REPORT

CENTRE FOR INTERNATIONAL ECONOMICS

Evaluation of Australia's HFR geothermal energy industry

Synopsis

Prepared for

Geodynamics Limited

Centre for International Economics
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The CIE solves problems for clients by rigorously analysing markets and regulations, appraising risks and evaluating strategies. We build economic and strategic frameworks to distil complex issues to their essentials. In this way we are able to uncover new insights about emerging developments and assess payoffs from alternative strategies.

The firm has been operating since 1986. Contact details are set out below and more information on what we do and our professional staff can be obtained from our website at www.TheCIE.com.au.

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Evaluation of Australia's HFR geothermal energy industry

HFR geothermal energy uses heat-producing granites beneath the Earth's surface to generate emission-free electricity

GAINS OF NATIONAL SIGNIFICANCE are expected following the demonstration of the commercial feasibility of electricity generation from Hot Fractured Rocks (HFR). The scale of Australia's hot rock resource is huge (see appendix). A conservative estimate of Australia's recoverable resources equates to Australia's current electricity consumption for 450 years. Tapping into Australia's HFR resources requires substantial investment, but by 2030 the HFR electricity supply industry could generate around 10 per cent of Australia's electricity requirements.

The Centre for International Economics (CIE) was commissioned by Geodynamics Ltd to provide an economic evaluation of the potential development of Australia's HFR geothermal energy industry.

Three phases of development

The study looks at the development and expansion of the HFR electricity supply industry over three broad phases. These are development scenarios reflecting HFR's technical potential and the hypothetical investments required for an economic analysis of this sort.

- Phase 1: Construction of a 40MW demonstration plant followed by the commercial development of the industry with total generation capacity of 420MW by 2016.
- Phase 2: Industry expansion, including base-load generating capabilities, providing additional generation capacity of 1320MW by 2021.

HFR electricity generation capacity of 4500MW by 2030

- Phase 3: An additional 2760MW of generation capacity by 2030.

The development is expected to incorporate several transmission augmentations, allowing HFR electricity supply to the National Electricity Market.

The value of the HFR electricity supply industry is not derived from what it costs, but what it does. That is the value that the industry will generate tomorrow. Key factors that are quantified and valued include:

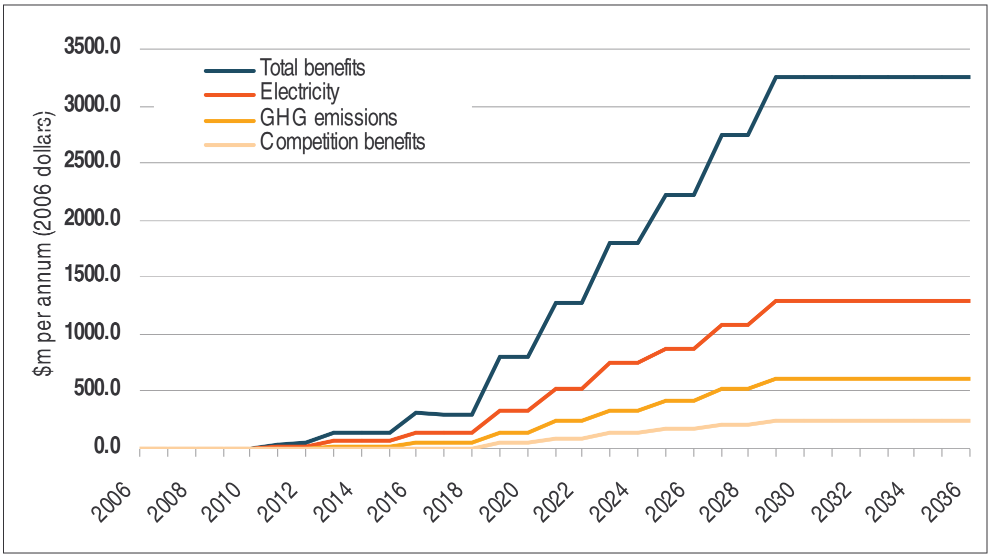
- electricity supplied;

- enhanced competition and reliability (related to network gains); and
- environmental gains from zero emissions technology.

Benefits from HFR's electricity resources are expected to increase as commercial development of the HFR resource accelerates. Chart 1 shows the benefits from the industry's commercial expansion out to 2030. Development and benefits may continue to grow after this period but are not included in the study's 30-year horizon.

HFR electricity provides long-term benefits

1 Benefits and other impacts from a HFR electricity supply industry



Data source: CIE estimates.

Of course there are also costs to consider. Most importantly, investments will be required to drill the hot rock field, build electricity generation capacity and transmit electricity to where customers are located.

Development of a HFR electricity supply industry is economically efficient

The results of the preliminary benefit-cost analysis (BCA) for each of the three phases and for the total HFR electricity supply industry are presented in table 2. The analysis indicates developing a HFR electricity supply industry will provide the Australian economy with net gains of $5 billion in today's dollars.

2 Summary of preliminary results

	Net present value[a]	*Benefit-cost ratio*
	$m	(ratio)
Phase 1	439	1.28
Phase 2	1 914	1.56
Phase 3	3 303	1.63
Total HFR electricity supply industry	5 048	1.49

[a] Based upon a discount rate that reflects the social opportunity cost of capital calculated to be 5 per cent (real).
Source: CIE.

Avoiding harmful greenhouse gas emissions

A feature of the potential HFR electricity is that in displacing energy from traditional sources in the future it would avoid greenhouse gas (GHG) emissions from combustion of fossil fuels. In addition, it would avoid the 'fugitive emissions' from the mining and transportation of fossil fuels. Estimates of emissions avoided for each phase are summarised as follows:[1]

- Phase 1: initially emissions of 0.3Mt per annum (pa) of CO_2-e are avoided rising to 2.3Mt pa by 2016. This is equivalent to avoiding the typical emissions of 750 000 passenger motor vehicles, or 271 000 typical households.
- Phase 2: emissions of 3.6Mt pa of CO_2-e are avoided in 2016 rising to 7.1Mt pa in 2021, in addition to the emissions avoided from phase 1. This is equivalent to avoiding the emissions of 2.4 million cars or 856 000 typical households.
- Phase 3: avoids CO_2-e emissions of 3.6Mt pa in 2023, rising to 14.9Mt pa in 2030, in addition to the emissions avoided in phases 1 and 2. This is equivalent to avoiding emissions from 5 million cars or 1.8 million houses.

The GHG emissions avoided through using HFR electricity is equivalent to reducing forecast GHG emissions for electricity generation in 2030 by over eight per cent (based on forecasts by the Australian Bureau of Resource and Agricultural Economics).

Creating new opportunities

The HFR electricity supply industry is also expected to contribute to many other indirect national and global benefits, including:

- competition benefits — transmission augmentation, creating inter-connection between major nodes in the National Electricity Market such as South Australia and New South Wales, would raise network reliability, improve the efficiency of the existing network and increase competition across the whole network;
- regional development — it is expected investment in transmission infrastructure will bring opportunities for expansion of some regional industries;
- development and potential export of intellectual property used to convert heat to electricity or identify and exploit HFR resources;
- avoidance of toxic emissions, such as sulfur dioxide, nitrous oxides and particulate matter;

[1] Emissions avoided are based on power generated and a marginal emissions factor of 0.66 tCO_2/MWh

- other environmental gains for example, lower water use in electricity generation;
- enhanced reliability and energy security through the diversification of energy resources; and
- new resource wealth from developing a use for geothermal rocks.

Robust estimates…

There is much that is new and untested in the development of the HFR electricity generation industry. It is likely that there is a wide margin of error around the preliminary estimates of the net economic impacts. Nevertheless, the analysis suggests the development of a HFR electricity supply industry is not overly sensitive to variations to forecasts and assumptions.

The discount rate of 5 per cent (real) used in the central case corresponds to the social opportunity cost of capital. The results of the BCA using alternative discount rates (3 per cent and 7 per cent) is reported in table 3. The findings indicate that under less conservative assumptions the net gains to the Australian economy of HFR electricity supply industry could be more than $10 billion.

3 **Sensitivity of results to variation in real discount rates**

	3%	*7%*	*3%*	*7%*
	NPV	***NPV***	***BCR***	***BCR***
Phase 1	1 081	57	1.60	1.04
Phase 2	3 925	813	1.89	1.31
Phase 3	6 882	1 459	1.91	1.39
Total HFR electricity supply industry	10 799	1 985	1.78	1.26

Source: CIE estimates

…that withstand sensitivity testing

Further analysis tests the sensitivity of factors that could be expected to be important. The findings indicate that unrealistically large changes to central case assumptions would be required for the project to viewed as being economically inefficient (see table 4). Furthermore, while the GHG savings are valuable the economic contribution of the project does not hinge on their value.

4 **Changes that would cause the central case to breakeven**

Factor	*Change that cause central case to breakeven*[a]	*Significant for BCA result?*
Electricity generation capital expenditure	+65%	Yes
Electricity prices	-55%	Yes
Value of greenhouse gas avoidance	-117%	No
Transmission loss factor	+882%	Yes
Capacity factor	-53%	Yes
Elimination of the residual value	-100%	Yes

[a] The estimates assume no other changes take place.

Source: CIE estimates.

Major conclusions

The key points of the economic evaluation of the Australia's HFR geothermal energy industry are that the:

- development would bring substantial benefits through the value of,
  - electricity supplied,
  - enhanced competition and network reliability, and
  - environmental gains from zero emissions technology;
- benefits exceed the costs with net gains to the economy of $5 billion and more than $10 billion under less conservative assumptions;
- results are not sensitive to forecasting error; and
- industry has broader potentialities through enhancing regional development and creating export opportunities through development of intellectual property for a global HFR geothermal energy industry.

A Generating electricity from HFR

USING GEOTHERMAL ENERGY for electricity generation is not new. Italy first established a geothermal electricity plant early last century and geothermal energy is now used for electricity generation in over 20 countries. Most working plants are based on heat sources that use water reservoirs associated with the volcanic regions, for instance New Zealand's well-established geothermal industry.

The use of hot fractured rocks is a different and even simpler concept. Heat is generated by special, high heat producing granites located three kilometres or more below the Earth's surface. The heat inside these granites is trapped by overlying rocks which act as an insulating blanket. The heat is extracted from these granites by circulating water through them in an engineered reservoir or underground heat exchanger. The heated water remains under pressure and is produced to the surface. The heat is then captured through a heat exchanger with the ground water cooling as it passes through. The cooler water ground water is then recirculated back below the surface to be reheated. The cycle means the water is continually under pressure so it never turns to steam and there is no loss of water from the system. Once the heat passes through heat exchanger it is transferred into another closed cycle system, with an ammonia-water working fluid that has a lower boiling point. It is this liquid that is piped into the power plant to generate electricity. In the power plant, the liquid is turned into vapour and used to spin the turbines. Afterwards, the vapour is cooled back to a liquid and returned to the heat exchanger.

HFR geothermal energy relies on existing technologies and engineering processes, for example drilling and hydraulic stimulation techniques established by the oil and gas industry. HFR power stations use technologies standard in the electricity supply industry, including within existing geothermal stations elsewhere in the world, to convert the extracted heat into electricity.

HFR geothermal energy is environmentally sound because it releases energy without:

- the production of greenhouse gases;

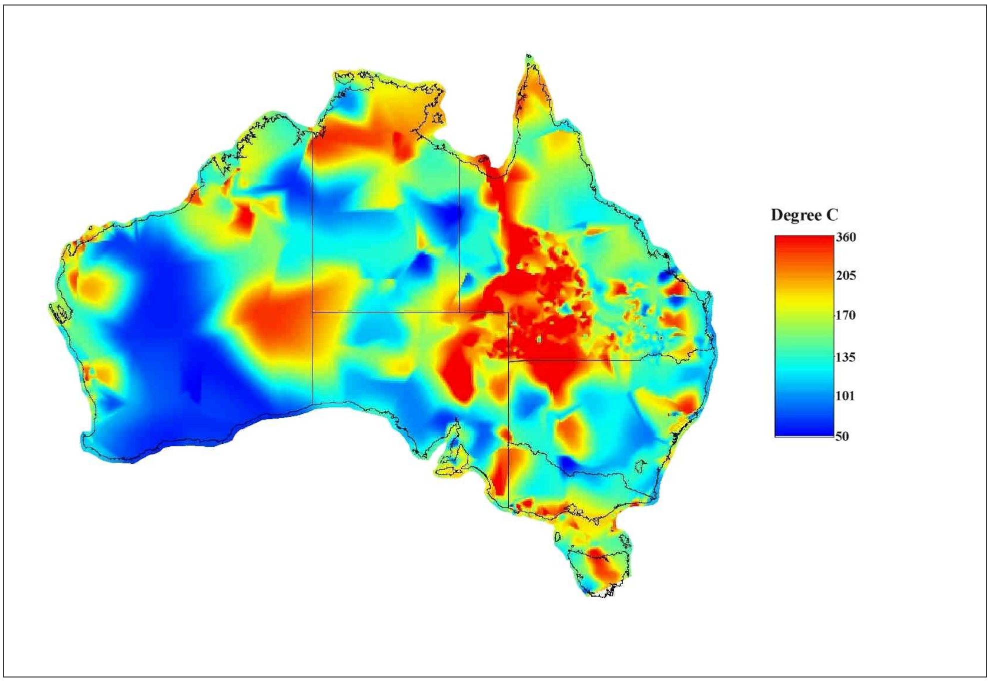
- nitrous oxides, sulfur dioxide or particulate matter emissions associated with the burning of fossil fuels; and
- depleting water resources — through the closed loop processes water from the underground reservoir is returned after it is used to generate electricity. The fractures in the hot rocks are naturally full of water.

Reflecting these characteristics HFR geothermal energy has been classified as renewable by national and international authorities.

Australia-wide HFR resources

There is evidence to indicate that there is considerable potential to extract HFR geothermal energy in many other parts of Australia. Much of Australia's HFR geothermal resource exploration and development is occurring in South Australia. However, there are many places over the continent with high sub-surface temperatures trapped in deep granite. While it would require further specific exploration and analysis, the implied potential HFR energy reserves are massive. The map shows inferred temperatures at a depth of 5km, is provided below.

A.1 **Map of inferred temperatures at a depth of 5km**



Data source: hotrock.anu.edu.au

There are now 14 companies pursuing geothermal energy in Australia, with 87 geothermal exploration licences and work commitments of over

$0.5b over 5 years. Most of the activity at present is in South Australia, where previous work by the oil and gas industry has enabled the delineation of hot rock resources. For example, Geodynamics have established that there is a large scale HFR energy resource located below the Cooper Basin, near Innamincka on the South Australian side of the border with Queensland. They have drilled the Habanero #1 and Habanero #2 wells into the hot granites and identified the resource as being the hottest outside of a volcanic region yet discovered — the HFR resource has a temperature of 287 degrees Celsius at around five kilometres depth. What remains to be done is demonstrate the capacity of HFR to convert a natural resource into electrical energy on a competitive and commercial basis. Once this is achieved it could put Australia into a leading position in what could become a major global industry.