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Country Update — Australia

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ABSTRACT

The five years from 2010–2014 saw mixed fortunes for the geothermal sector in Australia. Three deep wells were completed, of which two were stranded. The third, however, was used in the completion, commissioning and demonstration of Australia's first new geothermal power plant in 20 years. The 1 MWe Habanero Pilot Plant successfully completed a 160-day demonstration, powered by a closed-loop pumped system circulating water through an underground heat exchanger in granodiorite at almost 4,500 m depth. The production well exceeded expectations for productivity. Meanwhile, the Birdsville Geothermal Power Plant continued to generate 80 kWe net electrical power from a 98°C artesian well in Central Australia.

The commercial geothermal power sector in Australia underwent a period of retraction over the reporting period. Many of the companies exploring for geothermal energy in 2009 re-focused or diversified into other energy sources or commodities. The number and area of exploration licenses decreased, although key areas were still held under license.

Direct use of thermal groundwater, however, grew, especially in and around the City of Perth. This included the completion of a Ground Water Cooling project in Perth that involves the rejection of waste heat from a supercomputer into a shallow aquifer. At the time of writing (early 2014), there is renewed interest to re-commission a suspended geothermal district heating system in Portland, Victoria.

Ground source heat pumps were rapidly increasingly in popularity as an energy efficiency measure in new building complexes.

A recreational and balneological hot spring spa industry is emerging in Victoria and elsewhere around the country, establishing itself as a significant driver for local economic development.

The five-year period also saw the formation of the Geothermal Research Initiative, a collaborative framework of the key research institutions interested in geothermal energy in Australia.

Government support was variable. Broad recognition that previous support programs did not result in increased drilling success or power production caused funding bodies to reassess how best to support development of the industry. Financial support was limited to a small number of research and demonstration projects. In 2014, the key funding body, the Australian Renewable Energy Agency, carried out an in-depth review of the economic potential for geothermal energy in Australia, concluding that more fundamental research is needed. The federal government was also developing an energy white paper to set out the energy agenda in Australia. The results of the energy white paper will be presented at the WGC 2015.

1. INTRODUCTION

1.1. Geothermal legislation and policy environment

The Commonwealth of Australia (Figure 1) is a federation of states and territories. Under the constitution of Australia, regulation of geothermal resources falls under the control of the states. Different states have enacted individual pieces of legislation to control the exploration and development of geothermal energy.

In Western Australia, the Petroleum and Geothermal Energy Resources Act (2007) provides for the exploration and recovery of geothermal energy. It allows the Western Australian Government to progressively release blocks of land for open tender.

The South Australian Petroleum and Geothermal Act (2000), as amended in late 2009, allows 'over the counter' applications for geothermal licenses.

The Geothermal Energy Resources Bill (2005) governs exploration for geothermal resources in the state of Victoria. The Bill allows the state government to release blocks of land across the entire state for open tender.

Geothermal resources are classified as 'Category 6' minerals under the Mineral Resources Development Act (1995) in Tasmania. The Act allows 'over the counter' applications for licenses.

In New South Wales, the Mining Act (1992) defines a geothermal substance as "any substance occurring naturally underground that is heated by the natural processes of the earth to a temperature in excess of 100°C." The Act allows 'over the counter' applications.

The Geothermal Energy Act (2010) controls the exploration and development of 'large-scale' geothermal energy extraction in Queensland. The Act allows 'over the counter' applications.

The Geothermal Energy Act (2009) controls the exploration and development of geothermal energy in the Northern Territory. The Act allows 'over the counter' applications.

Figure 1. The Commonwealth of Australia, showing topography, state and territory boundaries and capital cities.

Australia's policy on renewable energy has been continually evolving (with some extinction events) over the last two decades. Australia's commitments under the United Nations Framework Convention on Climate Change Copenhagen Accord and the Kyoto Protocol calls for a reduction in greenhouse gas emissions by 5% (unconditional) to 25% of 2000 levels by 2020. Significant reductions in emissions have already been achieved through changes in land use and forestry practices, coinciding with a flattening or falling demand for electricity. This has reduced the incentive to meet Australia's targets through the supply of renewable energy.

Predating the observed reduction in electricity demand, the Australian government (with bipartisan support) in 2001 mandated a Renewable Energy Target (RET) calling for 20% of Australia's electricity generation to come from renewable sources by 2020. The Australian government subsequently established the 'Clean Energy Future' policy in 2011. Features of this policy relevant to geothermal energy included:

- A national carbon price with a fixed (indexed) price for the first three years before moving to a cap and trade scheme linked to the European Emissions Trading Scheme;
- Establishment via legislation of the Australian Renewable Energy Agency (ARENA) with initial funding of A$3.2 billion to improve the competitiveness and increase the supply of renewable energy in Australia;
- Establishment via legislation of the Clean Energy Finance Corporation (CEFC) with a total of $10 billion to invest in renewable energy and low emissions technologies over a five-year period;
- Continuation of the Renewable Energy Target.

A federal election in September 2013, however, resulted in a new government with a policy platform that included rescinding the carbon price, dismantling ARENA and the CEFC, and reviewing the RET. At the time of writing in September 2014, the government has achieved its first goal of removing the carbon price; legislation to abolish ARENA and CEFC remains the subject of negotiation between the government and minor parties that hold the balance of power in the upper house; and a report has recently been tabled recommending a substantial watering down of the RET. The new government's alternative approach to greenhouse gas emission reduction is a 'Direct Action' policy that includes the purchase of lowest cost emissions abatement through a reverse auction system. At the time of writing, the details of that scheme are yet to be finalized.

Uncertainty and volatility in emissions reduction and renewable energy policies at the federal level over the last five years have created a hazardous environment for investment in renewable technologies. This policy uncertainty continues to impact on the current and future market environment for geothermal energy.

1.2. Financial support from Governments

The Australian Renewable Energy Agency (ARENA) was established in 2012 to consolidate Australian government funding of renewable energy projects. Between then and early 2014, ARENA awarded or carried over five grants for geothermal projects:

- Paralana Engineered Geothermal Systems Project—$13 million to assist Petratherm Ltd to drill a reinjection well, connect it to an existing production well, and test the temperature, flow rate and other characteristics of hot water flowing

between wells to produce energy;
- Reservoir quality in sedimentary geothermal resources—$1.25 million to the University of Adelaide to analyze the only two geothermal wells drilled in hot sedimentary aquifer reservoirs in Australia to evaluate why the flow of fluid was significantly less than expected;
- Habanero Enhanced Geothermal Systems Project—$90 million to assist Geodynamics Ltd with the cost of its EGS project in central Australia;
- Construction of a 7 megawatt Engineered Geothermal System (EGS) Project—$24.5 million to assist Petratherm Ltd construct a 7 megawatt EGS demonstration power station by installing a 3.5 megawatt turbine to each of two geothermal wells; and
- Data fusion and machine learning for geothermal target exploration and characterization—$1.9 million to National ICT Australia Ltd to adapt modern machine learning and statistical methods to improve exploration, discovery and characterization of geothermal resources.

In July 2014, ARENA terminated its two funding agreements with Petratherm Ltd due to Petratherm's inability to raise a level of project equity required under the agreements.

Table 1 estimates the sources of funding spent by the various sectors involved in the geothermal sector in Australia from 2000 up until the end of calendar 2013. The figures only include government grant money expended (i.e. paid to companies upon completion of defined milestones), not the original program commitment. The table shows that funds from state and federal governments make up just over 20% of the total spent on geothermal energy over the past decade or so. Private industry provided the remaining approximately 80%.

Table 1. Estimated public and private spending on geothermal projects since 2000.

Category	Government (million)	Private/In-kind (million)	Total (million)
Industry	$107*	$721	$828
Research	$50	-	$50
Pre-competitive data	$30	-	$30
Totals	**$187**	**$721**	**≈$900**

* Includes $31 million in tax rebates

1.3. Geothermal research

A number of Australian universities retained geothermal research groups over the reporting period. The University of Adelaide hosted the 'South Australian Centre for Geothermal Energy Research'. The University of Queensland hosted the 'Queensland Geothermal Energy Center of Excellence'. The 'Western Australian Geothermal Centre of Excellence' co-hosted by the University of Western Australia, Curtin University and the CSIRO concluded formal activities during the reporting period. Although not supported by any targeted government assistance, the University of Melbourne, University of New South Wales, Newcastle University and others also supported geothermal research programs.

National ICT Australia (NICTA) also received ARENA and state government funding from Victoria for a two-year project that concluded in June 2014. The project saw NICTA lead a team including several university partners to develop software and tools for the application of data fusion and Bayesian inference to the exploration and characterization of geothermal drilling targets in Australia. The outputs allow a probabilistic assessment of geological parameters relevant to geothermal in Australia, and the methods can be further developed to apply to conventional geothermal exploration. The software was released 'open source' under the name 'Obsidian' at https://github.com/NICTA/obsidian.

Australia remained a member of the *International Partnership for Geothermal Technology* (IPGT). The purpose of the IPGT is to accelerate the development of geothermal technologies such as engineered geothermal systems and supercritical systems through international cooperation. Other members are the United States, Iceland, New Zealand and Switzerland.

1.4. Investment by geothermal companies

As of late 2013, 35 companies retained a total of about 200 geothermal licenses covering an area of about 300,000 km^2 across the country (Goldstein and Bendall, 2013; Figure 2). Three different companies had drilled a total of nine wells into 'deep' reservoirs. Of these, seven wells were associated with 'engineered geothermal system' (EGS) projects, while the remaining two targeted hot sedimentary aquifers. Six of the seven EGS wells had undergone hydraulic stimulation. The bulk of the work was carried out with private company funds.

Companies had also made substantial cumulative investments by way of geophysical surveys (for example, substantial MT surveys by Hot Rock Ltd and KUTh Energy Ltd, and smaller ones by Petratherm Ltd and Geodynamics Ltd), rock property measurements, seismic data analyses, heat flow modeling, and technology development partnerships with universities. As shown in Table 1 above, by the end of 2013 the total investment in the Australian geothermal sector was approaching one billion Australian dollars over a period of 13 years.

1.5. Geothermal organizations

A number of organizations represented the geothermal sector during the reporting period. The Australian Geothermal Energy Group (AGEG) and the Australian Geothermal Energy Association (AGEA) had overlapping membership and complimentary aims. Those two organizations are joint hosts of WGC 2015, along with the New Zealand Geothermal Association. The Australian

Chapter of the International Ground Source Heat Pump Association was formed in early 2014. The Australasian Spa Association (ASpa) was formed in 2010 and represents the interests of hot spring developers.

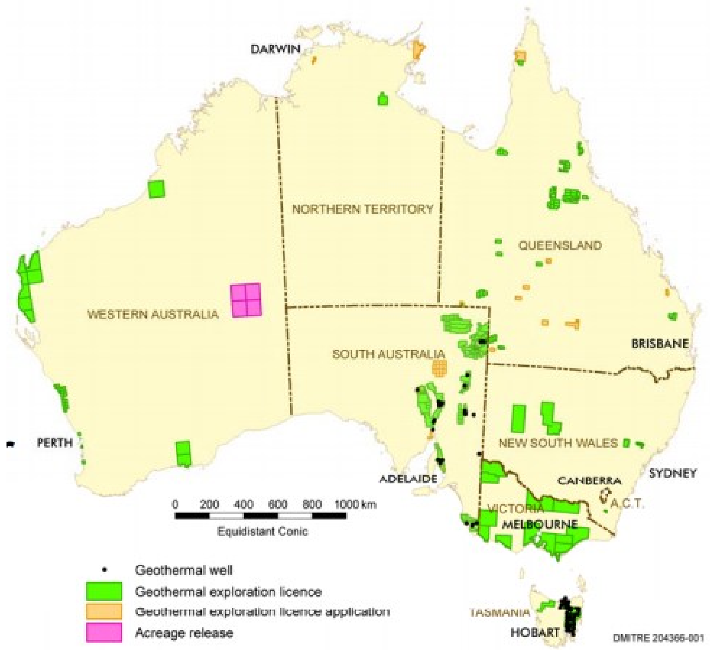

Figure 2. Distribution of geothermal exploration licenses and wells in Australia in late 2013. Goldstein and Bendall (2013).

AGEG is a collegiate body composed of companies, government agencies and academic institutions with a common interest in progressing geothermal energy development in Australia. AGEG was formed to provide support for Australia's membership in the International Energy Agency Geothermal Implementing Agreement.

AGEA grew out of AGEG as the national association of the geothermal industry. Its members are exploration, development and service companies with a predominant interest in geothermal energy. AGEA's mission is to foster and accelerate the development and commercialization of Australia's geothermal energy resources. The retraction in the geothermal industry over the past five years has seen diminishing corporate membership and the opening of membership to individual and institutional members from the research community.

ASpa brings together Spa professionals to deliver excellence in Spa, Health and Wellness. It aims to develop, promote, unify and professionalize the Australian spa industry, including natural hot spring developers.

2. GEOLOGY BACKGROUND

Continental Australia lies wholly within the Indo-Australian tectonic plate. No active plate boundaries encroach onto the land surface. Large earthquakes are limited to intra-cratonic events. Most active surface thermal features are clearly artesian in nature and none have yet been shown to have a volcanic origin. The age of the crust across most of the country is such that the heat of crustal formation dissipated long ago. Australia is barren of conventional high enthalpy hydrothermal geothermal energy resources.

There are, however, geological features of the country that make it prospective for low enthalpy and unconventional geothermal resources.

Australia can be broadly divided into three provinces based on the age of the underlying basement (Figure 3). In the west, the Western Shield Province is characterized by Achaean aged crust. Through the middle of the country the Central Shield Province is composed predominantly of Proterozoic crust. The relatively young crust of the Eastern Province is of Phanerozoic age. Although old when compared to most other parts of the Earth's crust, large sections of the Proterozoic crust in the Central Shield Province have been shown to host unusually high concentrations of heat producing radioactive elements such as uranium and thorium (McLaren et al., 2003). As well as giving Australia the world's largest uranium mine (Olympic Dam in South Australia), this unusual chemical enrichment also keeps the crust warmer than it otherwise would be. Heat flow values are much higher through central Australia than might normally be expected for a terrane of that age (Cull, 1982).

Most of the Australian continent is in a state of tectonic compression (Hillis and Reynolds, 2000), consistent with plate boundary forces arising from a complex collision of the Indo-Australian plate with South East Asia. The direction of maximum compressive stress rotates from a roughly NE–SW trajectory in the north of the country to E–W in the southwest, to NW–SE in the southeast.

The eastern portion of Australia has experienced regular volcanism throughout the Tertiary era (Figure 4). For example, Mount Fox (http://www.ga.gov.au/hazards/volcano/volcano-basics/gallery.html) in Queensland erupted as a pyroclastic cone about 560,000 years ago, while charcoal from beneath basalt flows at Mount Schank in South Australia has been dated at about 18,100 years (Sheard, 1990). Similar tests from nearby Mount Gambier suggest ages as young as 4,700 years (Sheard, 1990). While there is a general younging of events from north to south, the trend does not fit a model for a mantle hot spot and the underlying cause of the volcanism is still a topic of some debate.

Figure 3. Broad divisions of the Australian continental crust, based on basement age.

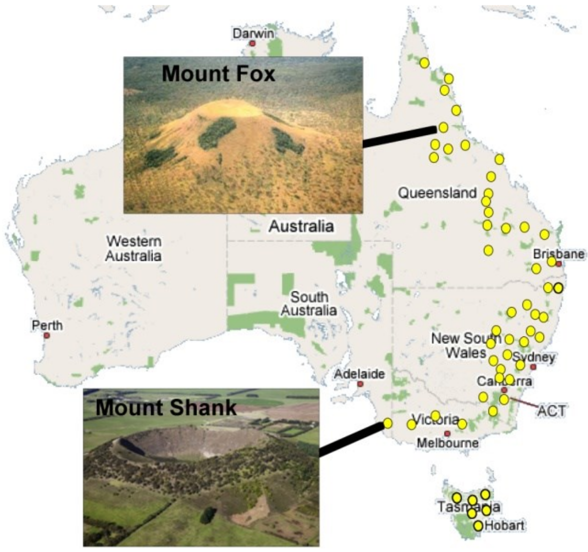

Figure 4. Locations (yellow) of Tertiary-aged volcanic eruption centers in eastern Australia.

Seismic tomography data have shed some light on a potential source of the volcanic material. Low seismic velocity anomalies that may indicate parts of the upper mantle with elevated temperatures have been interpreted beneath southern Queensland, the south coast of Victoria, and northeast Western Australia (Saygin and Kennett, 2010; Graeber et al., 2002). Some of these anomalies coincide with known regions of elevated heat flow.

From a geothermal perspective, no surface thermal manifestations have been identified in association with the volcanism. This is surprising for a volcanic zone with hundreds of identified vents arising from eruptive events spanning several million years, with the most recent only a few thousand years ago. One possible explanation is the fact that the youngest surface features coincide with regionally extensive shallow unconfined aquifers in southeast Australia. These aquifers may 'wash away' any steam or hot water discharge before it reaches the surface. The same aquifers also effectively mask the underlying heat flow over much of the region, hindering the exploration for geothermal resources.

Much of the country is overlain by Phanerozoic sedimentary basins of various size and depth. While some of these are filled with highly silicic material, others contain large amounts of clay and/or coal. The Gippsland Basin in the southeast of the country, for example, contains some of the world's largest deposits of brown coal, while basins throughout New South Wales and Queensland are well endowed with black coal. These basins provide excellent thermal insulation to retard the flow of heat to the surface and elevate average thermal gradients.

3. GEOTHERMAL RESOURCES AND POTENTIAL

Australia has considerable 'Hot Rock' geothermal energy potential. Where high heat producing rocks occur beneath thick blankets of thermally insulating strata, the thermal energy is retained in the basement rocks and overlying strata causing elevated temperatures at relatively shallow depths. There are extensive areas where temperatures are estimated to reach at least 200°C at around 5 km depth. There is also potential for lower temperature geothermal resources associated with aquifers deep in a number of sedimentary basins (Hot Sedimentary Aquifer geothermal). These are potentially suitable for electricity generation and direct use.

Australia's geothermal potential has only relatively recently been appreciated (e.g. Somerville et al., 1994). As a consequence, there is an incomplete knowledge of where the greatest geothermal potential lies. It is likely that further data acquisition will lead to increases in the estimated geothermal resource base. Current knowledge is largely based on a database of temperatures recorded at the bottom of more than 5,700 deep drill holes, most of which were drilled for petroleum exploration supported by more detailed local investigations by companies. National-scale maps published by Geoscience Australia showing the distribution of high heat-producing granites and sedimentary basins, together with other information such as basin depth, provide a national framework and basis for identifying areas likely to have the greatest hot rock potential.

Following the guidelines of the Australian Geothermal Reporting Code (AGRCC 2010) nine companies have declared geothermal resources in 36 leases across four States, totaling 337,395 PJ of heat in place.

Other than at Birdsville, Australia's reported geothermal resources are currently all sub-economic because the commercial viability of utilizing geothermal energy for large-scale electricity generation has not yet been demonstrated in Australia. It is not expected that any technological breakthroughs are needed. Rather there is a need for progression of projects through all stages from resource definition to production and marketing. Project economics is the main factor that has potential to impede the development of the industry. A recent review by ARENA of the economic potential of geothermal energy in Australia (ARENA, 2014) concluded that, while uneconomical in 2014, geothermal could become economically viable in Australia by 2030 with the earliest economic opportunities to be found 'off grid'.

4. GEOTHERMAL UTILIZATION

4.1. Present and planned production of electricity

At the end of 2014, Australia has 56,000 MWe of electricity generation capacity (Appendix Table 1). The Bureau of Resource and Energy Economics (BREE 2014) reported that electricity production for the 2012/13 financial year amounted to 249,000 GWh, of which 87.0% was generated from fossil fuels. 7.3% from hydro and 5.7% from a combination of wind, solar, biomass and biogas. Geothermal contributed just 1 GWh from the Birdsville Geothermal Plant.

4.2. Utilization of geothermal energy for electric power generation as of 31 December 2014

The Birdsville geothermal power plant is Australia's only operating source of geothermal electric power (Appendix Table 2). The organic rankine cycle binary plant operates on 98°C water flowing at 27 liters per second from a 1.2 km deep well to generate a net 80 kWe. Ergon Energy, the operator of the plant, is considering plans to drill a new high-capacity bore and to increase the capacity of the geothermal plant to more than 300 kWe.

Geodynamics Ltd ran its 1.0 MWe pilot plant at its Habanero EGS project near Innamincka in South Australia for a 160-day period in 2013, with the reservoir exceeding expectations for temperature and deliverability (Geodynamics 2013). The pilot operation has enabled a great deal of data gathering, and Geodynamics has announced a further study into commercialization options with a nearby gas developer (Geodynamics 2014). Media reports in early 2014 suggested that Geodynamics Ltd might expand its Habanero operation to 25 MWe over the coming years (http://www.industrialinfo.com/, 15 May 2014), but Geodynamics itself has not confirmed the scope of its expansion plans. Instead, it has announced (Geodynamics, 2014) an intention to partner with Beach Energy Ltd to provide Beach with power and process heat for shale gas developments.

4.3. Utilization of geothermal energy for direct heat as of 31 December 2014 (excluding heat pumps)

Australia's only geothermal district heating system, at Portland in Victoria, remains decommissioned since 2006 for a variety of reasons including environmental (spent water was being discharged into a surface stream). However, the Glenelg Shire Council announced in mid-2014 its intention to re-commission the system, and had approached the Victorian government for assistance to do so (source: Warrnambool Standard, 10 July 2014). As well as this, geothermal energy is increasingly being recognized as a cheap source of thermal power, particularly around the City of Perth in Western Australia (Appendix Table 3). The Yarragadee Aquifer in the Perth Basin is utilized for a number of direct heat purposes.

At Robe in South Australia, the company Robarra grows barramundi (edible tropical freshwater fish) in tanks that hold fresh geothermal water pumped directly from a 335 m deep bore in the Dilwyn Aquifer. The water comes from the bore at 29°C, in the optimal temperature range for growing barramundi, and provides over 43 TJ of thermal energy per year. In Victoria, Mainstream Aquiculture operates a barramundi farm at Werribee, using 28°C fresh geothermal water directly to grow the fingerlings. Midfield Meats in Warrnambool uses geothermal water for washing down and sterilizing its industrial meat processing facility. At the Quality Suites Deep Blue geothermal spa resort at Warrnambool, a 735 m bore produces 43°C water at a maximum of 50 liters per second. The bore provides the resort's domestic hot water and heats the resort's 122 rooms via a system of hydronic radiators.

The Yarragadee aquifer beneath the city of Perth is being increasingly utilized for its direct heating potential. The projects being developed largely involve the heating of swimming pools in public aquatic centers and schools. Wellhead temperatures are typically 40–50°C with flow rates of 10–40 liters per second. Regulations require 100% reinjection of the spent fluid.

The recreational / balneological use of geothermal water deserves special mention because of the strong interest in that sector in recent years. Every state in Australia has hot springs with over 40 unique locations so far identified. Of these, 15 support commercial bathing, day spa and accommodation centers with a combined estimated annual turnover of US$29 million in 2013.

While this is only a small fraction of the estimated 2013 global hot springs (thermal) industry sales value of $50 billion from 26,847 establishments in 103 countries (Johnston and Yeong, 2014), the industry is showing rapid growth in Australia.

At Fingal, on the Mornington Peninsula close to Melbourne, Peninsula Hot Springs draws 320 million liters of 46°C water per annum from the Mepunga Formation at 637 m. The tourism attraction received 420,000 visitors in 2014 and employs 228 full and part time staff. If its commercial growth pattern over the past nine years continues, it will become the largest tourism attraction in Victoria in 3-5 years time.

Around the rest of the country, recreational swimming and bathing centers use natural warm/hot spring water ranging in temperature from 28°C (Hastings, Tasmania) to 72°C (Innot Hot Springs, Queensland). The artesian geothermal water at Hastings supplies a single outdoor public swimming pool after passing through a filtration and chlorination system. The water used in the bathing facility at Innot Hot Springs is produced from a 56 m deep bore and is discharged into a cooling pond at the rear of the property. Natural artesian flows also occur on the edge of a creek adjacent to the hot springs development.

Other locations around the country where artesian water is utilized for bathing purposes include Moree (New South Wales; 41°C), Pillaga (New South Wales; 37°C), Lightning Ridge (New South Wales; 41.5°C), Mataranka (Northern Territory; 34°C), Dalhousie Mound Springs (South Australia; 38–43°C) and Zebedee Springs (Western Australia: 28-32°C), but this list is not exhaustive.

Dalhousie Springs, for example, is a group of over 60 natural artesian springs located in Witjira National Park on the western fringe of the Simpson Desert in northern South Australia. In 1915, the total flow rate of the Dalhousie Springs complex was over 23,000 liters/second, but drilling and production had reduced this to 17,360 liters/second by 2000 (Ponder, 2002). For tens of thousands of years, the Arrente people (indigenous language group) managed the water resources in a harmonious and sustainable way to provide water, food, life and connection on an important traditional travel path. Today, indigenous elder Dean Ah Chee from Dalhousie Springs works closely with the South Australian state authorities to manage and conserve the resource through a combination of traditional skills and knowledge and Western scientific methods (Ah Chee, unknown).

Utilization rates are difficult to determine for most of the springs measured above. Many discharge to the surface and ‘outlet’ temperatures are unrecorded. For others, the flow rate is poorly constrained. Table 3 includes all information available at the time of writing.

4.4. Geothermal (ground source) heat pumps as of 31 December 2014

The Geoscience Australia (GA) building in Canberra (ACT) remains the country’s largest ground source heat pump (GSHP) installation (Appendix Table 4). The system supplies 2,500 kW of thermal power to 210 ‘Water Furnace Premier’ ground source heat pump units of various capacities within a building with a floor space of 40,000 m^2. The ground loops are arranged in 44 sets of eight vertical boreholes (total of 352 boreholes) drilled to 104 m depth in the ground with an undisturbed temperature of 18.2°C. These loop-sets are connected to four flow and return headers in the plant room, each with its own primary circulating pump. The four pumps reject or extract heat evenly across the entire loop field.

However, the ground source heat pump sector in Australia appears to be on the verge of a rapid period of growth. Two major research institutions, the University of Melbourne and the University of Queensland, have active research projects to demonstrate the practicality and value of GSHP’s under Australian conditions. An Australian chapter of the International Ground Source Heat Pump Association was inaugurated in early 2014. A number of commercial GSHP service providers have emerged into the market, including one of the largest Australian utility companies. New projects are being announced at increasingly regular intervals, including plans for one of the largest integrated residential GSHP networks in the world; an 800-block housing estate being developed by Australand at Fairwater near Blacktown in Sydney’s west which will include a network of ground source heat pumps into which future homeowners can connect for heating and cooling (source: Australian Financial Review, 26 July 2014).

4.5. Summary of geothermal direct heat use as of 31 December 2014

Unfortunately, the absolute energy usage for direct heat and ground source heat pumps in Australia is very poorly constrained. The data are not routinely collated by any central organization. The authors of this paper have been able to collect the necessary data for a number of individual projects, but most remain unmeasured. The best-constrained are the set of swimming pools heated by geothermal water from the Yarragadee Aquifer in the Perth Basin (Appendix Table 5).

4.6. Wells drilled for electrical and direct use of geothermal resources from 1 January 2010 to 31 December 2014 (excluding heat pump wells)

The ‘Country Update’ presented for Australia at the 2010 World Geothermal Congress in Bali, Indonesia, reported on completed and planned geothermal drilling in Australia from 1 January 2005 to 31 December 2009 amounting to at least 84 wells with a total depth of 58.8 km (Beardsmore and Hill, 2010). Geothermal drilling activity slowed considerably in the succeeding five-year period.

Since 2010, Geodynamics Ltd has added one more well to its previous five wells drilled into the 250°C, fractured granodiorite beneath the Cooper Basin. Habanero 4 was drilled to 4,204 m and became (with Habanero 1) part of the successful EGS demonstration loop in 2013. Geodynamics’ joint venture partners Origin Energy drilled Celsius 1 to 2,417 m, also in the Cooper Basin, to test a ‘hot sedimentary aquifer’ play. Celsius 1 failed to flow at a commercial rate and a second planned well was not drilled.

Petratherm Ltd and Panax Geothermal Ltd each completed wells to about 4,000 m depth within six months prior to WGC 2010. Petratherm completed a successful ‘fracking’ program in Paralana 2, but subsequently suspended the project through lack of funding. Panax Geothermal suspended Salamander 1 shortly after drilling, due to poor sustained flow from the well.

The Peninsula Hot Springs drilled a reinjection well to about 650 m depth, while a number of direct use projects in Western Australia drilled production and injection wells in the five years 2010–2014.

4.7. Allocation of professional personnel (with university degree) to geothermal activities

A significant contraction in employment has accompanied a general reduction in the number of companies and research institutions active in the geothermal sector over the past five years. Detailed employment statistics are not recorded for the geothermal sector in Australia, but the authors estimate that professional employment within the sector has shrunk from 198 person-years in 2009 to fewer than 50 in 2014 (Appendix Table 7).

4.8. Total investments in geothermal for 2010–2014

Approximately AU$500 million was spent on geothermal exploration and development in Australia in the period 2010–2014 (Huddlestone-Holmes, 2014). Assuming a mean exchange rate of AU$1.00 = US$0.90, that equates to about US$555 million (Appendix Table 8). This compares to US$437 million reported for the five-year period 2005–2009.

5. DISCUSSION

It is fair to say that the Australian geothermal power sector has not lived up to the promise expressed in the last Country Update paper (Beardsmore and Hill, 2010). This can be attributed to a range of factors including unsupportive and risk-adverse investment markets, unexpected technical issues and unstable policy settings. In spite of the major contraction in the geothermal power sector over the past five years, however, there remain reasons for optimism. The ground source heat pump sector looks set to grow over the coming years as awareness grows, installation costs decrease and as the price of domestic natural gas (the most common alternative heating fuel) and electricity continue to climb. The hot water resource beneath Perth and elsewhere is increasingly being utilized for heating public buildings and swimming pools. And there is a growing movement towards establishing a geothermal spa industry in the country.

6. FUTURE DEVELOPMENT AND INSTALLATIONS

Geodynamics Ltd hopes to expand its Habanero project from the current 1 MWe demonstration plant to an unspecified size in order to provide power and process heat to a growing shale gas industry in the Cooper Basin (Geodynamics 2014). That would likely make Habanero one of the biggest EGS projects in the world. One of the largest residential GSHP networks is also planned in New South Wales, and the Portland geothermal district heating system looks set to be re-commissioned. A geothermal spa development looks set to become Victoria's largest tourist attraction in the coming few years (Figure 5). These and other projects will be 'good news' stories to look forward to at WGC 2020.

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Anthony Budd publishes with the permission of the CEO, Geoscience Australia.

Figure 5. The Peninsula Hot Springs in Victoria represent the dawn of a new era of direct geothermal utilization. Photo courtesy of Peninsula Hot Springs.

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APPENDIX: STANDARD TABLES

Table 1. Present and planned production of electricity

	Geothermal		Fossil Fuels		Hydro		Other Renewables		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
Operating 2014	1.12	1	42,400	216,509	8,500	18,270	5,100	14,296	56,000	249,076
Under construction December 2014	0		n/a		n/a		n/a		n/a	
Total projected for 2020	~25?		n/a		n/a		n/a		58,000	275,000

Sources: BREE (2014), ESAA (2014), GA/BREE (2014), AEMO (2013), Industrial Info (2014)

Table 2. Utilization of geothermal energy for electric power generation as of 31 December 2014

Locality	Power Plant Name	Year Commi-miss-ioned	No. of Units	Status1)	Type of Unit2)	Total Installed Capacity MWe	Total Running Capacity MWe	Annual Energy Produced 2014 GWh/yr	Total under Constr. or Planned MWe
Birdsville, QLD a)	Birdsville	1992	1		B (ORC)	0.12	0.08	0.5	0.3
Innamincka, SA b)	Habanero	2013	1	N	B (H2O)	1.0	0.7	0	25
Mulka, SA c)	Mulka	1987	1	R	B (ORC)	0.02	0	0	
Total						1.1	0.08	0.5	25.3

1) N = Not operating (temporary), R = Retired; 2) B = Binary, ORC = organic Rankine Cycle, H2O = water Rankine Cycle; Sources: a) Ergon Energy 2014; b) industrial Info (2014); c) Popovsky 2013.

Table 3. Utilization of geothermal energy for direct heat as of 31 December 2014 (excluding heat pumps)

Locality		Maximum Utilization			Capacity	Annual Utilization		
	Type1	Flow Rate	Temperature (°C)			Average Flow	Energy	Capacity Factor
		(kg/s)	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	
Bicton Polo Club, WA2	B	8.1	40	n/a	0.300	2.9	3.78	0.35
Claremont, WA	B	13.7	43	29	0.802	8.3	15.3	0.61
Christchurch School, WA2	B	12.2	42.4	30	0.625	4.1	6.84	0.35
Challenge Stadium, WA2	B,O	60	43	35	2.00	28	29.5	0.46
Craigie Leisure, WA2	B	18	38.3	33	0.400	7	10.2	0.39
St Hilda's School, WA2	B	21	49.8	35	1.275	6	11.5	0.29
Canning Leisure, WA2	B	26	47	38	0.975			
Beatty Park Leisure, WA2	B	34.7	49.1	36	1.925	13.5	21.6	0.39
Hale School, WA2	B	26.6	45.5	30	1.725	12.4	25.2	0.47
Robe, SA	F	96	29		2.3	58	43.5	0.60
Peninsula Hot Springs, Rye, Vic	B	50	45	39	1.26	4.5	3.56	0.09
Mainstream Aquaculture, Werribee, Vic	F	6	28					
Quality Suites Deep Blue Resort, Warrnambool, Vic	B,H,O	50	43				10.5	
Midfield Meats, Warrnambool, Vic	I	11.6	45					
Hastings, Tas	B		27					
Moree, NSW	B		41					
Pilliga, NSW	B	650	37					
Lightning Ridge, NSW	B		41.5					
Mataranka, NT	B	260	34					
Innot Hot Springs, QLD	B	3	72					
TOTAL		1347			13.59		181.5	

1) B = Bathing, swimming, balneology; O = Domestic hot water, F = Fish farming, H = Individual space heating, I = Industrial process heat; 2) Source: Pujol (2014)

Table 4. Geothermal (ground source) heat pumps as of 31 December 2014 (note that data are unavailable for many other installed systems)

Locality	Ground Temp. (°C)	Typical heat pump rating or capacity (kW)	Number of units	Type1	COP2
Geoscience Australia, ACT	18.2	2500	210	V	3.5

1) V = vertical ground coupled; 2) COP = output thermal energy/input energy of compressor

Table 5. Summary table of geothermal direct heat uses as of 31 December 2014[1]

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr)	Capacity Factor
Individual space heating			
District heating			
Air conditioning (cooling)			
Greenhouse heating			
Fish farming	2.3	43.5	0.6
Animal farming			
Agricultural drying			
Industrial process heat			
Snow melting			
Bathing and swimming[2]	11.29	138	0.42
Other uses			
Sub total	13.59	181.5	0.46
Geothermal heat pumps	2.50	12.86	n/a
Total	16.09	194.36	

1) Only quantifiable values are shown; 2) Includes a minor component of domestic hot water heating

Table 6. Wells drilled for electrical and direct use of geothermal resources from January 1, 2010 to December 31, 2014 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled		Total Depth (km)
		Electric Power	Direct Use	
Exploration	(all)	3	0	6.6
Production	>150°C	1	0	4.5
	100–150°C	0	0	--
	<100°C	0	4	4.3
Injection	(all)	0	5	3.2
Total		3	9	18.2

Table 7. Allocation of professional personnel to geothermal activities (personnel with university degrees)

Year	Professional person-years of effort						
	(1)	(2)	(3)	(4)	(5)	(6)	Total
2009[7]	*21*	*1*	*18*	*5*	*0*	*153*	*198*
2010	21	1	20	4	0	120	166
2011	15	1	20	2	0	90	128
2012	12	1	20	1	0	50	84
2013	10	1	20	1	0	35	67
2014	5	1	15	1	0	25	47
Total ('10–'14)	63	5	95	9	0	320	492

1) Government; 2) Public utilities; 3) Universities; 4) Paid foreign consultants; 5) Contributed through foreign aid programs; 6) Private industry; 7) From Beardsmore and Hill (2010)

Table 8. Total investments in geothermal (2014 US$)

Period	Research and Development (incl. exploration drilling) (2014 US$million[1])	Field Development (incl. production drilling and surface equipment) (2014 US$million)	Utilization (2014 US$million)		Funding Type (%)	
			Direct	Electricity	Private	Public
1995–1999	--	--	--	--	--	--
2000–2004	2.2	32	--	--	70	30
2005–2009	96	339	1.8	--	92	8
2010–2014[2]	455	100	100	455	90	10

1) Exchange rate at September 2014: AU$1.00 = US$0.90; 2) All numbers are approximate only