

CONVERTING GEOTHERMAL PLAYS TO PROJECTS IN AUSTRALIA – A NATIONAL REVIEW

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ABSTRACT

Reliable well productivity will be the linchpin for success in Australian geothermal projects. Grant programs from the Australian Federal and state governments totalling AU\$296 million (US\$293 million) are targeting the conversion of identified geothermal resources into proven reserves via proof-of-concept and demonstration projects. Australia's geothermal projects are focused on developing both Engineered Geothermal System (EGS) (or Hot Rock systems) and Hot Sedimentary Aquifer (HSA) plays to generate electricity, power large scale air conditioning and industrial-scale direct use applications (including coal drying, mine water recycling and desalinization processes).

Nationally, over the January 2000 through December 2010 term, applications for exploration licences have resulted in 56 companies holding 418 license areas (covering 477,000 km²) to progress proof-of-concept amagmatic EGS and HSA projects. In the term 2002 through 2010, more than AU\$671 million (US\$663 million) has been estimated spent on studies, geophysical surveys, drilling, reservoir stimulation and flow tests which comprise the work programs required to sustain tenure in geothermal licenses areas. In the term 2002-2015, investment for Australian proof-of-concept geothermal projects is forecast to exceed AU\$3,227 million (US\$3,187 million).

These collateral efforts are all directed at achieving the Australian Geothermal Energy Group's (AGEG) aspirational targets of at least 10 successful research and proof-of-concept geothermal projects, and at

least 3 power generation demonstration projects in distinctly different geologic settings by the end of 2013, with the results providing compelling evidence to justify investment in the development of Australia's vast EGS and HSA plays (IEA-GIA, 2008). The shared vision of Australia's peak representative organisation for the geothermal industry (the Australian Geothermal Energy Association, AGEA) and the AGEG is to see geothermal energy providing the lowest cost, emissions-free, renewable base load energy for centuries to come.

This paper summarizes: (1) proof-of-concept amagmatic EGS and HSA geothermal projects co-funded by investors and governments in Australia; and (2) policies, programs and alliances put in place to support the development of geothermal plays.

Success in Australia will have positive implications for similar projects, world-wide.

A SUPPORTING FRAMEWORK

Interest and activity in the Australian geothermal sector continues at an unprecedented pace. As of December 2010, 56 companies have secured exploration or retention licences and commenced exploration activities in 418 licence application areas nation-wide (Figure 1), equating to an estimated investment of AU\$3,227 million (US\$3,187 million¹) over the period 2002-2015, in pre-competitive geothermal projects.

¹ US\$1 = AU\$1.0124 as at Jan 2010.

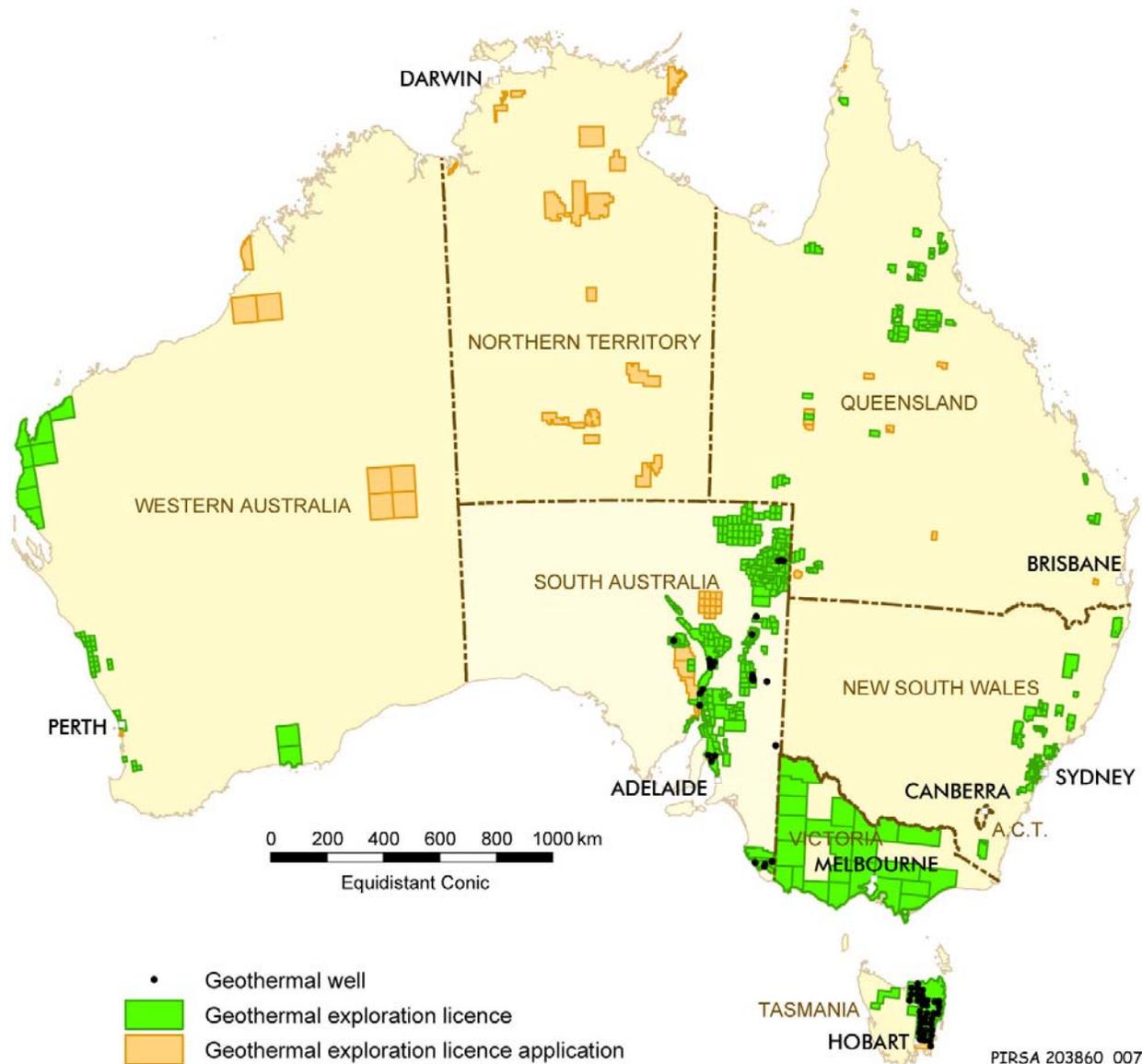


Figure 1 Australian geothermal licence areas and acreage releases at January 2011. Geothermal exploration licences are shown in green, exploration licence applications in orange and acreage releases in pink.

In line with the National Renewable Energy Target, the Australian Government’s goal is to have at least 20 per cent of Australia’s electricity supply coming from renewable energy sources by 2020. Recognising the tremendous potential of geothermal energy to provide substantive base-load, renewable energy resources toward the future Australian energy mix, Australian governments at both Commonwealth and State level, have been pro-active in developing and implementing key supporting policy, legislative frameworks and generous grant funding.

Building upon the findings of the Australian Government’s Energy White Paper, “Securing Australia’s Energy Future” (DPMC, 2004), the Geothermal Industry Development Framework (GIDF) (DRET, 2008a) and the Council of Australian Governments’ (CoAG) Technology Roadmap (DRET, 2008b), a number of Federal Government policy instruments are aimed at fast-tracking the uptake of geothermal energy within Australia. Many Commonwealth and State initiatives are designed to support the development of the sector by providing access to a staged continuum of funding mechanisms.

Table 1. A summary of Commonwealth and State government grant options currently available to the Australian geothermal sector.

Agency	Research & pre-drill	Shallow drilling & early exploration	Deep drilling to resource depth	Proof of Concept	Pre-competitive production demonstration	Production
Commonwealth Government (federal)	Geoscience Australia (GA) data	Resources Exploration Rebate (RER)	Energy Technology Innovation Strategy ~AU\$5M awarded to date		Renewable Energy Future Fund (REF)	Renewable Energy Credits (RECs)
			REDI: ~AU\$100M total @ A\$5M per well	REDI+ ~AU\$100M total @ A\$50k – 5M per proposal	REDI: ~AU\$100M total @ A\$50k – 5M per proposal	
			GDP~ A\$50M total available @ \$7M per well		REDP~ A\$435M total available @ \$50 – 100M per proposal	
				Energy Innovation Fund ~AU\$50M total.	Energy Innovation Fund ~AU\$50M total.	
South Australia Government	SA PACE ~ AU\$1.6M total @ up to \$100,000 per proposal	SA PACE ~ AU\$1.6M total @ up to \$100,000 per well			Regional Development Infrastructure Fund	
Victoria Government		Rediscover Victoria AU\$250,000 total	Energy Technology Innovation Strategy	Energy Technology Innovation Strategy	Renewable Energy Support Fund	
Western Australia Government	Exploration Incentive Scheme ~\$81M total available @up to \$200,000 per proposal.					
NSW Government				NSW Climate Change Fund ~AU\$40M total	NSW Climate Change Fund ~AU\$40M total	
Queensland Government		Qld Collaborative Drilling Initiative				Qld Renewable Energy Plan~ AU\$4.3M

Table 2. Synopsis of the applicable legislation currently governing geothermal exploration activities in the various Australian States.

State Government Jurisdiction	Applicable Legislation for Geothermal Exploration	Comments
South Australia	Petroleum and Geothermal Energy Act, 2000.	Regulates licensing and activity approvals for upstream petroleum, geothermal, gas storage and petroleum pipeline projects. An 'over the counter' system, where explorers can apply for those areas desired. Licences can co-exist with existing or future minerals and petroleum exploration titles.
Victoria	Geothermal Energy Resources Act, 2005.	Regulates large-scale commercial and sustainable exploration and extraction of Victoria's geothermal energy resources.
New South Wales	Mining Act, 1992.	Governs geothermal exploration in New South Wales. Geothermal exploration is considered as Group 8 - Geothermal Substances. Application for a Group 8 geothermal exploration licence requires the Minister's consent.
Queensland	Geothermal Exploration Act 2004 and Geothermal Exploration Regulation, 2005.	Applies a competitive permit system to encourage and facilitate efficient and responsible exploration.
Tasmania	Mineral Resources Development Act, 1995.	Geothermal tenements are granted as a Category 6 mineral 'Special Exploration Licence' (SEL). An 'over the counter' system, where explorers can apply for those areas wanted to be explored. Licences can co-exist with existing or future minerals and petroleum exploration titles.
Western Australia	Petroleum and Geothermal Energy Resources Act, 2007.	Provides legislative coverage for the exploration and recovery of both conventional (hydrothermal) geothermal energy and EGS (hot dry rock) geothermal energy. Does not cover non-commercial uses or heat pumps.
Northern Territory	Geothermal Energy Act, 2009.	Intent is to reserve a relatively small region around the Katherine area for later tendered release, while providing for "over-the-counter" application for geothermal authorities over the remainder of the Territory.

which come online as any given project progresses through the phases of;

- pre-drill research studies and early exploration shallow drilling efforts,
- through the proof of concept stage encompassing deep drilling, stimulation operations and extended flow tests, and
- finally to the pre-competitive demonstration of electricity production from a power plant.

Current Commonwealth and State government support initiatives include; Renewable Energy Certificates (RECs), the Renewable Energy Development Initiative (REDI) Program, Geothermal

Drilling Program (GDP), Renewable Energy Demonstration Program (REDP), Renewable Energy Future Fund (REFF), Australian Centre For Renewable Energy (ACRE), Energy Innovation Fund (EIF), Plan for Accelerating Exploration (PACE - South Australia), Renewable Energy Support Fund (Victoria), Victorian Energy Technology Innovation Strategy, Rediscover Victoria strategy, Western Australian Exploration Incentive Scheme and the New South Wales Climate Change Fund. Regulation of onshore geothermal energy exploration activities is a State-level responsibility, with every Australian state and the Northern Territory having now implemented governing legislation (Table 2).

As Australia's geothermal resources are generally amagmatic Engineered Geothermal Systems (EGS) or Hot Sedimentary Aquifer (HSA) systems (i.e. hydrothermal groundwater resources in sedimentary basins), these policy and funding initiatives are designed to support the development of a range of projects testing different geothermal resource concepts along the path to commercialisation. To date a total of AU\$291 million (US\$293 million) in Australian Commonwealth and State grants have been committed to support Australian geothermal research, exploration and proof-of-concept projects for the period 2000 to end March 2010. However while most geothermal companies are currently engaged in early stage exploration activities, the majority of the expenditure to date has been towards proof-of-concept phases.

COMPANY ACTIVITIES

Growth and activity in the Australian geothermal sector have substantially benefited from the implementation of these key policy and grant funding frameworks, with many companies steadily progressing individual projects along the path from early to advanced exploration and proof-of-concept activities toward commercial demonstration.

The relationship between policy and funding structures initiated by Australian governments, and the advance of projects successful in leveraging off these initiatives is demonstrated in the following overview on the status of six diverse geothermal projects.

Proof of Concept and Demonstration Phases (EGS) - Geodynamics Limited (ASX Code GDY)

Geodynamics Ltd's range of geothermal projects has been strongly supported by private funding through the Australian Securities Commission (ASX), as well as winning substantial Australian Commonwealth and relevant state government grant funding.

Geodynamics' Habanero project near Innamincka in the Cooper Basin region of South Australia, is probably the best known and most advanced of the Australian Engineered Geothermal System (EGS) projects. In this region Geodynamics is exploring three separate fields, (Habanero, Jolokia and Savina) and have drilled a total of five wells into the granite resource to depths of 3800 – 5000 metres, with the aim of appraising the nature and extent of the resource present. In 2009 Proof of Concept was achieved at Habanero, when circulation tests confirmed sub-surface flow between Habanero 1 and 3 wells. In April 2009 a 1MW pilot plant at Habanero was built for the purpose of supplying electricity to the nearby township of Innamincka.

Commissioning of this plant has been postponed due to casing material failure in Habanero-3 resulting from hydrogen embrittlement caused by the presence of dissolved gases in the reservoir fluid (Geodynamics, 2009a). Further drilling is to be undertaken before confirming the location of a 25 MW Commercial Demonstration Project (CDP) which aims to demonstrate EGS technology is cost effective at a commercial scale. Commissioning of the 25 MW CDP geothermal power plant is expected to occur in 2012 (Geodynamics, 2009b; Geodynamics, 2010).

To date about AU\$119.3 million (US\$117.8 million) has been awarded to Geodynamics' Cooper Basin project from various federal funding programs and a further AU\$700,000 (US\$691,000) in South Australian government grants. An initial AU\$5 million (US\$4.9 million) Renewable Energy Development Initiative (REDI) for construction and operation of a demonstration Kalina cycle generation plant, was followed by a AU\$90 million (US\$89 million) Commonwealth Government Renewable Energy Demonstration Program toward development of a 25 MW commercial plant. The SA Government also contributed AU\$560,000 (US\$553,000) from the Regional Development Infrastructure Fund toward construction of transmission lines between the 1MW Pilot plant and Innamincka township. This funding will be received incrementally following completion of technical milestones as the project develops.

Geodynamics have Origin as a Joint Venture partner under the Innamincka 'Deeps' JV where Geodynamics is the Operator with a 70% project interest and Origin has a 30% project interest. In February 2010, Geodynamics announced that it had agreed to enter into a second joint venture with Origin to explore for shallow geothermal resources in the Eromanga Basin in South Australia. In the 'Shallows' JV, Origin is the Operator with a 50% interest. Geodynamics also have cornerstone investors The Sentient Group, Sunsuper Pty Ltd, and the Tata Power Company Limited (Geodynamics, 2010).

Advanced Exploration Phase (EGS) – Petratherm Limited (ASX Code PTR)

Petratherm's Paralana project is another EGS project, located adjacent to the northern Flinders Ranges in South Australia. This project concept differs from other EGS examples in that the company intends to create an EGS reservoir in the insulating sedimentary rocks overlying the high heat producing basement. Termed the Heat Exchanger Within Insulator (HEWI) concept, this method offers potential advantages in hydraulic stimulation of a reservoir and reduced drilling costs.

The Paralana project has received an AU\$5 million (US\$4.9 million) REDI grant toward development of the Heat Exchanger Within Insulator (HEWI) model, and an AU\$7 million (US\$6.9 million) Geothermal Drilling Program (GDP) grant for the drilling of their first deep well (Paralana 2) into the Paralana resource. Spud in June 2009, Paralana 2 was successfully completed to a depth of 3725 metres (Petratherm, 2009a and 2009b), and will undergo mini-fracture stimulation operations and subsequent multi-zone hydraulic stimulation shortly (Petratherm, 2010). A second deep well, Paralana 3, will be designed and drilled as a first production well, followed by construction of a 3.75 MW pilot plant planned for 2011 - 2012. An AU\$62.7 million (US\$61.9 million) REDP grant from the Commonwealth government will assist in subsequent construction of a 30 MW commercial power plant. The future target for the project is the development of over 260 MW capacity to supply power to the National Electricity Market (NEM).

Petratherm have two significant Joint Venture partners in the Paralana Project. Beach Energy Ltd entered an agreement with Petratherm in early 2007, to contribute up to AU\$30 million (US\$29.6 million) for a 36% interest in the Paralana project, while TRUenergy (a wholly owned subsidiary of China Power and Light) agreed to pay up to AU\$57 million (US\$56.3 million) to earn 30% equity in the Paralana Project in August 2008.

Advanced Exploration Phase (HSA) - Panax Geothermal (ASX Code PAX)

Panax Geothermal Ltd's Penola Geothermal Project is testing a Hot Sedimentary Aquifer resource in permeable reservoirs of the Otway Basin, located in the Limestone Coast area of south-eastern South Australia. The Otway Basin is a producing oil and gas province with an extensive background of knowledge and data from historical petroleum exploration activities. Data from existing wells suggest that exploitable hot groundwater resources are present within the permeable Crayfish Subgroup at depths of up to 4000 metres. In this instance, the sedimentary rocks provide both the overlying insulation and geothermal reservoir, heated by conduction from the basement rocks below.

Awarded an AU\$7 million (US\$ 6.9 million) GDP grant from the Commonwealth government to assist with the drilling of their first appraisal/production well, Panax Geothermal spud Salamander 1 in January 2010. This well was drilled to a total depth of 4025 metres in 44 days, and was the first to test a deep HSA target. Early assessment of the well data is promising with a measured bottom hole temperature of 171.4°C at 4000 metres and transmissivities of up

to 13.5 Darcy metres (Dm) in the ~ 1000 metre thick reservoir section (Panax Geothermal, 2010; De Graaf et al, 2010).

Looking forward, Panax Geothermal forecast a staged development of the Penola project. Phase 1 will entail commissioning of a pilot generation plant serviced by three production wells including Salamander 1. Phase 2 will require further drilling of additional production and injection wells and commissioning of a 59 MW (net) plant (Panax Geothermal, 2009).

Advanced Exploration Phase (HSA and Direct Use) - Green Rock Energy Limited (ASX Code GRK)

Green Rock Energy in conjunction with the University of Western Australia, is investigating the potential to use medium enthalpy Hot Sedimentary Aquifer resources in the Perth Basin of Western Australia for heat and cooling of the University campus. In 2011, two wells of about 3000 metres depth each are intended to be drilled within the University campus grounds, to access hot groundwater at about 100°C (212°F). The geothermal energy from the hot aquifer resource will then be used as the primary power source for building air conditioning using adsorption chillers (Green Rock Energy, 2009).

Due to Perth's hot and dry climate, significant electricity and natural gas resources are used through the spring and summer months to cool commercial buildings, hospitals and shopping centres. Geothermal energy is already being recovered to heat aquatic centres in the company's permit area held jointly with the University, and pending success at this first location, Green Rock intends to promote the concept as an environmentally sensitive solution for air conditioning of large buildings and infrastructure in the Perth Metropolitan area.

In support of this project, Green Rock has been awarded a \$7M Commonwealth GDP grant (US\$6.9 million), two Western Australian government drilling grants totalling AU\$295,000 (US\$291,000) and a further AU\$5 million (US\$4.9 million) from the Western Australian Low Emissions Energy Development (LEED) fund..

Exploration Phase (HSA) - Hot Rock Limited (ASX Code HRL)

Hot Rock Limited hold exploration permits covering about 27,521 km² of the Otway Basin in south western Victoria, where data from existing oil and gas wells indicate temperatures of 130°C occur at depths of about 2800 metres. In this area, water

temperatures of up to 152°C have been recorded at depths of around 3700 metres in permeable sedimentary sequences overlain by insulating mudstones. The permeable sandstone reservoir is locally up to 3km thick in sub-basins located within Hot Rock Ltd's permits and can contain a lower section of highly fractured, clean, coarse sandstone which provides an attractive reservoir target.

Hot Rock Ltd intends to investigate the potential for a Hot Sedimentary Aquifer resource in the Koroit area with the drilling and testing of two appraisal wells scheduled for 2011. The licences are close to population centres and infrastructure, and Hot Rock Limited is assessing the potential for direct use applications as well as electricity generation. Success at this Proof-of-Concept stage will lead to the commissioning of a small binary pilot power plant by end 2013 (Hot Rock Limited, 2009). Progress on the Proof-of-concept phase of this project has been supported by the awarding of an AU\$7 million (US\$6.9 million) grant by the Commonwealth government under the second round of the GDP.

Exploration Phase (EGS and Direct Use) - Greenerth Energy Limited (ASX Code GER)

Greenerth Energy's flagship project is the Geelong Geothermal Power Project (GGPP) located east of Melbourne, Victoria, near the city of Geelong. The strategy for this project is similar to that adopted by Hot Rock Ltd, which is to exploit Hot Sedimentary Aquifer resources within the underlying Otway Basin for electricity generation.

The project is planned to be developed in stages, with operations associated with the initial Proof-of-Concept stage scheduled to commence in 2011. This stage will involve the drilling and flow testing of two wells up to 4000 metres deep into a Hot Sedimentary Aquifer resource. Given that adequate temperatures and flow for commercial exploitation are achieved at Stage 1, Stage 2 is scheduled to commence in 2012 and will involve drilling of a further two wells and construction of a modular 12 MWe Organic Rankine Cycle power plant. Adoption of a modular plant design will enable periodic expansion of the facility toward a longer term goal of 140MW total production.

To date, Greenerth Energy have been awarded AU\$7 million (US\$6.9 million) under the second round of the Commonwealth government's Geothermal Drilling Program, plus an AU\$5 million (US\$4.9 million) grant from the Victorian Government's Energy Technology Innovation Strategy (ETIS) program toward their Proof-of-Concept drilling program. The Victorian Government has awarded a further AU\$20 million (US\$19.7

million), also under the Energy Technology Innovation Strategy (ETIS) program, to assist in the construction of the stage 2 geothermal demonstration plant. Total Victorian government grant contributions toward the Geelong Project total AU\$25 million (US\$24.6 million), with the AU\$20 million (US\$19.7 million) grant for Stage 2 being contingent on successful completion of Stage 1.

Conclusion

As discussed above, supportive legislation and well considered government policy frameworks, coupled with targeted, generous grant funding mechanisms have significantly benefitted the Australian geothermal industry. Interest and goodwill toward the sector continues to grow and expectations remain high. With the ongoing support of Australian governments and communities, the industry's keen desire to succeed will see the Australian geothermal sector continue to meet the challenges it faces in achieving the goal of commercial production of large scale, base load geothermal energy in Australia.

References

- De Graaf, B., Reid, I., Palmer, R. and Parker, K., (2010). Salamander-1: A geothermal well based on petroleum exploration results. Proceedings Australian Geothermal Energy Conference, Adelaide November 17 – 19, 2010. Accessed online: <http://clients.weblink.com.au/clients/panaxgeothermal/article.asp?asx=PAX&view=4226335>
- Department of the Prime Minister and Cabinet (DPMC), (2004). Securing Australia's Energy Future. Commonwealth of Australia, Canberra. 193pp. See: http://pandora.nla.gov.au/pan/79623/20080117-2207/dpmc.gov.au/energy_future/index.html
- Department of Resources Energy and Tourism (DRET), (2008a). Australian Geothermal Industry Development Framework. Commonwealth of Australia, Canberra. See: http://www.ret.gov.au/energy/clean_energy_technologies/energy_technology_framework_and_roadmaps/geothermal_industry_development_framework_and_technology_roadmap/Pages/GeothermalIndustryDevelopmentandTechnologyRoadmap.aspx
- Department of Resources Energy and Tourism (DRET), (2008b). Australian Geothermal Industry Technology Roadmap. Commonwealth of Australia, Canberra. See: http://www.ret.gov.au/energy/clean_energy_technologies/energy_technology_framework_and_ro

- admaps/hydrogen_technology_roadmap/Documents/GEOTHERMAL%20ROADMAP.pdf
- Geodynamics Limited, (2009a). 2009 Interactive Annual Report. Accessed online: <http://www.geodynamics.com.au/IRM/content/OAR/index.html>.
- Geodynamics Limited, (2009b). ASX Announcement 06 November 2009: Federal Government Awards \$90 million in Funding to Cooper Basin 25 MW Geothermal Demonstration Project. Accessed online: <http://www.geodynamics.com.au/irm/Company/ShowPage.aspx?CPID=2060&EID=84470685>
- Geodynamics Limited, (2010). Annual Report 2009-2010. Accessed online: <http://www.geodynamics.com.au/IRM/Company/ShowPage.aspx?CPID=2277&EID=11787609>
- Greenearth Energy Limited, (2009). ASX Announcement 14 December 2009: \$7M Grant Awarded to Geelong Geothermal Power Project. Accessed online: <http://www.greenearthenergy.com.au/downloadfile.php?filename=files/announcements/GER%20GDP%20R2%20Announcement%20Final%2014122009%5B1%5D.pdf>
- Green Rock Energy Limited, (2009). ASX Announcement 14 December 2009: Green Rock Energy offered \$7 million Geothermal Drilling Program Grant. Accessed online: http://www.greenrock.com.au/media/2009_12_14__GRKGDPPGrant.pdf
- Hot Rock Limited, (2009). ASX Announcement 14 December 2009: Hot Rock Offered \$7m Government Grant. Accessed online: [http://www.hotrockltd.com/IRM/Company/ShowPage.aspx?CPID=1179&PageName=Hot_Rock_Offered_\\$7m_Government_Grant](http://www.hotrockltd.com/IRM/Company/ShowPage.aspx?CPID=1179&PageName=Hot_Rock_Offered_$7m_Government_Grant)
- International Energy Agency Geothermal Implementing Agreement (IEA-GIA), (2008). Chapter 7 Australia – National Activities. In IEA Geothermal Energy Annual Report 2007. Accessed online: <http://www.iea-gia.org/documents/GIA2007AnnualReportWebcompressed31Dec08.doc>
- Panax Geothermal, (2009). Penola Project – Limestone Coast, South Australia: 59 MW “Stand Alone” Case, Project Evaluation. Accessed online: www.panaxgeothermal.com.au/Images/File/20090910%20PANAX%20SCALE%20UP%20CASE%20WEBSITE%20VERSION.pdf
- Panax Geothermal, (2010). ASX Announcement 20 May 2010: Steam release from Salamander 1 well. Accessed online: <http://clients.weblink.com.au/clients/panaxgeothermal/article.asp?asx=PAX&view=4220812>
- Petratherm Limited, (2009a). ASX Announcement 06 November 2009: \$62.8 million grant awarded to Paralana Geothermal Energy Project. Accessed online: <http://www.petratherm.com.au/LiteratureRetrieve.aspx?ID=56413>
- Petratherm Limited, (2009b). ASX Announcement 14 December 2009: Paralana Joint Venture Project Update. Accessed online: http://www.petratherm.com.au/_literature_59178/Paralana_Joint_Venture_Project_Update
- Petratherm, (2010). ASX Announcement 9 December 2010: Paralana Project Update. Accessed online: <http://www.petratherm.com.au/announcements.html>
- Torrens Energy Limited, (2009). ASX Announcement 14 December 2009: \$7m GDP-R2 Grant Awarded to Torrens Energy. Accessed online: http://www.torrensenergy.com/announcements/091214_grant.pdf