PROCEEDINGS, Thirty-Eighth Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 11-13, 2013
SGP-TR-198

GEOTHERMAL CODIFICATION IMPACTS ON GEOTHERMAL DEVELOPMENT AND INVESTMENTS

Brittany Segneri[1], Dale S. Jenne[2], Katherine Young[2], Hildigunnur Thorsteinsson[3*], Eric Hass[4]

[1]New West Technologies, LLC, 901 D Street, SW, Suite 910, Washington D.C. 20024
[2]National Renewable Energy Laboratory, 15013 Denver West Parkway,Golden, CO 80401-3305
[3]Geothermal Technologies Office, U.S. Department of Energy, 1617 Cole Blvd., Golden, CO 80401, USA
[4]Geothermal Technologies Office, U.S. Department of Energy
1000 Independence Ave. SW, Washington, DC 20585, USA
*Now at: Reykjavik Energy, Bæjarhálsi 1, 110 Reykjavik, Iceland

Email: brittany.segneri@ee.doe.gov

ABSTRACT

The United States leads the world in geothermal energy production with 3187 MW online in 2012. Across the globe, advancing geothermal exploration technologies serves an important role in lowering geothermal development costs and decreasing exploration risk. However, the aggregation, analysis, and reporting of new geothermal resources lack standard reporting guidelines in most geothermal producing countries with the notable exception of Australia and Canada. In order for the United States to remain the global leader in geothermal energy development, the industry must continue to grow its investment potential. Providing prospective investors with geothermal resource estimates under clearly defined industry guidelines and standards would enhance industry credibility and ultimately encourage greater investor confidence in geothermal development. In 2009, an intergovernmental collaboration of experts developed the United Nations Framework Classification (UNFC), a universally applicable system for classifying and evaluating fossil energy and mineral resources. The U.S. geothermal industry can leverage the Canadian and Australian codes efforts and the UNFC to develop its own reporting standard for geothermal resources. This paper will review lessons learned from Australia and Canada's Geothermal Codification, analyze the impact of each effort on the nation's geothermal industry and investment climate, and begin to evaluate the utility of the UNFC in geothermal applications.

INTRODUCTION

The Geothermal Energy Association (GEA) reported 11,224 MW of installed geothermal capacity online worldwide as of May 2012. Countries across Europe, North America, South America, and Asia have all contributed to the rising global installed geothermal capacity. However, both Australia and Canada's contributions remain negligible despite favorable conditions for geothermal development shown in Figures 1 and 2 respectively.

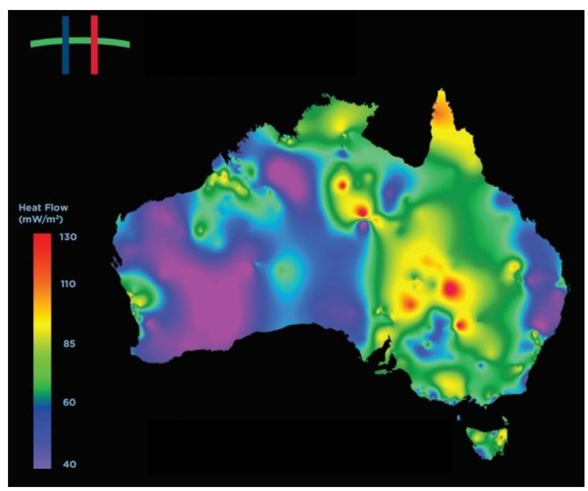

Figure 1. Heat Flow Map of Australia (Source: Hot Dry Rock Ltd., 2011)

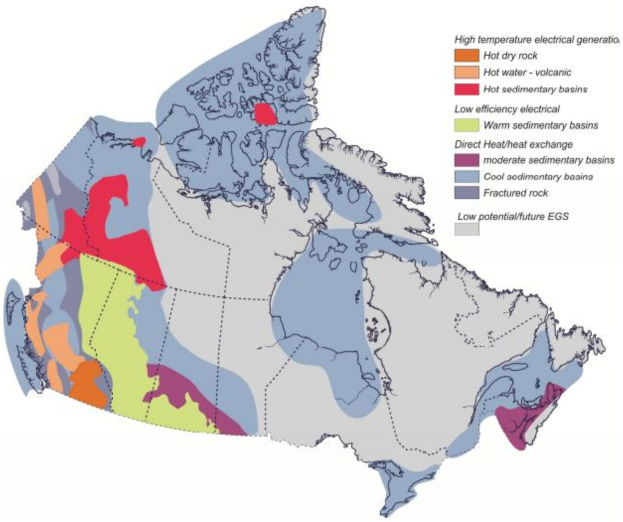

Figure 2. Geothermal Resource Potential in Canada (Source: Geological Survey of Canada, 2012)

Securing financing for research and development efforts in this industry remains a key barrier to success (Williams, 2011). Taking steps to improve resource-reporting accountability is a key component to attracting investors. The geothermal community in Australia recognized the need for greater investor confidence and in 2008 formed the Australian Geothermal Reporting Code Committee (AGRCC) to develop the world's first unified reporting code. In 2010, Canada followed suit and distributed 'The Canadian Geothermal Code for Public Reporting,' and Australia released a 2nd Edition of its code. Both codes were designed to be living documents to evolve with technology and the needs of the industry (Williams, 2011). As a result, Canadian and Australian geothermal efforts continue to slowly expand with several projects currently under development. Both nations are one step closer to significantly contributing to global geothermal installed capacity in the future. Studying and understanding the impacts of the Australian and Canadian geothermal codes will encourage broader implementation into the international geothermal community.

THE AUSTRALIAN GEOTHERMAL CODE

The Australian code was developed under a joint initiative between the Australian Geothermal Energy Group (AGEG) and the Australian Geothermal Energy Association (AGEA). The geothermal code development was strongly influenced by the JORC code for mineral deposits by adapting its governing principles, terminologies, and concepts. Modeling the code after an existing and widely accepted code offered an opportunity for a more rapid implementation and utilization. The geothermal code leveraged existing concepts already familiar to many investors (Williams, 2011). The governing principles that were adapted from the JORC code include: transparency, materiality, and competence (JORC, 2004). The geothermal code is broken into two categories: geothermal resources and geothermal reserves. Based on increasing amounts of geological knowledge and confidence, 'Geothermal Resources' are divided into three levels: inferred, indicated, and measured. Figure 3 shows the organization of the categories and levels in the code. Geothermal Reserves are distinguished from Geothermal Resources through 'Modifying Factors,' that directly impact the probability of commercial delivery.

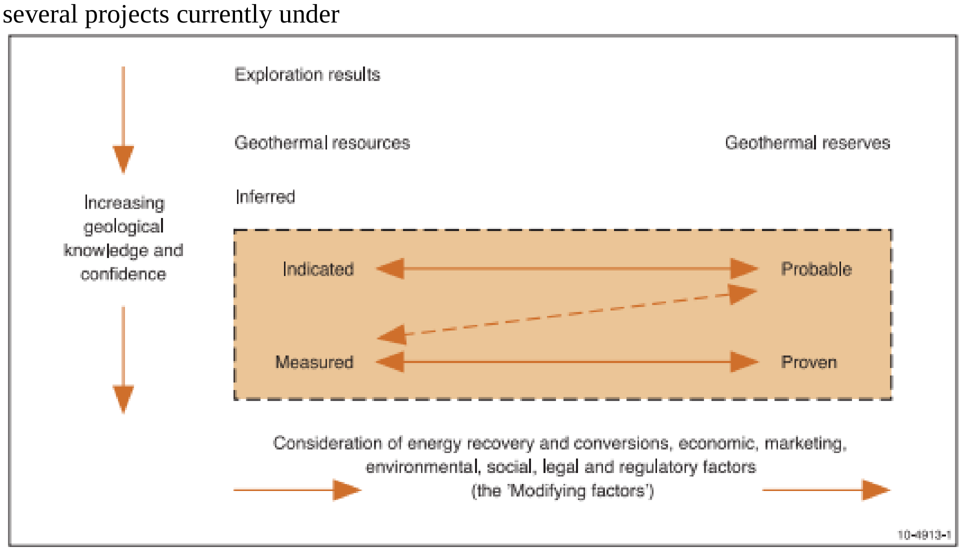

Figure 3. Relationship between Exploration Results, Geothermal Resources and Geothermal Reserves (AGCC, 2010)

'Modifying Factors' include: energy recovery and conversion, production, economic, marketing, environmental, social, legal, land access and regulatory factors. The two categories of Geothermal Reserves (Probable and Proven) are based upon confidence in both the underlying geothermal resource estimate and the 'Modifying Factors' (AGCC, 2010).

THE CANADIAN GEOTHERMAL CODE

In 2008, the Canadian Geothermal Energy Association (CanGEA) established the Canadian Geothermal Code Committee (CGCC) to prepare a national code for Canada's emerging geothermal industry. CanGEA released 'The Canadian Geothermal Code for Public Reporting.' in 2010 providing a minimum set of requirements for the public reporting of exploration results, geothermal resources and geothermal reserves in Canada (CanGEA, 2010). Working in close collaboration with the Australian Geothermal Energy Association, CGCC developed a code that very closely followed the format and criteria established in the Australian code including the classification breakdown in Figure 3.

CODE ACCEPTANCE AND IMPLEMENTATION

The Australian and Canadian geothermal codes are still awaiting endorsement by the Australian Securities Exchange and Canadian Securities Exchanges respectively. However, these codes were designed as "living documents" meant to evolve as the geothermal industry grows and its needs continue to change overtime (Williams, 2011). Since the release of the Australian Geothermal Code's first edition in 2008, geothermal companies across Australia, Canada, and beyond have utilized the reporting codes. As of 2011, both Australian Geothermal Energy Association (AGEA) and Canadian Geothermal Energy Association (CanGEA) members must comply with its country's established code for geothermal exploration reporting. Table 1 shows the 30 companies listed as current members of AGEA and CanGEA. Many of these companies are conducting geothermal exploration projects in Australia and Canada. However, several companies also have active international portfolios in geothermal exploration and development. These companies are following the code for geothermal reporting throughout their portfolio and beyond the borders of Australia and Canada, consequently expanding code implementation and impact on the international geothermal market. As the codes continue to gain acceptance on a global scale (similar to the JORC), cross boarder capital investment will become more appealing. Resource and reserve assets of a company in one region can be assessed and valued with a standard and accepted template by investors anywhere in the world (Lawless et al, 2010). Enabling investor confidence to seek out projects on a broader international scale creates a

Code Compliant Association Members	
Company	Affiliation
Australian Geothermal Solutions	AGEA
Borealis Geopower Inc.	CanGEA
Caldera Geothermal Inc.	CanGEA
Deep Earth Energy Production Corp.	CanGEA
EBA Engineering Consultants LTD.	CanGEA
Enbridge	CanGEA
Enerpro Engineering	CanGEA
Finlaysons	AGEA
Geodynamics LTD.	AGEA
Golder Associates	CanGEA
Green Rock Energy LTD	AGEA
Greenearth Energy LTD	AGEA
GT Power PTY LTD	AGEA
Hot Rock LTD	AGEA
M.K. Ince and Associates LTD.	CanGEA
Mannvit Engineering	CanGEA
Meridian Environmental Inc.	CanGEA
Nevada Geothermal Power Inc.	CanGEA
Nexen Inc.	CanGEA
Pan Pacific Power Corp.	CanGEA
Petrotherm LTD	AGEA
Queensland Geothermal Energy Centre of Excellence	AGEA
Ram Power, Corp.	CanGEA
Sinclair Knight Merz	CanGEA
SNC Lavalin	CanGEA
South Australian Centre for Geothermal Energy Research	AGEA
Suncor Energy Inc.	CanGEA
The Great Basin Center (UNR)	CanGEA
ThinkGeoEnergy	CanGEA
Yukon Energy	CanGEA

Table 1. Members of the Canadian Geothermal Energy Association (CanGEA) and the Australian Geothermal Energy Association (AGEA) required to follow the Australian and Canadian codes for geothermal reporting. (Source: CanGEA, AGEA)

larger and more important role for national energy policies, namely renewable energy development incentives. Adopting geothermal reporting codes is a crucial step, but countries that wish to expand their geothermal market share must also attract investors with enticing renewable energy policies.

GEOTHERMAL DEVELOPMENT IN AUSTRALIA

Australia contains large potential for geothermal energy development especially in Enhanced Geothermal Systems (EGS)[1] and Hot Sedimentary Aquifers (HSA).[2] However, there are key barriers to successful Australian geothermal energy demonstration and deployment:

- High costs of drilling
- Achieving proof of concept
- Ability to provide electricity at a competitive price
- Lack of investor confidence in the geothermal sector (Allen Consulting Group, 2011)

The Australian Geothermal Reporting code is meant to directly address the industry's low investor confidence. Although investors largely remain on the sidelines waiting for a carbon price, successful/ sustained demonstration plant, or even additional state incentives (Allen Consulting Group, 2011), companies across Australia are utilizing the code and conducting exploration and early stage demonstration. Table 2 lists ten companies with major geothermal activities in Australia. Five of these companies are members of the Australian Geothermal Energy Association (AGEA), which requires code compliance. The other five non-AGEA members (Torrens Energy, KUTh Energy Ltd, Panax Geothermal, Geothermal Resources Ltd, and Eden Energy Ltd) also followed the geothermal code standards for resource reporting. For example, KUTh Energy Ltd updated resource assessments for their geothermal efforts in Tasmania (Figure 4). As all of these projects progress and the geothermal code's utility is seen in practice, a more optimistic market outlook will attract the investments needed to move geothermal from resource potential to commercialization and deployment in Australia.

TASMANIAN GEOTHERMAL RESOURCES (100% KUTh)			
Depth Interval (m)	Inferred Resource of Recoverable Energy (PJ_{th}) According to the Code 2nd ed.	Estimated Power Potential (MWe for 30 years)	Previous Inferred Resource (PJ_{th}) [at 30 June 2010]
LEMONT			
< 4,000	3,400	411	260,000 [14 July 2009]
4,000 – 4,500	11,000	1,391	
4,500 – 5,000	13,000	1,824	
FINGAL			
< 3500	370	43	101,000 [9 March 2010]
3,500 – 4,000	2,300	291	
4,000 – 4,500	3,900	519	
4,500 – 5,000	4,800	685	

Figure 4. Tasmanian geothermal resources reassessed (30 June 2011) to comply with The Australian Code for the Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves, 2nd Edition. (Source: KUTh Energy LTD, 2011)

GEOTHERMAL DEVELOPMENT IN CANADA

Estimates of 5,000 MW of Canadian geothermal potential for shallow conventional resources exist throughout the nation. Successful proof of concept for Enhanced Geothermal Systems (EGS) would add an additional 10,000 MW of geothermal potential (CanGEA, 2013). Canada and Australia face the same unfriendly investor environment, resulting in the Canadian geothermal industry taking a similar proactive role in geothermal reporting code efforts. Seeking also to improve investor confidence, CanGEA requires all members to comply with the 2010 "Canadian Geothermal Code for Public Reporting." Geothermal development is still in very early stages across Canada. CanGEA members such as Borealis GeoPower, Ram Power, and DEEP Earth Energy Production are acquiring geothermal leases and entering feasibility phases (Table 3). These project's progression from feasibility to development phase are crucial to validate the reporting code and offer investors a more enticing market with better risk mitigation.

[1] Enhanced Geothermal Systems (EGS): Fluid is artificially circulated through naturally hot rocks to produce super-heated water or steam. (Allen Consulting Group, 2011)

[2] Hot Sedimentary Aquifers (HSA): High temperatures are reached at depths shallow enough for natural porosity and permeability in sedimentary rocks to be preserved, so that fluid circulation can occur without artificial enhancement. (Allen Consulting Group, 2011

Table 2. Major Australian Activities of Geothermal Companies (Source: The Allen Consulting Group, Table 3.2 of Australia's geothermal industry: pathways for development)

Company	Project Area	
Geodynamics	Cooper Basin, SA	Geodynamics has announced plans fo Plant, which is expected to be operati Geodynamics has conducted concept Cooper Basin to major load centers su supported by a grant of $90 million fr [illegible] Program (REDP).
	Hunter Valley, NSW	[illegible] borehole is underway production, supported by a grant of $ Drilling Program (GDP).
Petratherm	Parlaana, SA	The purpose of the project is to devel pilot plant. Two deep wells have been GDP. The project was recently award
	Renmark, SA	Two geothermal exploration licenses initiative is looking to test a Hot Sedi hot brine waters from aquifers near th
	East Gippsland	A geothermal exploration permit has geothermal project.
Torrens Energy	Parachilna, SA	The Parachilna Geothermal Play Proj geothermal resource. The current foc of $7 million from the GDP.
	Port Augusta, SA	Heat flow drilling has indicated a larg situated adjacent to the Davenport Su Market
Green Rock Energy	Olympic Dam, SA	The objective of this project is to dev from an existing high voltage transmi grid) and 10km from the Olympic Da successfully shown that fractures can seeking a joint venture partner to assi an injection well and a production we
	Perth Basin, WA	In the Central Perth Basin, a proof of the University of Western Australia c temperatures are achieved, Green Ro chilled water for the campus reticulat may also be considered. Planning and commencing drilling in the first half o from the GDP and $5.4 million from
Geothermal Resources Ltd	Frome, SA	Eight exploration wells have been co found a thermal gradient capable of g next stage of the project will involve and reservoir parameters, followed by The project is supported by grants of Energy Development Initiative) and $
Hot Rock Ltd.	Otway Basin, SA	Hot Sedimentary Aquifer resources h areas. A proof-of-concept drilling pro million from the GDP. It is anticipate Koroit by mid-2013
KUTh Energy	Central Tasmania	Results from an extensive exploration geothermal potential of resources at I drill, and is investigating different op
Greenearth Energy	Geelong, Vic	The objective of this project is to con work is underway for Stage 1 (proof- GDP ($7 million) and the Victorian G Innovation Strategy). The Victorian G funding upon successful completion o
Panax Geothermal	Limestone Coast, SA	The Penoala Project targets Hot Sedi deep geothermal well was completed GDP. Following a well testing progra to assist with a completion problem w
	Cooper Basin, SA	Two projects in this region are at the believed to be suitable for a mini thre the vicinity. The Tirrawarra project h generation of saleable electricity, foll with Santos Ltd (owners of nearby ga
Eden Energy Ltd	Cooper Basin, SA	Eden holds a number of geothermal l Quarterly Report, Eden has secured a its geothermal licenses. This is to ena development of their geothermal proj

Location	Project Type	Developer	Size	Status	Funding
Swan Hills, Alberta	Power Generation	Borealis GeoPower, Free Energy, Devron	2 MWe	Unclear	Private/Public
Ft Liard, NWT	Power/Heat Generation	Acho Dene Koe First Nation, Borealis GeoPower	.6 MWe/1.0 MWh	Feasibility Phase	Private/Public
Kinbasket Lake, Valemount, British Columbia	Power Generation	Shuswap and Simpcw First Nations, Borealis GeoPower	+/- 10 MWe	Feasibility Phase	Private

Rafferty/Estevan, Saskatchewan	Power Generation	DEEP Earth Energy Production	5 MWe	Feasibility Phase	Private
Lillooet, British Columbia	Power Generation	Alterra Power Corp., 2149749 Ontario Inc.	Unknown	Unknown	Private
Meager Creek, British Columbia	Power Generation	Ram Power	Unknown	Unknown	Private

Table 3. Geothermal Development in Canada (Source: CanGEA, 2013)

UNITED NATIONS FRAMEWORK CLASSIFICATION

Australia developed the world's first geothermal reporting code using the framework and governing principles of the widely accepted JORC code for mineral deposits, leveraging its existing credibility and understanding with investors. Similarly as the United States and other nation's begin to move towards a unified geothermal code, adapting a previously established and accepted framework can expedite the code's impact. The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC 2009) is a universally acceptable and internationally applicable scheme for reporting and a strong candidate for a geothermal reporting code adaptation. A collaboration of United Nations Economic Commission for Europe (ECE), other United Nations agencies and international organizations, intergovernmental bodies, professional associations and the private sector developed the UNFC. Figure 5 displays the basic 3-D model of classification with the following criteria:

- Economic and commercial viability (E)
- Field project status and feasibility (F)
- Geological knowledge (G)

The three main components shown in Figure 5 are further broken down into subcategories (Figure 6): three to describe economic and commercial viability; three to describe field project status and feasibility; and four to describe the level of geological knowledge (ECE, 2009).

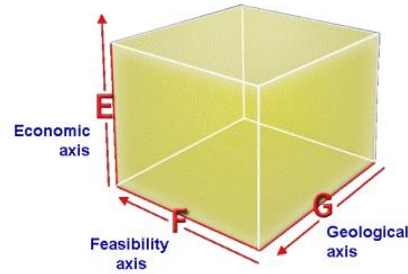

Figure 5. 3-D depiction of the UNFC three criteria for classification (UNFC 2009)

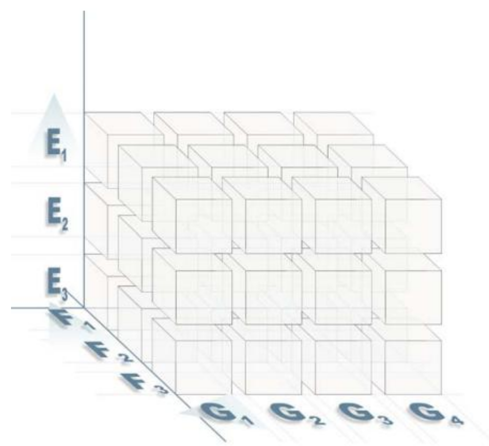

Figure 6. Criteria Breakdown for Classification (UNFC 2009)

Both the Australian and Canadian codes currently operate on a 2-D scheme, (Figure 3) which considers factors in commercial feasibility (energy recovery and conversion, production, economic, marketing, environmental, social, legal, land access and regulatory). Modeling a geothermal reporting code after the UNFC, which includes a third dimension to directly address commercial viability, offers an opportunity to enhance geothermal reporting code standards by providing a further detailed resource representation to investors.

CONCLUSIONS

Broadening the use of a geothermal reporting code is a crucial next step in advancing global geothermal energy development. The United States needs to increase investment potential to continue expanding its geothermal portfolio. Australia and Canada pioneered geothermal code deployment. Both nations have seen positive movement towards greater investor confidence. As their project portfolios advance, code impacts will be more fully realized. Adapting existing codes for United States geothermal reporting standards would capitalize on the groundwork of the UNFC and Australian and Canadian geothermal codes. Furthermore, utilizing an already accepted code framework and terminology will expedite the establishment of strong investor confidence and interest in the United States geothermal energy market.

REFERENCES

Allen Consulting Group (2011), “Australia’s Geothermal Industry: Pathways for Development,” prepared for Australian Centre for Renewable Energy.”

Canadian Geothermal Energy Association (CanGEA) (2010), “The Canadian Geothermal Code for Public Reporting.”

Canadian Geothermal Energy Association (CanGEA) (2013), “Canadian Geothermal Projects Overview 2013.”

Economic Commission for Europe (ECE) (2009), “United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009” ECE Energy Series No. 39.

Falcone, G., G.J. De Witt, C. Teodoriu. (2011), “Worldwide Classification and Reporting Requirements for Geothermal Resources” Canadian Unconventional Resources Conference, 15-17 November 2011, Alberta, Canada, 146435-MS.

Geothermal Energy Association (GEA) (2012), “Geothermal: International Market Overview Report.”

Grasby, S.E., D.M. Allen, S. Bell, Z. Chen, G. Ferguson, A. Jessop, M. Kelman, M. Ko, J. Majorowicz, M. Moore, J. Raymond, R. Therrien. (2012), “Geothermal Energy Resource Potential of Canada,” Geological Survey of Canada, Open File 6914.

Hot Dry Rocks Pty Ltd. (2011), Heat Flow Map of Australia http://www.hotdryrocks.com/content/view/504/116/.

Joint Ore Reserves Committee (JORC) (2004), “Australian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves; The JORC Code 2004,” The Australian Institute of Mining and Metallurgy, the Australian Institute of Geoscientists and the Minerals Council of Australia.

KUTh Energy Ltd (2011), “Managing Director's Presentation to Australian Geothermal Energy Conference (AGEC)” Proceedings, Australian Geothermal Energy Conference 2011, Melbourne, November 16-18, 2011. http://www.kuthenergy.com/index.php?item=file&target=presentation_agec_nov2011.

Lawless, J. (compiled) The Australian Geothermal Code Committee (AGCC) (2010), “Geothermal Lexicon For Resources and Reserves Definition and Reporting: Edition 2,” Australian Geothermal Energy Group (AGEG) and the Australian Geothermal Energy Association (AGEA).

Lawless, J., M. Ward, G. Beardsmore. (2010), “The Australian Code for Geothermal Reserves and Resource Reporting: Practical Experience,” Proceeedings, World Geothermal Congress 2010, Bali, 25-30 April, 2010.

The Australian Geothermal Code Committee (AGCC) (2008), “Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves; The Geothermal Reporting Code 2008 Edition,” Australian Geothermal Energy Group (AGEG) and the Australian Geothermal Energy Association (AGEA).

The Australian Geothermal Code Committee (AGCC) (2010), “Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves; The Geothermal Reporting Code, Second Edition 2010,” Australian Geothermal Energy Group (AGEG) and the Australian Geothermal Energy Association (AGEA).

Williams, C. F., Reed, M. J. and Anderson, A. F. (2011), “Updating the Classification of Geothermal Resources,” Proceedings, Thirty-Sixth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 31 - February 2, 2011, SGP-TR-191.