 1 to inform the design of a deep well stimulation. Thirteen zones were tested and the well bore was imaged with a slim-hole acoustic televiewer to enable the analysis of fractures, post fracture stimulation. The data gathered from this program will provide the Company with information to assist the design of the first of two deep wells to be drilled nearby and the fracture stimulation program to set up a water circulation system between those wells. Greenrock was awarded a \$68,000 South Australian PACE Grant Greenrock to advance its Blanche project. Greenrock also has a 32% interest in a project in Hungary which plans to produce geothermal water for electricity generation and direct heat for industrial and agricultural uses. Production testing of water flow rates from existing wells has commenced at the Hungarian Project. For more information, visit <http://www.greenrock.com.au>

Hot Rock Limited listed on the Australian Stock Exchange in November 2007 (ASX Code: HRL) and holds four Geothermal Exploration Permits (GEP 06 to 09) in Victoria covering over 18,000 km² in the search for commercial hot wet rock targets. The permits are located proximal to transmission infrastructure and power markets.. Prospective water temperatures have been measured in petroleum wells in HRL's Otway Basin GEPs, including: 143°C in Windermere 2 at 3,595 m in tenement GEP 7; and 142°C in Ross Creek 1 at 3,659 m in GEP 8. HRL is planning to develop these hot wet rock resources. The selection of the site of HRL's first geothermal test well will be based on the reinterpretation of the extensive existing seismic data, well data and a planned magneto-telluric survey to be completed by June 2008. The well is planned to be spudded by the end of 2008 and if successful, a small binary power plant will be installed by the end of 2009. If the pilot plant operation is successful Hot Rock will be the first company to generate electricity from geothermal energy in Victoria, using proven technology employed by commercial projects worldwide. In addition to becoming a power generator the company is investigating the direct use of geothermal energy for additional revenue. For more information visit: <http://www.hotrockltd.com>

Hot Rock Energy Pty is an unlisted company exploring for hot rocks in Exploration Licence (EL) 6212 in the Sydney Basin, New South Wales. This licence area covers approximately 5,500 km² and was granted in 2004 to Longreach Oil Ltd (50%) and Hot Rock Energy Pty Ltd (50%). A company is currently undertaking a technical review of the Sydney Basin, incorporating petroleum, coal and water well data with the aim of identifying areas of high heatflow. The outcome of the study will lead to the isolation of certain areas of abnormally high geothermal gradients to provide the focus for shallow drilling. For details, see: http://www.longreachoil.com/Exploration_Review.html

Inferus Resources is an unlisted company with four licence applications (GELAs 297, 301–303) in the Torrens Hinge Zone in South Australia. These applications will be determined in 2008. For more information, contact Russell Hetherington – Email: russell@hemts.com.au; Phone: 61 (0)2 9967 4844

KUTh Energy Limited listed on the Australian Stock Exchange in 2007 (ASX Code: KEN). It acquired a large geothermal exploration licence in Tasmania in 2006 and has since been granted another, bringing its total acreage to 14,171 km². These tenements cover much of eastern Tasmania, including high heat flow granites (up to 159mW/m² in boreholes), and a sedimentary pile above the granites averaging 3-5 km; this includes some coal measures. Both the national high voltage grid and the state low voltage distribution electrical grids traverse the licence area in a number of locations.. The Tasmanian licences were also applied for to capture 'direct heat' opportunities (industrial heating and drying) in urban and industrial areas, such as Hobart and Launceston. The company has been named as the preferred tenderer for two geothermal tenements in Queensland and is currently reviewing conventional geothermal opportunities overseas. On its Tasmania tenements, the company completed an in-fill gravity survey in 2007 and this data was used to produce a new bouguer gravity model of the state. Interpretation of the gravity data showed an enlarged area where the depth to the top of the granite was between the favourable 3 to 5km range. In late 2007, the company commenced a 20km x 20km shallow drilling programme across its entire tenement holding. These drill holes, 250-300m deep, will be thermally logged when thermally equilibrated and have rock conductivity data measured on the cores. This survey, expected to be completed during 2008, is believed to be one of the largest systematic shallow drilling programmes designed for geothermal data in Australia, and will result in a comprehensive thermal anomaly map of eastern Tasmania. From this, the company will plan deep drilling and, ultimately, production drilling. KUTh Energy's strategy is to take advantage of the favourable thermal, geological and infrastructure characteristics of eastern Tasmania to establish a generation capacity within five years, and to have a commercial Direct Use project within three years. KUTh was granted a \$2.3 million REDI Grant to \$1.8 million REDI Grant to explore a possibly hybrid 'hot rocks' hydrothermal geothermal project near Launceston, which may be a way to expedite the commercialisation of geothermal energy in Australia. Additionally, it aims to involve itself in offshore conventional geothermal electricity generation at the earliest opportunity available. KUTh's web site is www.kuthenergy.com or the company can be contacted via its Chief Operations Officer Malcolm Ward mward@kuthenergy.com

New World Energy Solutions is a privately-owned company based in Western Australia. The company currently holds two Geothermal Exploration Licence Applications in South Australia (GELA 353 near north of Renmark and GELA 352 south of Moomba). It plans to aggressively progress exploration on these licences upon grant. While the Company plans to be involved in all major electricity markets in Australia, NWES' focus at this stage is on Western Australia where it has primarily worked for the past 12 months. New World Energy Solutions is reviewing options to list on the ASX in the second half of 2008. For more information, contact John Libby by Email: john@digirock.com.au or Phone: 61 8 6477 4388

Origin Energy Ltd is a diversified ASX-listed energy company (ASX Code: ORG). Origin owns, develops and procures energy and related products and services. It is an upstream oil and gas exploration and production company – with more than 2,400 PJe of proven plus probable reserves – of which 90% is gas. Origin is significant producer of coal seam gas in Queensland. Origin owns and operates gas- and wind-fueled power stations in Australia, and owns 51.4% of Contact Energy – a major electricity (from geothermal and wind) and gas retailer in NZ. Origin is a cornerstone investor in

Geodynamics. In 2007, Origin purchased a 30% equity position in Geodynamics' South Australian geothermal tenements together with 30% of the Lightning drilling rig. In addition to its 30% share of on-going project expenditure, Origin will contribute up to \$105.6 million towards all project cash costs comprising \$96 million. For more information see: <http://www.originenergy.com.au>

Osiris Energy Ltd is an unlisted company currently exploring for geothermal resources in two Geothermal Exploration Licences in South Australia (GEL223 in the Penola Trough, Otway Basin, and GELs 220-223 in the Cooper Basin) and one Exploration Licence Application in New South Wales (ELA3326 in northern NSW) and is actively pursuing additional prospective project areas. The Penola Trough in the southeast South Australian Otway Basin, is the setting of GEL 223, and represents an area of anomalously high heat flows proximal to the National Electricity Market transmission grid with an extensive database of petroleum well and seismic data that define hot wet sedimentary rock targets. Osiris Energy and Origin Energy negotiated a participation agreement under which Osiris Energy will undertake the exploration of the permit and Origin will be offered the option to participate in any capital raisings associated with development of identified geothermal resources in the permit area. Osiris has also signed an agreement with Protavia Pty Ltd to delineate potential to economically supply approximately 2 Petajoules of geothermal heat per annum for drying the final pulp in Protavia's (to be commissioned) paper pulp plant in SE South Australia. For more information see www.osirisenergy.com.au.

Pacific Hydro Ltd is owned by IFM Renewable Energy under the control of Industry Funds Services Pty Ltd. Pacific Hydro holds 18 Geothermal Exploration Licences covering 9,000km² in the South Australian extent of the Mesozoic Eromanga Basin (also called the Great Artesian Basin). In the second quarter of 2006, Pacific Hydro conducted downhole temperature measurements on three water bores to a depth of 1,500m to confirm 56.1 °C /km, which suggests temperatures of 133 °C at 2,000m in the Jurassic-aged (Hutton and Poolowanna Formations) hot wet sedimentary rock targets. Laboratory permeability tests of Hutton core samples and thin section analyses provide further verification of high permeability at target reservoir depths. Two slim holes are planned to be drilled in 2009, in the gravity low (deepest, so hottest Jurassic targets) in the eastern section of Pacific Hydro's GEL. That drilling program will establish potential upside above the 133 °C temperature projected from measurements taken at 1,500m. These wells will drill in a geological setting with benign fluid chemistry, high permeability and lateral continuity. This drilling aims to establish a very large scale hydrothermal resource that could be developed with existing technologies. For more information – contact Terry Teoh Email: teoh@pacifichydro.com.au

Panax Geothermal Ltd is listed on the Australian Stock Exchange (ASX Code: PAX). Panax's key Australian asset is the Limestone Coast Geothermal Project in the South Australian Otway Basin covering six Geothermal Exploration Licences (GELs 170-173, 184 and 212) totalling 2,674km². The Otway Basin in the southeast South Australian is the setting of GELs 170-173, 184 and 212, and represents an area of anomalously high heat flows proximal to the National Electricity Market transmission grid with an extensive database of petroleum well and seismic data that define hot wet sedimentary rock targets. The extent of three sub-basins within the boundaries of GELs 170-173, 184 and 212 have an estimated generating potential in excess of 1,500 MWe. Scopenergy drilled three slim-hole wells (Heatflow 1A, 3A and 4) in the Limestone Coast Project near Millicent and Beachport in southeast South Australia in 2006. Scopenergy was acquired by Panax in 2007. Surveys of those three slimholes added to measurements in 19 petroleum exploration wells and 26 water wells in the vicinity of Panax's tenements. This well data supports interpretations of temperatures of 170°C or higher at depths between 3,300m and 3,700m and 186°C to 200 °C at 4,000m in Lower Cretaceous – Jurassic aged sandstones, and this prospectivity was recognised by the Federal Government through the issue of a \$4 million REDI grant (not consummated). Panax is currently (1) preparing a submission to the Australian Government to reinstate a \$4 million REDI grant offered for, but not implemented to advance the Limestone Coast Project; (2) defining locations for deep well tests; and (3) assessing options to secure a rig for drilling a deep geothermal test well; and (4) searching for a joint venture partner. Scopenergy was awarded a \$130,000 South Australian PACE grant to advance understanding of the Limestone Coast Geothermal Project area. For more information please visit www.panaxgeothermal.com.au

Petratherm Ltd listed on the Australian Stock Exchange in 2004 (ASX code: PTR). Petratherm's four geothermal projects in Australia are located in South Australia. These are: (1) Paralana (GELs 156, 178, 180, 254 and 336 covering 2,802 km²); (2) Callabonna (GELs 157 and 170 covering 996 km²); (3) Ferguson Hill (GEL 158 covering 499 km²); and (4) Renmark (GELs 241 and 242 covering 917 km²). In 2005, Petratherm drilled two shallow wells in the first phase of its geothermal exploration program; one in the Paralana project area and one in the Callabonna project area. Results from both wells were encouraging, with the Callabonna and Paralana sites respectively exhibiting 68 °C/ km and 81°C/ km thermal gradients. In June 2006, Petratherm's second phase of drilling program at Paralana was successfully completed with the geothermal test well being extended from 485 metres to 1,807 m. Temperature logging of the well suggests a world class thermal resource is located at Paralana, with extrapolations indicating 200°C can be expected at a depth of 3,600 m within insulating sedimentary rocks that are predicted to be susceptible to fracture stimulation. Petratherm refers to this play concept as Heat Exchange Within Insulator (HEWI). High heat producing basement rocks are a prerequisite for high quality HEWI plays. Petratherm's modelling of the Paralana resource suggests that a single block of high heat producing granite, with a surface area of 20 km² by 1 km thick, and an average temperature of 200°C, could easily support the generation of 520 MW of electricity to the National Electricity Market for 25 years. Petratherm's South Australia project areas are nearest to national grid connection points at Port Augusta and Olympic Dam. Petratherm plans to create a HEWI system with the circulation of water between the two Paralana wells to demonstrate hot rock EGS energy production from an initial small scale power plant that will supply up to 7.5 MW to a growing electricity market 10 km away at the Beverley Uranium Mine. This plan is the subject of a Memorandum of Understanding between Petratherm and the owners of the Beverley Mine, Heathgate Resources. An ASX-listed upstream oil and gas company (Beach Petroleum) has taken an equity position in the Paralana project. In November 2007, Petratherm signed a Letter of Intent for Ensign International Energy Services to secure a suitable rig and drill a Paralana well to 4,000 metres. Stimulation, flow testing and the drilling of a second well would follow, pending results of the first deep Paralana well. Petratherm was granted a \$5 million Federal REDI Grant and \$240,000 in two South Australian PACE Grants to underpin its Paralana project, and more generally advance the prospects for developing Hot Rocks in Australia.

Petratherm also has geothermal projects in Spain (mainland and Canary Islands) and is undertaking studies to identify prospective geothermal projects in China. For further information, visit <http://www.petratherm.com.au>

Red Hot Rocks Pty Ltd is the unlisted geothermal subsidiary of Mobius Resources Australia Pty Ltd. Red Hot Rocks has been offered three geothermal tenements in Queensland including GL-2005A (located between Boulia and Winton), GL-2005B (located between Boulia and Winton) and GL-2005D (located west of Thargomindah). For further information is available from both Dr John E Shirley (Email: jjshirley@bigpond.com) and Domain Capital at Level 16, 379 Collins Street, Melbourne. Vic 3000

Stuart Petroleum is a petroleum exploration and production company listed on the Australian Stock Exchange (ASX code: STU). The company 26 licence applications (GELAs 378–389; 393–406) over petroleum producing areas of the Cooper and Eromanga Basins in South Australia. These applications will be determined in 2008. For information, contact Iain Macdougall Email: macdougall.i@stuartpetroleum.com.au

Teck Cominco Australia Pty Ltd is a Canadian company listed on the Toronto Venture Market and has been offered two adjacent South Australian Geothermal Exploration Licences (GELs 294 and 295 covering 994 km²). The tenements are located in the eastern Gawler Craton – South Australia, an area highly prospective for “hot” radiogenic granites. Teck Cominco’s Carrapateena Cu-Au discovery and its surrounds are located within the limits of GELs 294 and 295. Teck Cominco’s exploration for geothermal gradient is being done in parallel with ongoing exploration and evaluation of the Carrapateena and the surrounding mineral tenements. Temperature data has just been collected in three existing Carrapateena drill holes and evaluations are underway. For more information see <http://www.teckcominco.com>.

Torrens Energy Ltd is listed on the Australian Stock Exchange in 2007 (ASX Code; TEY). Torrens has sixteen geothermal licences and two licence application spread across three project areas covering 7,688 km² in South Australia. These three projects are: (1) Torrens (GELs 230-235, 278 and 285 totalling 3,857 km²); (2) Barossa-Clare (GELs 227-229 and 263 totalling 1,963 km²); and (3) Adelaide (GELs 226, 260-262 and GELAs 266 and 293 over a total of 1,868 km²). All of Torrens’ licence and licence applications areas are located close to the National Electricity Market transmission grid and markets. Torrens Energy drilled five wells to depths ranging 375m to 601m its Torrens project area in late 2007. Results from drilling those 5 wells are encouraging, suggesting temperatures of 202°C (± 6°C) to 248°C (± 6°C) at 5,000m in the Lake Torrens project area. The aim of this program is to delineate heat flow trends as a precedent to locating deep proof-of-concept wells in proximity to the National Electricity Grid and power markets, near to gas- and coal-fired power stations to pre-heat feed-waters and for seawater desalination. Torrens was awarded a \$3 million REDI grant (in 2007) to develop demonstrate and refine a 3D modelling method for the prediction of Hot Rock plays, and also a \$100,000 South Australian PACE grant (in 2006) for heat flow exploration in the Adelaide Geosyncline. In 2008, Torrens will continue its delineation of heat flow with shallow drilling, 2D reflection seismic and magneto-tellurics surveys. For more information see <http://www.torrensenergy.com> or Email: chris.matthews@torrensenergy.com

Tri-Star Energy Company is a privately held company with petroleum production and exploration projects in Queensland, and its primary focus is the development of coal seam methane. Tri-Star has two geothermal licences west of Marree in the western Great Artesian Basin of South Australia (GELs 264 and 265 covering 994 km²) and two geothermal application areas in the Cooper Basin of northeast South Australia (GELAs 309 and 310 covering 955 km²). For further information contact Tri-Star Energy Company in Brisbane Email: brisbane@tri-starpetroleum.com

Waterflea Pty Ltd is a Newcastle based geothermal exploration company that applied for ELA 2809 about 12 km southeast of the township of Awaba, near Lake Macquarie in New South Wales. Postal address: PO Box 683, Newcastle, NSW 2300.