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Valuing Geothermal Projects – Beyond Levelised Costs

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ABSTRACT

There are a number of ways of assessing the value of power projects from simple return on investment, simple payback, net present value (pre and post tax) to a calculation of levelised costs. The industry has, in general, adopted a levelised cost approach to demonstrating the attractiveness to investors of geothermal power projects compared with alternative generation options. This approach is in line with general practice in the power sector.

There are a number of ways of determining levelised costs ($/kWh). One of the more robust approaches, preferred by investment banks, uses a full financial model based on discounted cash flows to calculate levelised costs. This can be used to determine a sale price for energy at a level that drives net present value to zero for a given discount rate.

However, levelised costs are not only used by project developers and investors/funders in determining which projects to develop or invest in. They are often used by policy makers in comparing the relative merits of different power generation technologies, particularly renewable energy technologies. In this respect, the use of levelised cost as a comparator undervalues the benefits of geothermal energy projects as it does not recognize the important benefit that geothermal energy projects have over most other renewable technologies, that is base load power potential. Further, geothermal energy provides other benefits such as protection against possible future fuel price increases or carbon cost imposts.

As such, geothermal energy is often undervalued by policy makers leading to the potential for ill informed decision making and inappropriate treatment in terms of government support mechanisms.

This paper describes and proposes an alternative to use of levelised costs to value geothermal project options compared to other, intermittent, renewable energy and other fossil fuel technologies, using the GENCHOICE framework. This framework captures the benefits of geothermal energy as being base load, a major contributor to carbon emissions reduction and an efficient user of the electricity grid. The framework measures levelised cost at a common point of comparison, in this case the regional reference nodes. The levelised cost is estimated as a function of capacity utilisation and explicitly includes system costs as a function of intermittency, in addition to breaking down capital and operating costs into major components. The framework uses a probabilistic framework to provide a value for the hedge against future fuel and carbon price rises.

The approach has been used to determine the advantages of geothermal relative to other fossil fuel and renewable technologies and suggests that the cost difference is much narrower when all these other factors are taken into account. The approach also provides guidance on which aspect of the technology would benefit from further research and development.

1. INTRODUCTION

There are a number of ways to value power projects. The most common method is the levelised cost approach, which involves the calculation of an average cost of generation for a power project over its life, where cost includes a return to capital invested as well as fuel and operating costs. The levelised cost has several uses: as a benchmark of the price that is required to justify investment in the power project, to enable comparison with alternative generation options to determine optimal investment options and as a comparator of the relative merits of alternative technologies. The latter is typically used by Governments to determine support for alternative technologies.

The levelised cost is at best only a guide to relative cost competitiveness and typically undervalues the benefits of alternative technologies particularly renewable technologies. In this paper, the limits of the levelised cost approach are explored in terms of evaluating the benefits of geothermal technologies. The approach developed in this paper extends the levelised cost framework to provide a nuanced evaluation of the comparative cost that explicitly considers the comparative advantages of the geothermal technologies relative to other renewable energy technologies, explicitly considers the premium value of the technology as a hedge against a number of uncertainties and its option value. We will demonstrate that the levelised cost approach may not capture the full costs of intermittent renewable generation arising from it possibly being an inefficient user of transmission grid infrastructure and arising from the need to invest in peaking plant and or energy storage schemes to compensate for this intermittency. Also that the result of this intermittency is that base load coal fired generation is driven by the market to be a load follower, reducing the efficiency of the plant, and increasing CO_2 emissions that negate some of the benefit of certain intermitted renewable technologies.

2. WHY IS IT NECESSARY TO GO BEYOND LEVELISED COSTS?

Two trends have seen renewed interest in renewable technologies such as energy (electricity) generation from renewable sources.

First, globally there is a push towards renewable energy technologies as a means to reduce greenhouse gas emissions. To date this push has mostly benefited wind and solar PV technologies, and not base load technologies such as biomass, solar thermal (with back-up or storage) and geothermal. Part of this is due to a perceived lower cost for wind and solar PV technologies (this is particularly true with respect to the lower cost and risk of resource evaluation if not project implementation). This advantage has been aided in most countries by incentives such as renewable energy certificate schemes or feed in tariffs and their minor role to date is such that systems issues associated with large scale deployment of intermittent sources of generation have not yet emerged to a significant extent.

However, these intermittent technologies can only have a limited role to play in making substantial cuts in greenhouse emissions (at low cost) without substantial investments in storage technologies. In the longer term continuing cuts in emissions will require dispatchable base load options such geothermal and solar thermal. Recent curtailment in carbon capture and sequestration (CCS) projects for coal fired power plant demonstrates that CCS is not a near term solution to clean, base load power generation.

Take the example of Australia. The following chart illustrates the type of generation required in Australia if a 80% reduction in emissions (on 2000 levels) is required by 2050. Clearly the level of fossil fuel generation has to fall significantly to meet this target, although the level of fossil fuel generation can stabilise from around 2035 onwards if carbon capture and storage is deployed. The level of wind generation also increases but the increase is limited by system constraints on the deployment of grid scale intermittent systems. But as can be seen from the light blue strip at the of chart, the message is that significant amounts of other low emissions (e.g. renewable) generation will be required from around 2025, to reach around 100 TWh to 150 TWh by 2050.

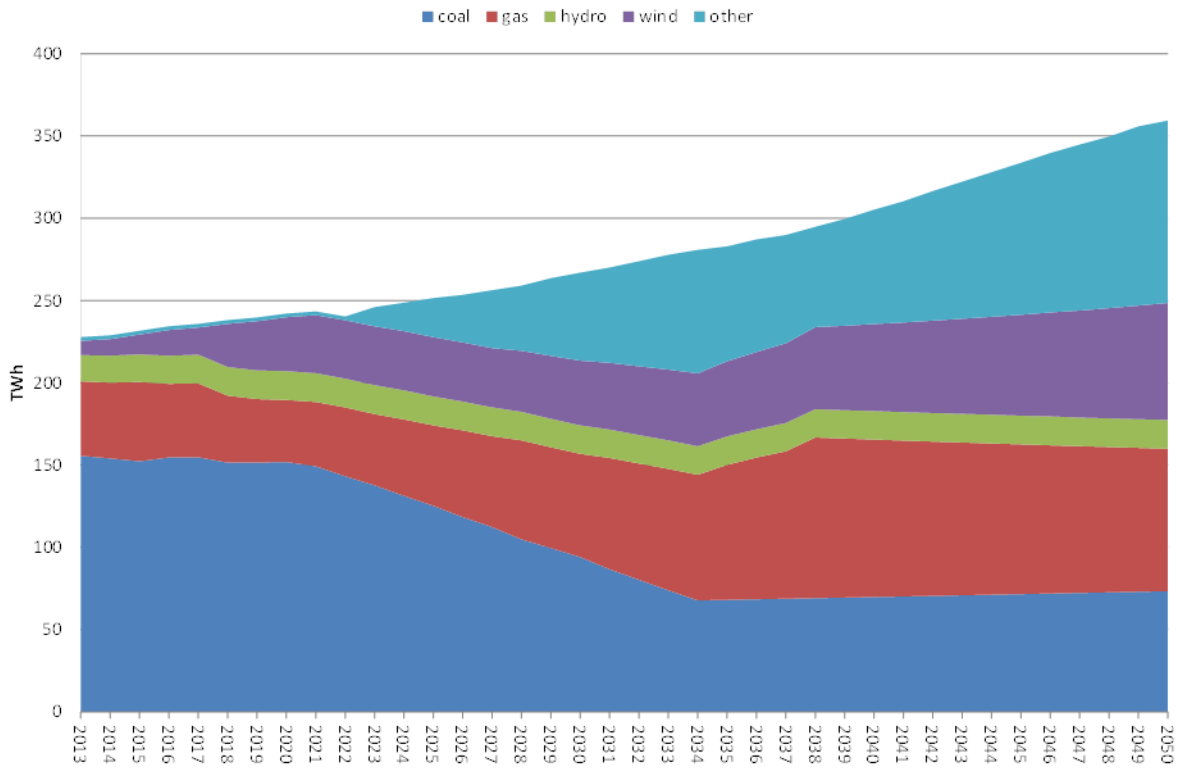


Figure 1: Generation mix to meet Australia's emission targets.

These types of projections are illustrative only, but it does indicate geothermal could be an option that can fill this market need in the medium term, in competition with solar thermal or other renewable technologies with storage capability.

Second, many countries are now looking to increase the share of renewable generation in the face of anticipated rising fuel (coal and gas) prices. For geothermal, there are regions where volcanic reservoirs are available close to load and where there are expensive fossil fuel alternatives. Indonesia is an example where geothermal is already economic in many regions.

Any view of the future transformation of the electricity generation sector will come to the following conclusions. First, in most regions, there will be a need for renewable energy to fulfill a number of roles: as dispatchable generation meeting base load, mid-merit, shoulder and peak demand needs, and as a provider of ancillary services to maintain smooth operation of power systems. Second, relatively mature renewable technologies (such as wind, hydro-electric and solar PV technologies) will only be able to fulfill a portion of the need for renewable generation in the long term especially if we wish to minimise the cost of the required transformation.

Thus, the long term potential for geothermal to play a more prominent role in the future, particularly from 2025 onwards in more advanced electricity systems, if not sooner for some developing regions. Geothermal will be competing with other like

technologies such as solar-thermal (with storage or back-up fuel supply) and biomass based generation. In order to this, geothermal technologies would need to be cost competitive with these technologies as well as conventional generation technologies. The technology has some disadvantages in competing with these other technologies such as small scale of operation and relatively higher capital costs which is hindering its development.

However, simple cost comparisons of technologies, even considering the relative sophistication of levelised costs, can undervalue the true contribution that geothermal can play in electricity systems. The aim of this paper is to outline the additional value, provide a proper account of this value in cost comparisons and to use the cost framework to focus the efforts required to develop the technology to reduce costs.

3. COMPARING COST COMPETITIVENESS

In this section we compare cost competitiveness of renewable and fossil fuel technologies. We outline a range of approaches to measure cost competitiveness using costs in Australia as a point of comparison. The analysis is illustrative only but it will enable a comparison of the relative merits of different valuation techniques. The assumptions behind the analysis are included in appendix.

The analysis is undertaken using SKM's GENCHOICE model, an analytical frame work that is used to assess least cost options for new generation. The model allows appraisal of the full cost of each option over time (and proposed start date) and for the identified need (base load, mid merit, peak) as identified by determining costs for specified capacity factors. The model is sued to screen the technologies that are likely to be the competitive options for new generation.

3.1 Standard Approach: levelised cost approach

Levelised cost of energy (LCOE) is a proxy for the long-run marginal cost of generation from a technology. The metric allows comparison of technologies with different time streams of capital, fixed and variable operating costs and translates this cost into a common metric. Mathematically, the levelised cost is given by:

$$LCOE_i = \sum\{(C_{it} + OC_{it})/(1+r_t)\}/\sum\{(G_{it})/(1+r_t)\}$$

Where $LCOE_i$ is the levelised cost of generation in \$/MWh for a technology i, C_{it} is the capital cost stream for technology i in year t, OC_{it} is the operating cost (fuel, ancillary plus O&M costs) for technology i in year t, G_{it} is the generation level of the technology i in year t, and r is the discount rate usually set at the weighted cost of capital for a merchant plant.

The period of analysis is usually the technical life of a particular plant.

More sophisticated calculations of levelised costs use discounted cash flow modelling (real, post tax), where the levelised cost is the price of energy exported needed to set net present value to zero for a given discount rate.

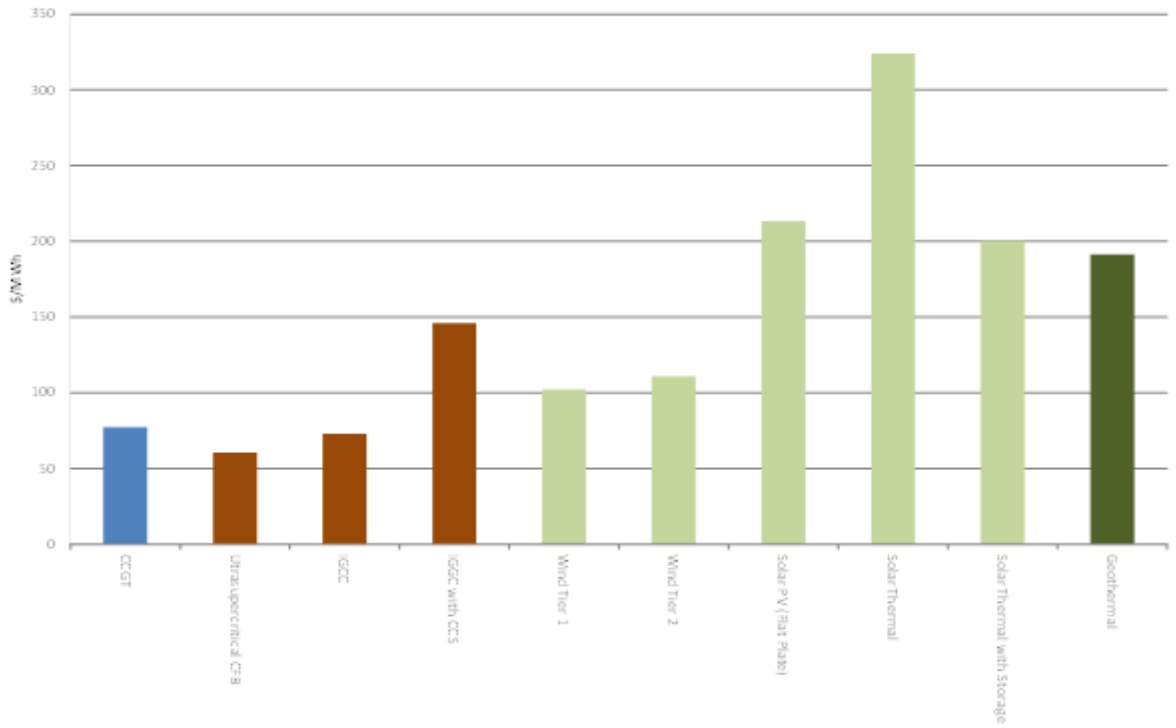
The LCOE can be used for a number of purposes. First, as formulated above, it can be used to determine the average price a generation technology would need to receive for it to be economic (including providing a sufficient return to capital). Second it can be used to determine cost competitiveness across technologies. Investors can use it to compare relative costs of a power project relative to other technologies or projects. Policy makers also use it to compare the costs across a range of technologies to gauge the impact of technology support policies.

An example of its application is shown in the following chart, which illustrates the LCOE for generation technologies in Australia' National Electricity Market projected for 2015. Conventional coal plant remains the lowest cost generation option mainly due to the high gas prices assumed. Wind generation remain the lowest cost source of renewable energy generation due to historically low turbine costs and reasonable wind regimes. The analysis also indicates the high cost of less mature renewable energy technologies such solar thermal and geothermal.

The advantages of this approach to providing comparative costs is that it is simple to calculate and easy to understand the findings. The analysis can be more sophisticate by indicating a range of costs based on reasonable variations in key assumptions such as capital costs and fuel prices.

But there are some inherent disadvantages to this approach that lead to an overestimate of costs of generation of geothermal and can underestimate the benefits of geothermal and other renewable energy technologies.

First, the analysis treats costs for each technology as homogenous. In fact, costs for each technology can vary depending on location of the plant (which can affect transmission connection costs, marginal losses during transmission to load centres and delivered fuel costs), the availability and incidence of the resource (which can affect the level of generation possible from variable sources of renewable energy such as wind and solar), and size of plant. To take an example, we now examine the cost curve for proposed wind farms in the national electricity market, as shown in Figure 2. The LCOE estimates range from around \$90/MWh to \$190/MWh. Clearly, geothermal even at current costs would be competitive against the higher cost wind projects.



Source: SKM analysis. Assumes weighted average cost of capital of 10% in real terms, project start in 2015, mean capacity factors (e.g. 33% for wind and 92% for coal and gas plant).

Figure 2: Generation mix to meet Australia's emission targets.

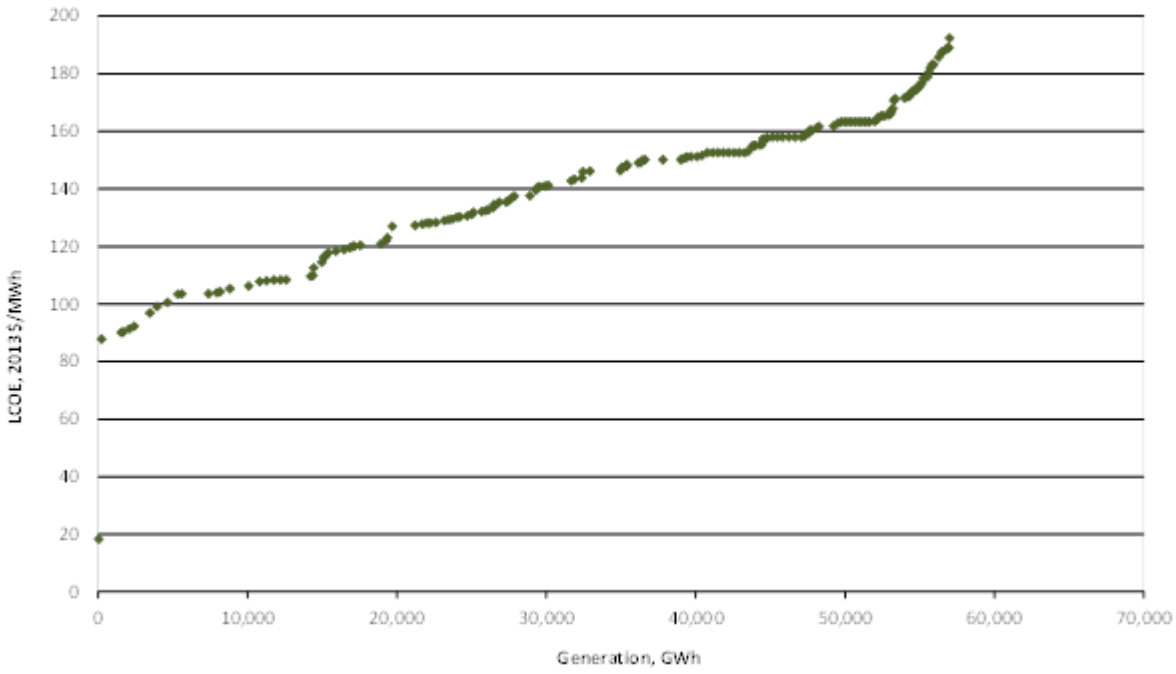


Figure 3: LCOE cost curve for wind generation in the NEM

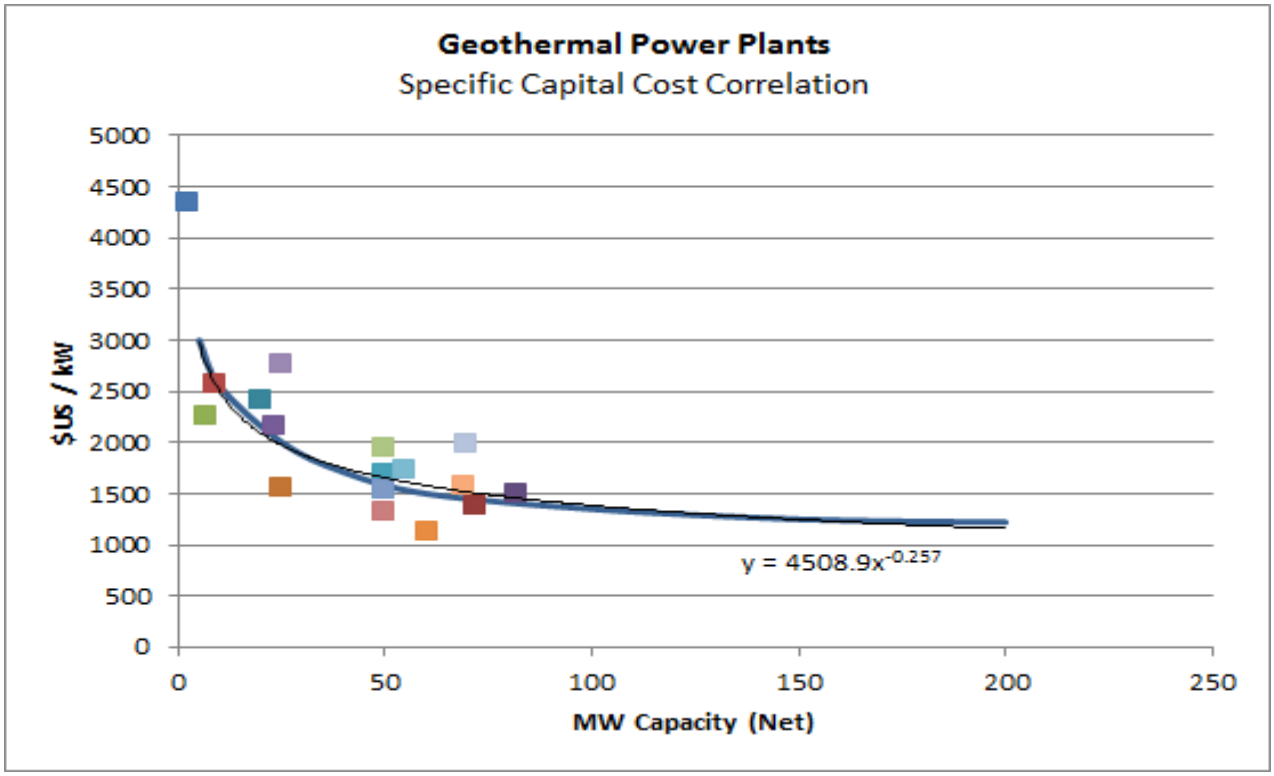
Second, the LCOE technique is silent on the stage of development of a technology. The costs estimates for the geothermal technology in Figure 1 reflect costs for a 'first-of-a-kind" or early deployment costs[1]. Capital costs for the early tend to be high as assemblage of the plant is untried, non-standard parts are being used, lack of experience in constructing parts of the plant (e.g. establishment of the wells), poor economies of scale in the manufacture of plant parts and there is a tendency to over engineer the

[1] Geothermal technology based on enhanced geothermal systems or hot sedimentary aquifer based geothermal are relatively novel options for the Australian market

plant. As plant builds accumulate the learning by doing tends to reduce the capital costs of construction of the plant. The cost decrease through learning by doing can be a rapid process – witness the price decrease in cost for solar PV systems – and this is possible for geothermal technology as standard equipment is being used as a whole and the main novelty of the technology is around the development of geothermal wells.

Similarly, experience with technologies can lead to increasing size of plant. The increasing size of plant over time will impact on cost in $/kW terms through economies of scale.

An example of the change in cost on a $/kW basis for geothermal energy by size of plant is shown below:



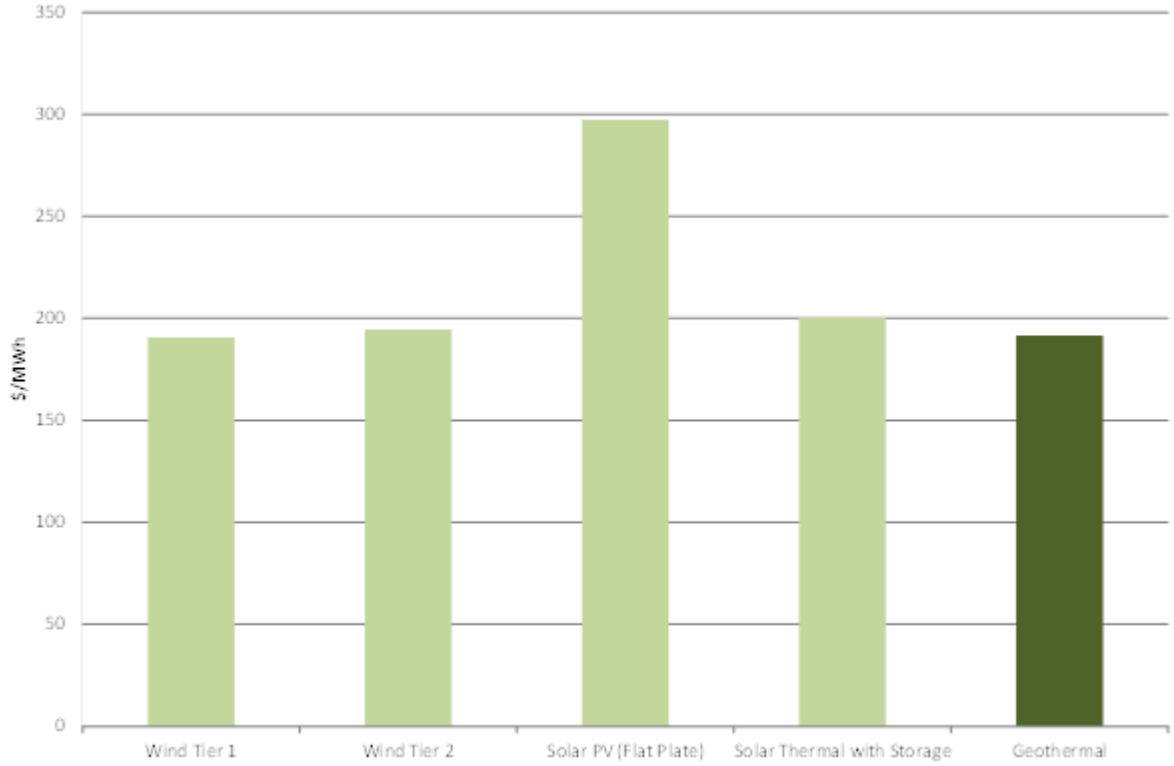
Source: SKM Data from Geothermal Project SKM has supported.

Figure 4: Example of impact of size on economies of scale and $/kW installed costs

Third, the analysis does not consider the relative operating advantages of base load power plant and the levelised cost of intermittent resources does not capture the expenditure required elsewhere in terms of strengthening grid infrastructure to cope with intermittent power flows from generators and in the building of peaking plant capacity or energy storage capacity to compensate for the intermittency of non-base load renewable energy systems. The electricity market is not a homogenous market selling electrons. The market also has a time dimension (base-load, mid-merit and peak markets) and quality dimension (reliability of supply and firmness of capacity available). Geothermal technologies can reliably supply power on a base load basis, one of the few renewable technologies that can do so reliably. To consider the implications for base load duty, consider the levelised cost of energy when electricity has to be sourced from a thermal generation source or renewable storage option to back up renewable energy supply to ensure high capacity factor (see Figure 5). The LCOEs of the technologies become similar as a result.

The LCOE approach does not take into account the inherent risks faced by fossil fuel technologies. Renewable technologies such as geothermal have no or low carbon emissions and so are not exposed to the impact of carbon pricing or carbon mitigation policies. Renewable technologies are also not exposed to price rises in fuel prices, which is an acute risk for natural gas-fired generation. Avoiding these risks adds value to renewable energy projects (Awerbuch, 2003).

Considering the possible variations in fuel prices, carbon prices and capital costs, the LCOE can be reformulated to obtain expected costs. The following chart compares the simple LCOE (shown in Figure 1) with the LCOE where the values for key assumptions are weighted by the probability of the distribution of their possible values. The chart illustrates that consideration of possible variation in the values of key inputs generally increases the expected costs for fossil fuel technologies and reduces the gap between fossil fuel and renewable energy costs – for example making wind generation at least as competitive as fossil fuel generation. Put another way, the impact of potential adverse variations on key costs increases the premium (above fossil fuel generation costs) that investors are willing to accept on the cost of renewable energy generation.



Source: SKM analysis. The costs comprises the LCOE of the renewable generation cost plus the cost of obtaining power from a backup fossil fuel plant or storage medium

Figure 5: LCOE for base-load duty

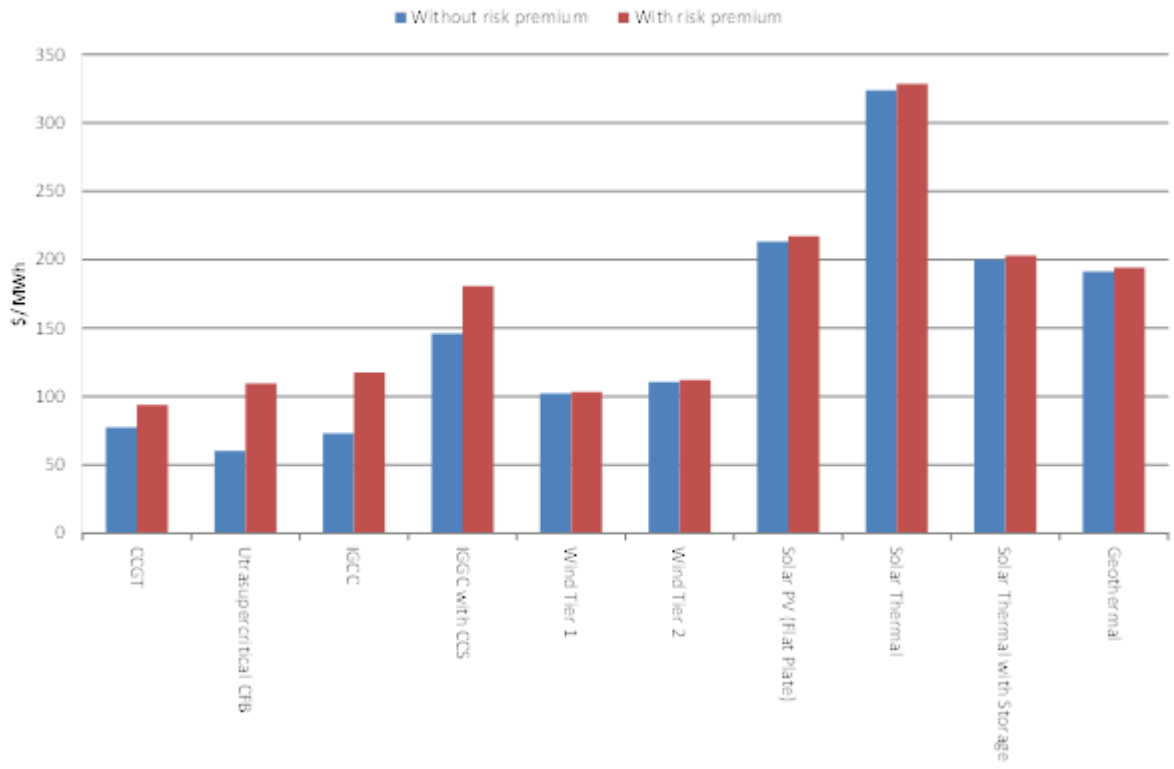


Figure 6: LCOEs with and without premiums for potential variations in key costs

Other factors that make the LCOE approach problematic include:

- Does not take into account for the significant development risks that are included in the capital costs and returns to capital expected for technologies like geothermal during the early phases of development of these technologies;

- Does not adequately account for projects with long lead times (such as typical geothermal projects) ;
- Does not take into account the high return on equity required for high risk projects.
- Does not take into account the trade-offs involved in increasing unit size (economies of scale versus increased market and resource risk). Although cost of fossil fuel options are often favored by the economies of scale that come with increased unit size, the LCOE method does not take into account the increased market risks incurred with entry of large sized units.
- Does not take into account the cost of externalities such as:
    - The inefficient use of grid infrastructure
    - The need to build peaking plant or energy storage plant
    - The reduced efficiency of coal fired plant being forced to be load followers rather than base load

The levelised cost methodology can be enhanced to consider externality costs where information is available. For example, recent studies by the NREL have indicated system costs of intermittent generation being around $2/MWh to $5/MWh. Recent studies by AEMO have also determined similar costs at current levels of deployment. However, these cost estimates are averages across the grid and there may be localised variations in costs which would increase the cost of intermittent generation substantially more in some regions. These regional variations in costs are typically ignored in levelised cost analysis, especially for policy making purposes.

3.2 Risk based approaches

Standard approach relies of specifying set values for uncertain assumptions. Sometimes sensitivity analysis is deployed to get a potential range of values. A probabilistic approach to uncertainty around input values goes one step further by specifying each assumption as a distribution of possible values so that a distribution of possible LCOEs for each technology can be derived. If done correctly, this probabilistic analysis provides additional information to investors and policy makers in terms of the spread of potential costs and the relative riskiness of different generation technologies.

The basis of this approach is to specify probability distributions for all uncertain assumption variables. GENCHOICE can specify probability distributions for the following variables: carbon mitigation policies (start of those policies and the cost or subsidy impact of those policies), capital costs, fuel costs, transmission connection costs, marginal network loss factors, labour costs and externality taxes. In terms of geothermal plant, resource potential and availability can also be represented as a distribution curve.

A typical representation of the distribution of values for an input is shown in Figure 7. This is shown for the input of geothermal resource potential. The shape of the distribution and the parameters describing the shape can be derived either from a statistical analysis of historical data, an understanding of the underlying factors driving input values or from subjective judgments of specialists.

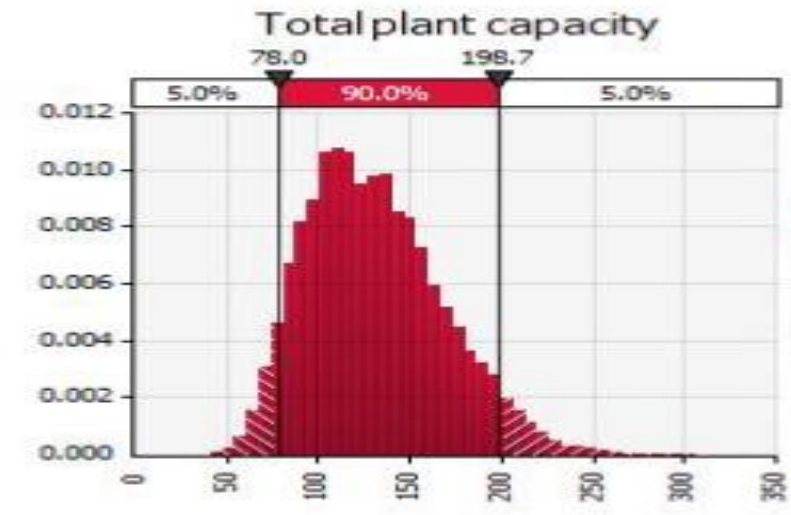


Figure 7: Example of probabilistic assessment of geothermal resource potential

The value of this analysis is that it looks at the levelised cost of new power generation assets in the way that sophisticated investors would. Investors in power assets have consider multiple potential outcomes for the future value of key inputs. For example, gas prices can exhibit marked volatility – witness the recent sharp rise in gas prices in the eastern seaboard of Australia. The potential variations can affect both the cost of relative generation options and the financial viability of those options. Investors may (depending on their appetite for risk) wish to choose or pay a premium for options that, although have an initially higher cost than other options, have lower exposure to adverse movements in key input costs. For example, an investor may wish to pay a premium for renewable energy options that do not have any exposure to fuel price risk and carbon mitigation risk.

This approach also provides additional information for investors and policy makers. The output specifies a range of possible levelised costs for each technology, with technologies with more certain input values or less potential volatility in input prices having a narrower distribution of levelised cost values. The spread of the distribution gives investors additional information on the inherent riskiness of a technology. As illustrated in the following diagram, a generation technology may have a higher cost than another, but there is a high probability that the alternative technology may end up having higher costs. In the diagram, technology B has a higher average LCOE vale than technology A. But there is a wider spread of possible LCOE of technology (due to plausible variations in key input variables) that mean that there is a not insignificant probability of technology A having a higher LCOE than technology B (the shaded area represent the probability of technology having a higher cost than the average cost of technology B)

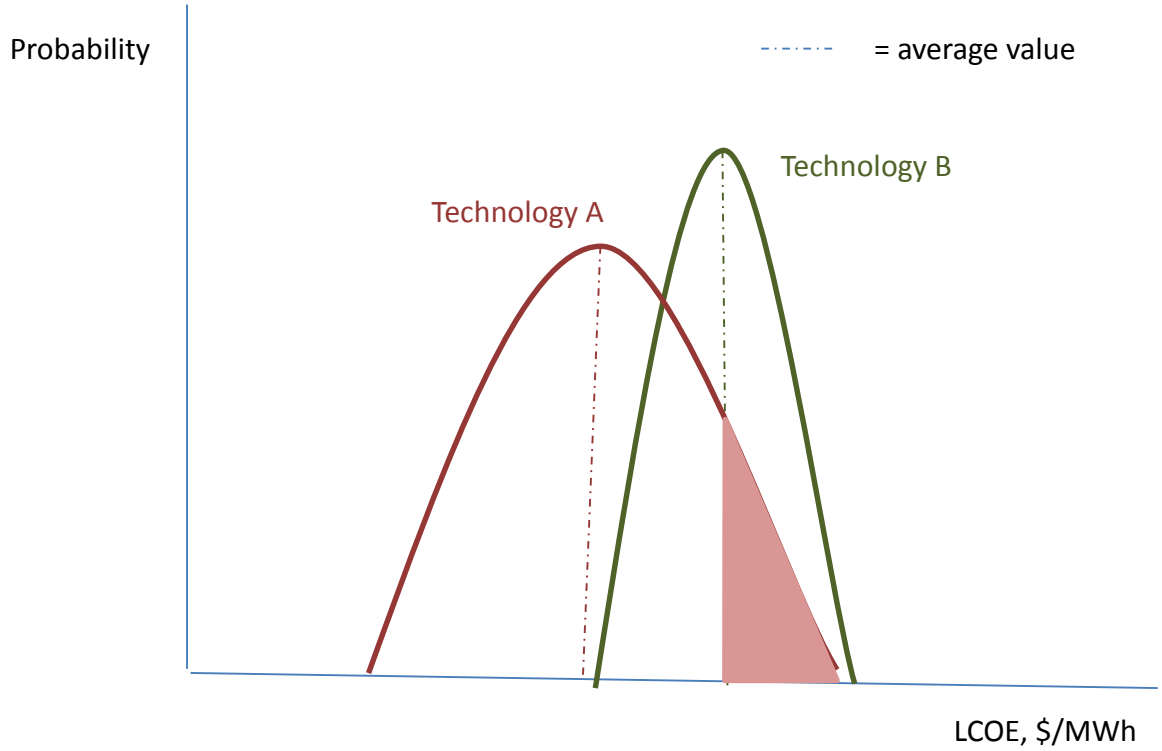


Figure 8: Illustration of distribution of LCOE for two technologies

The implication is that given the range of possible future values for key inputs, an investor may be willing to invest in a technology even do it has a higher cost on mean assumptions if there is a reasonable probability of even higher costs for some of the other technologies.

The approach can be extended to consider key financial risks facing geothermal technologies. The biggest risk, or barrier, to this technology is the high cost to prove the resource before FID and hence before debt financing becomes available. Funding of the high cost exploration and production drilling to achieve sufficient capacity under the well head to de-risk the project to the point where a commercial bank will provide debt funding is typically done from shareholder funds (equity). The probabilistic approach can place distribution of potential values for equity premium and the length of time it takes to prove the extent of the resource[2].

The approach can be extended to consider some of the other costs that could potentially be incurred by the intermittent renewable energy technologies. For example, ancillary service costs (in $/MWh) could rise exponentially with increased penetration of wind or solar PV generation. The uncertainty in the range of future ancillary costs can be explicitly modelled. The same applies to other network costs associated with higher penetration of intermittent generation.

The main advantage of this approach is that explicitly considers the uncertainties in key input variables, which means cost comparisons based on LCOE can be extended to consider the plausible distribution of costs for each technology. This technique can be used to place premiums for technologies avoiding input uncertainties and can also provide insights into some of the key technical/commercial risks inherent in each technology. The method is particularly when comparing the cost of renewable technologies with fossil fuel technologies as many renewable energy technologies typically do not face uncertainties in fuel prices and externality penalties that hamper fossil fuel technologies.

[2] It can be used to determine the reduction in costs and equity premiums if the initial resource proving activity is aided by the government funding or general data collection.

The main disadvantage of this method is that it is data and information demanding. The availability of rich historical data sets can help overcome this limitation. The veracity of the method depends on their being enough data or information to correctly specify the distribution of potential input values.

3.3 Option valuation

This approach takes the risk approach one-step further by valuing the ability of investors to alter, delay or defer investment until better information is known – say for example on the future of carbon mitigation policies. Is useful when:

- Investments involve large upfront capital costs
- The investment is irreversible

In other words, electricity generation especially renewable electricity generation!

It is the concept of option valuation that will led investors to invest in OCGT (instead of a CCGT) as an investor can design the OCGT to be able to be converted into a CCGT if market conditions become favorable in the future.

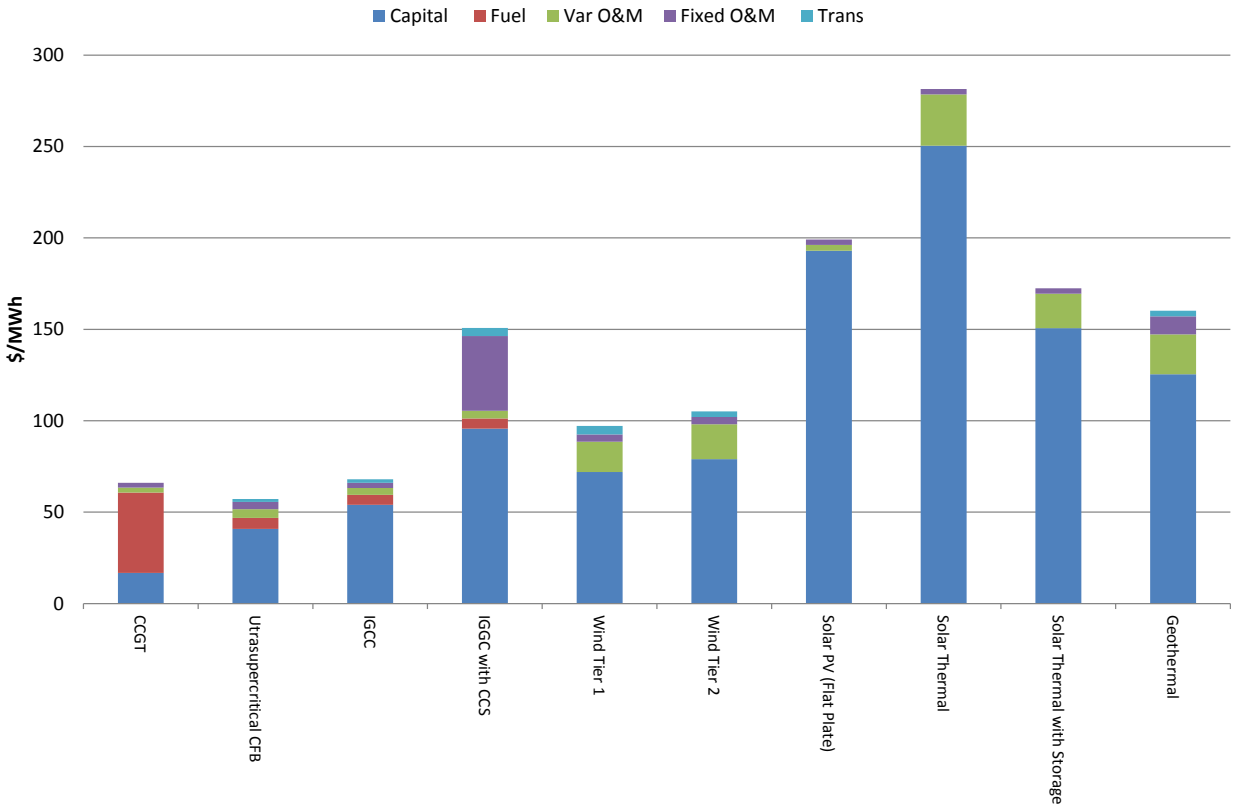
The ability to provide this optionality provides inherent advantages to a technology but the option value is not easily estimated by the LCOE methodology.

The option value can be significant for renewable energy technologies including for geothermal generation. Renewable technologies can be more modular or have smaller unit sizes so can be more easily be built to match increments in load growth as they happen. Securing a geothermal resource and proving it has an option value because then the resource is ready to be exploited when the market is favorable. Carrying out research and development of renewable technologies has a similar option value.

4. POTENTIAL COMPARATIVE ADVANTAGE OF GEOTHERMAL TECHNOLOGIES

4.1 Cost structure of generation technologies

Different technologies have different compositions of upfront, fixed and variable operating costs. Figure 8 illustrates the cost breakdown for a range of fossil fuel and renewable energy technologies.



Source: SKM analysis using GENCHOICE model

Figure 9: Cost breakdown of generation technologies, Victoria

Like other renewable energy technologies, a significant portion of the cost of geothermal generation is upfront capital cost including the cost of proving the resource and developing the required wells. Ongoing operating costs (including the cost of transmission losses) are minimal as long as the geothermal plant is located near the load.

The upfront cost of geothermal in Australia is relatively high compared to say wind and natural gas because of the following factors:

- Relatively new technology in the Australian context with costs for for first or early plant.
- High resource development cost component. Around 35% to 40% of the upfront capital cost is spent on proving the geothermal resource and developing the wells. The cost is made even higher by the high return to equity required for resource development because of the high risk involved. Well costs also increase exponentially with depth (SKM 2007). Further, there may ongoing capital cost incurred to construct replacement wells.
- Potentially widespread buy sporadic distribution of the resource.

However, a simple comparison of the levelised cost masks some important factor that could mean that geothermal could become relatively competitive with other option.

First, as already mentioned, geothermal in Australia is relatively disadvantage by its early stage of development compared with the more mature alternatives such as wind and even solar PV. First of a kind plant tend to be more expensive than follow up plant as more experience is gained in developing wells, understanding the energy potential of the resource and constructing plant (especially ancillary plant). The above analysis assumed a first of a kind cost of around $8,500/kW to $9,000/kW. Potential reductions on this cost are feasible with experience and with improved economies of scale with development of larger resources. If you take the example of large scale solar thermal with storage, which is at a similar stage of development as geothermal in Australia, we have already witnessed around a 20% reduction in capital cost from the first 50 MW plant to the second 50 MW plant built in Spain.

Second, drilling costs comprise 35% to 40% of total capital cost. There is potentially a significant learning by doing effect: success rate of proving and developing wells improves from early exploratory phase to development and then operating phase.

Third, costs of geothermal projects vary with drill depth, geology, and location. Just as there are favorable wind sites, there will be favorable geothermal resources with an extensive relatively shallow geothermal resource located close to the grid or major loads. Moreover, some sites may be located close to other heat loads meaning an additional market for the steam once it has gone through the steam turbine and before reinjection into the basin.

Fourth, the LCOE analysis, as described previously inexhaustible, does not account for the inherent advantageous of geothermal compared with fossil fuel and other renewable technologies. Local air pollutants and CO_2 can be low. Land requirements are not as extensive as for other options. The above ground of geothermal plant have a generally proven performance although there will be some work to adjust to Australian conditions. There is no –ongoing fuel cost meaning that project is not exposed to volatility or rising fuel price (or any associated externality taxes) during its operating life. And development of a geothermal project can be scaled to match load, achieving economies of scale as development progresses. A more nuanced analysis (using the probabilistic or option methods) would add value to the geothermal projects.

Fifth, and importantly, the technology offers stable and base load energy during its operating life. Stable generation provides an advantage against intermittent sources of generation such as wind and solar. At current levels of deployment of intermittent generation in Australia, the cost of intermittency (ancillary service and associated network costs) is relatively low at around $2/MWh to $5/MWh due to the relatively low level of deployment and widespread diversion of the generation. However, the cost is likely to increase exponentially if penetration increases to above around 30% of average demand. Base load generation can provide a significant advantage in that high upfront costs can be spread over more output.

There are some cost disadvantages to the technology. Resource depletion can happen at individual wells necessitating the need to develop replacement wells. Sulphur and even CO_2 content can be high in some reservoirs. Land or right of way issues can hinder optimal development of the resource. There is limited ability to follow load and respond to demand. As previously mentioned there is a high resource development risk and an associated long project development cycle. Fields may require sophisticated maintenance and extensive drilling for larger plant.

4.2 Valuing the comparative advantage

To illustrate the potential value of the technologies advantageous, we use the GENCHOICE model to highlight the potential additional value brought about by some of these advantageous. The analysis considered:

- And a shadow cost for carbon emissions of around $20/t CO_2e
- Based on recent research on the cost of intermittency, added a cost of $5/MWh for additional ancillary service cost and around $5/MWh for network stability costs
- Added a premium of $5/MWh for natural gas plant and $2/MWh for coal plant to reflect the potential cost of variable future prices for these fuels

The results of the analysis are shown in Figure 10. Although the cost gap is now narrower the high development costs for geothermal is still a disadvantage compared with mature renewable energy and fossil fuel technologies.

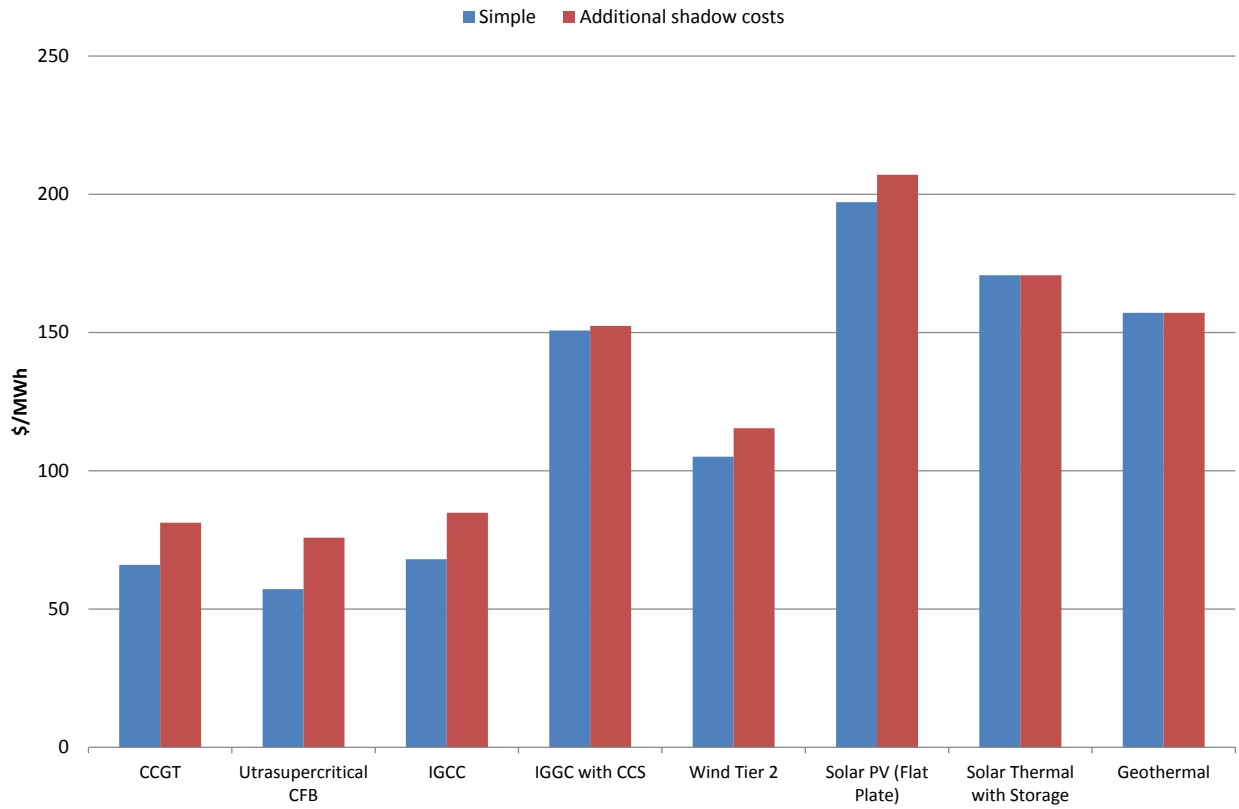


Figure 10: Cost comparison when carbon price and fuel risk plus cost of intermittency are considered.

The main prospect for geothermal technology to reduce cost to become competitive is to reduce its upfront cost. The fact that the technology can achieve base load duty means that capital and development costs do not need to be as low as wind and solar PV generation for the cost to be commensurate. Analysis using the same analytical framework indicates that capital costs need to reduce to around $6,300/kW (a reduction of around 30% on current estimates) to achieve similar costs to wind generation.

Other advantageous include the technology being dispatchable (to time of high prices if necessary and to minimise system ancillary costs), no fuel cost other than the need to drill make up wells every three or four years to maintain production from the resource, and potentially reliable fuel cost in that once the characteristics of the reservoir are known. It is worth noting that few geothermal power plants have been decommissioned in the 100 plus year history of geothermal power development, although some are run below capacity due to resource limitations and the fact that, until recently, injection of brine to preserve reservoir pressure was not standard so this is one further source of cost reduction.

5. FULFILLING THE POTENTIAL – IMPROVING THE COST COMPETITIVENESS OF GEOTHERMAL

The above analysis also provides insights into the areas in which research and development should focus on in order to improve the competitiveness of geothermal technology in Australia. It is clear that the focus should be on reducing upfront development and capital costs. This can be done by further understanding of the resource quality of the many identified geothermal fields in Australia and through gaining a better understanding of the associated geology to reduce well development costs and development risks. A number of countries seeking to encourage geothermal development have put in place Government backed geothermal well insurance programs. These programs compensate the developer for the cost of any earlier exploration wells that are not commercially productive, thereby reducing the risk of proving the resource and hence reducing the cost of capital for the early stages of the project. In short, mechanism need to be put in place to reduce the risk and hence cost of capital to the developer for the high capital outlay exploration and resource proving stage of the development.

The Australian Government's recognition of the advantages that geothermal has as base load generation over other renewable technologies would go some way to justifying funding such a scheme.

6. CONCLUSIONS

The electricity sector is likely to undergo a significant transformation over the next few decades in response to wider social and environmental concerns. Simple cost comparisons using LCOE techniques are likely to mislead policy makers and investors into the nature of this transformation. The transformation is likely to involve a mix of technologies, each playing to their comparative strengths. Current policy settings based on levelised cost analysis cannot come to these conclusions.

Geothermal technologies have an important role to play in this transformation. But simple LCOE analysis would indicate that its costs are higher than alternative technologies. A more nuanced approach taking account of the advantageous of lower operating risk, low pollution profile, base load operation and potential adaptability to market needs is required to recognize the value that geothermal can play in the transformed electricity market.

REFERENCES

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