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MJA Report on future prospects for electricity generation technologies over the life of the Alpha Coal Mine

prepared for the Queensland Land Court in the hearing of the objection to the Alpha Coal Mine

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Glossary

AEMO	Australian Energy Market Operator
AETA	Australian Energy Technology Assessment
AUD	Australian Dollar
Base Load Generator	Generation that by virtue of its low variable costs operates at near full load all the time
BNEF	Bloomberg New Energy Finance
BREE	Bureau of Resources and Energy Economics
CCAQ	Coast and Country Association of Queensland Inc.
CCGT	Combined Cycle Gas Turbine
CCS	Carbon Capture and Storage
CEFC	Clean Energy Finance Corporation
CO_{2e}	Carbon Dioxide Equivalent
EDO	Environmental Defenders Office (Qld) inc.
Energy	MWh (Megawatt hour)
GJ	Gigajoule
GW	Gigawatt
GWh	Gigawatthour - one Gigawatt supplied over 1 hour
HSA	Hot Sedimentary Aquifer
IDAE	Instituto para la Diversificación y Ahorro de la Energía - Spain
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IRENA	International Renewable Energy Agency
kW	Kilowatt
LBNL	Lawrence Berkley National Laboratory
LCOE	Levelised Cost of Energy
LNG	Liquefied Natural Gas
LRMC	Long Run Marginal Cost
MW	Megawatt = 1000 Kilowatts
MWh	Megawatts over 1 hour
NEM	National Electricity Market
NOAK	Nth of a kind refers to mature commercial power plants
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NTNDP	National Transmission Network Development Plan
OCGT	Open Cycle Gas Turbine
OECD	Organisation for Economic Co-operation and Development

PV	Photovoltaic
SRMC	Short Run Marginal Cost
SWIS	South West Interconnected System
UKDECC	UK Department of Energy & Climate Change
USD	American Dollar
VOM	Variable Operational and Maintenance Costs
WACC	Weighted Average Cost of Capital

1. Introduction

1.1 Background

I have been retained as an expert witness by Environmental Defenders Office (Qld) Inc. (EDO) on behalf of Coast and Country Association of Queensland Inc. (CCAQ) for an objection hearing in the Land Court of Queensland concerning the Alpha Coal Mine, a large thermal coal mine proposed in the Galilee Basin. I have been retained to provide my opinion on a number of matters concerning the relative costs and development of electricity generation technologies over the 30 year life of the mine.

My instructions are set out at Section 1.3 of this Report.

1.2 Experience / Qualifications

I have over 32 years of experience in the energy sector on matters relating to forecasting demand and investment in the electricity, gas and water industries in Australia and Singapore.

A copy of my Curriculum Vitae is appended to this Report (see Appendix 1).

1.3 Instructions

Set out below are the instructions provided to me by EDO:

1) Whether the relative costs of energy sources expressed in Exhibit 6 of Mr Stanford's report and paragraph 4.3(a)(iii) of Mr Offen's report are reasonable?
2) Whether the cost of generating wind and solar power is decreasing? If so, at what rate?
3) Whether you agree with the statement by Bloomberg New Energy Finance that unsubsidised renewable energy is now cheaper than electricity from new-build coal-fired and gas-fired power stations in Australia?
4) Whether black thermal coal is currently the cheapest or most attractive form of power generation internationally?
5) If the answer to question 4 is 'yes', under what conditions, if any, would black thermal coal cease to be the cheapest or most attractive form of power generation?

1.4 Facts and Assumptions

The facts, matters and assumptions on which my opinions are based are stated in the body of this report.

2. Generator Investment Drivers

My instructions for this report are concerned with the type of generator technology that will be used and developed over the next 30 years to meet electricity demand, both within and outside of Australia. In addressing the five issues presented in Section 1.3, I will be referring to and assuming certain matters relating to the nature of power generation and the economics of power generation. This chapter is provided as an introduction to the matters of this report, and to avoid repetition in the matters being addressed.

The economics of electricity provision is a complex matter that entails current and future factors that include:

- The technologies and associated costs of power generators. This includes:
  - current power station (or generator) technologies;
  - developments and status of new generator technologies;
  - generator cost structures (i.e. the key components of cost);
- The availability and cost of fuels for power stations;
- Government policy, particularly that associates with climate change; and
- The manner that electricity delivery in the future may be different to that of power grids today. This includes decentralisation of generation, more efficient appliances, battery storage to capture intermittent energy from generation such as wind and solar. The term “smart grid” has been used to describe this innovative technology. This would reduce the reliance on large scale power stations.

Regardless of this, the need for large scale generation will continue over the next 30 years. The unknown question is the amount of this that will be required.

As background to the issues, the following sections present:

- Cost structure of power stations;
- Existing and potential new generation technologies;
- The status of renewable generation;
- The change in technology mix being observed; and
- The factors involved in committing to develop a new power station.

2.1 Generator Cost Components

The cost structure of a power station is similar to many industrial assets, in that costs can be broadly categorised into cost to build and cost to operate. These components are discussed below.

Construction Cost, or what is often referred to as the Capital Cost, includes obtaining the land, civil works, building the power station (and all the requirements of this) and connecting to the transmission system. Capital cost is often expressed as dollars per kilowatt ($/kW) to build. For example, a station might be quoted as $1,800/kW to build.

Operating cost refers to all the costs associated with running the power station. For power stations that normally operate near full output fuel cost is usually the largest cost item. Fuel cost is usually expressed as dollars per gigajoule ($/GJ) delivered to the power station (incorporates all the costs to deliver the fuel to the burner tip in the power station). The amount of fuel (in GJ) required to produce 1 megawatthour (MWh) of electricity generation is related to the thermal efficiency of the generator unit and is referred to as the heat rate of the generator. The fuel cost ($/GJ) multiplied by the heat rate (GJ/MWh) results in the production cost due to fuel expressed as $/MWh. The requirement for maintenance can also increase with use, and this is also expressed in terms of $/MWh. The sum of these, results in a total variable cost[1] expressed as $/MWh. There are also operating costs that are fixed and do not change with the amount of electricity generated (usually expressed at a $/kW value each year).

The amount of CO_{2e}[2] produced per MWh of electricity production is referred to as the emission intensity. If there is a cost on CO_{2e} emissions then the emission intensity multiplied by the carbon price results in a $/MWh value associated with carbon emissions. Emission intensity is measured for each power plant that emits CO_{2e} regardless of the imposition of a carbon price.

Thus we have capital cost expressed as $/kW to build and operating cost expressed as $/MWh. Often total power station costs are expressed in terms of $/MWh (as they are in Exhibit 6 of Mr Stanford's report). This requires that the capital cost be expressed as $/MWh. To do this, assumptions are required on:

- The life of the power station;
- The amount of energy (MWh) the generator will produce each year. This is often expressed in terms of capacity factor;[3]
- The financial discount rate to use (Weighted Average Cost of Capital or WACC). The risk of the project is expressed through the WACC used.

For example, if a power station has a capital cost of $1,800/kW, and we assume an economic life of 30 years, a capacity factor of 80% and a WACC of 9%, then its capital cost expressed in terms of $/MWh would be $25/MWh. Tax has not been included here.

When the fixed cost and variable operating cost (and carbon cost if applicable) are added together, the result is the total power station cost expressed as $/MWh. This is referred to as the Long Run Marginal Cost. The term Levelised Cost of Energy (LCOE) is also used.

As noted in this section, there are a number of assumptions that need to be considered to arrive at total power station cost.

Changes to the assumptions can significantly impact the total cost of a power station. These assumptions vary internationally due to locational and regional factors, manufacturing resources, governments' environmental policies and regulations, etc.

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[1] Often referred to as the Short Run Marginal Cost.

[2] Under carbon pricing regimes, emissions costs apply to a specified variety of gases each that has a different impact on global warming. Carbon dioxide equivalent (CO_{2e}) is the amount of a greenhouse gas that would cause the same amount of global warming as CO_2.

[3] The Capacity Factor of a power station which is defined as the ratio of the actual or expected generation the plant produces over the maximum generation at full output which it can produce over a period of time, say one year.

2.2 Energy Generation Technologies

For the purpose of this report, I refer to a number of electricity generation technologies which are currently commercially viable and others which are widely reported to be under development and would reasonably be expected to be commercial over the next 30 years. The technologies described are included in Exhibit 6 of Mr Stanford's report.

These are described below under the categories of non-renewable and renewable generation.

2.2.1 Non-renewable Generation

The common definition of a thermal power station is a power station that burns fuel (such as coal or gas) in a boiler to produce steam which is then run through a turbine[4]. These power stations are classified as either subcritical or supercritical. Supercritical power stations operate with higher steam pressure and are more efficient. The advantage of supercritical technology is that less coal is required thus lowering production cost. Most of the coal power stations in Australia are subcritical power stations.

Efficiency of thermal coal plant can be further improved by using pulverised coal technology. This changes the coal to more like gas and enhances the efficiency of the process.

Open Cycle Gas Turbines (OCGT) power stations usually operate as peaking plants in integrated power systems. In general, they run for less that 5% of the time to meet peaking demand periods or during emergency situations. OCGT stations are no longer developed as thermal power stations as higher efficiencies can be achieved utilising combined cycle technology. This combines gas turbines (like jet engines) and a thermal boiler that uses fuel and the waste heat from the gas turbines. This is known as Combined Cycle Gas Turbine (CCGT) plant.

2.2.2 Renewable Generation

Renewable technology refers to generation technologies that come from resources that do not deplete such as wind, solar or geothermal.

The most common renewable technologies and that are referred to in Exhibit 6 of Mr Stanford's report are described below.

- Wind generation. This has been developed for many decades and has improved in efficiency in capturing wind and in cost. They are clearly only suitable in locations that have a good wind resource. In Australia they have been the main technology of renewable generation development.
- Large scale solar. This has been developed overseas although for cost reasons this technology has not been deployed on a large scale in Australia (although there have been various proposals). These technologies include:
  - Solar Thermal – Parabolic Trough without storage;
  - Solar Thermal – Parabolic Trough with storage;
  - Solar Thermal – Central Receiver with storage.

  These solar technologies use radiation from the sun to produce steam which generates electricity through generator turbines. The sun position is tracked via reflecting mirrors to

[4] Thermal engines can include gas turbines and any other device that converts heat to mechanical energy.

capture radiation from the sun. These technologies have been mainly installed in the US and in some designs they use gas when the sun is insufficient to meet demand. Some of the installed capacities of these plants can be up to 60 MW[5].

- Rooftop Photovoltaic (PV). The costs of Solar PV have decreased very significantly over the past 10 years. In Australia this technology has been subsidised resulting in a significant amount of this technology being installed.
- Geothermal – Hot Sedimentary Aquifer Technology. This requires drilling deep wells in porous sedimentary rocks to reach high temperature groundwater and produce steam to generate electricity.
- Geothermal – Hot Rocks. This is the geothermal technology that is being considered more suited for development in Australia. After optimistic appraisals some years ago this technology appears to be more difficult than first thought and this is unlikely to be economically viable for many years.

2.3 Carbon Emissions and Carbon Capture and Storage

2.3.1 Emissions Intensity

Carbon emissions and climate change has been a major policy issue in Australia and also internationally. A major issue with coal generation moving forward is CO_{2e} emissions. This is because coal generation emits more CO_{2e} per unit of electricity generated than other generating technologies.

The amount of carbon dioxide equivalent (CO_{2e}) emitted by a power station is referred to as its emissions intensity, and is expressed as tonnes CO_{2e} per MWh of generation. Typical emission intensities for various generator types are as follows[6] (expressed as tonnes CO_{2e} per MWh of generation):

Thermal brown coal generation such as in the Latrobe Valley	1.25
Subcritical black coal generation	0.9
Supercritical black coal generation	0.85
CCGT	0.4

This means that the cost of carbon emissions is about twice that for a black coal generator than a CCGT generator. For example, if the carbon emissions price was $20/tonne then the cost of CO_{2e} emissions for a black coal generator would be approximately $18/MWh, and for a CCGT plant about $8/MWh.

2.3.2 Carbon Capture and Storage

Given the importance of carbon capture and storage (CCS) technology to the ability of coal power stations to operate in a carbon constrained world, particular attention has been given to this technology.

CCS is a technology that is being developed to reduce the amount of CO_{2e} produced by coal fired power plants that is released into the atmosphere.

[5] http://www.solaripedia.com/13/32/solar_energy_generating_systems_%28mojave_desert,_california,_usa%29.html

[6] http://www.aemo.com.au/Electricity/Settlements/Carbon-Dioxide-Equivalent-Intensity-Index

"The technology involves capturing CO_{2e} produced by large industrial plants, compressing it for transportation and then injecting it deep into a rock formation at a carefully selected and safe site, where it is permanently stored."[7]

Progress of this technology has been very slow due to the substantial challenges involved. In Australia, the Clean Energy Finance Corporation (CEFC) set up by the Federal Government to be responsible for funding clean energy proposals, will not invest in CCS[8].

This technology is not proven commercially and in my opinion it should not be considered as an economic option over the next 30 years.

2.4 Investment Decision Drivers

The selection of technology for a power system is a complex matter that involves more issues than a simple comparison of expected development and operating costs. Power generation assets have economic lifetimes of 30 years or more and any decision on this matter needs to consider issues that could affect the asset over this time. These issues include cost, government policy and regulatory risk, and also public acceptability.

Uncertainty in these issues is usually considered through an assessment of the proposed power station over a number of potential and conceivable scenarios of how the investment environment may change over the asset lifetime.

Key issues that are and would be expected to be considered in developing a power station and that would impact the technology used, include the following:

- Capital Cost. Capital costs vary globally depending on materials costs, exchange rates, demand for and supply of equipment etc.
- Fuel availability and cost. Here I note that proximity of generator to fuel supply can be an important issue to economics and reliability of fuel supply.
- Security. This refers to the risk that the fuel will continue to be available at economic prices.
- Regulatory risk. This refers to the risk of potential adverse changes in regulation.
- Environmental issues and policy. This refers to potential policy changes such as pricing carbon emissions, constraints on emissions, and possibly the position taken on any potential compensation.
- Community acceptability and reputational issues. Developments that are seen as adverse to the local or global environment have increasingly been subject to campaigns by environmental, community and other groups, such as opponents of wind farms. Such actions increase the risk to such projects both in the short and longer term. They also have reputational issues for supporters (equity or lending) of such projects.

7 Global CCS Institute, < http://www.globalccsinstitute.com/understanding-ccs/what-is-ccs>

8 http://www.cleanenergyfuture.gov.au/?s=CCS&x=0&y=0

3. Question 1 – Generator Costs

Whether the relative costs of energy sources expressed in Exhibit 6 of Mr Stanford's report and paragraph 4.3(a)(iii) of Mr Offen's report are reasonable.

To address this question my answer is structured as follow:

- Exhibit 6 from Mr Stanford's report is first presented together with the definition of the costs shown and the understood basis of the assumptions;
- The context in which Exhibit 6 of Mr Stanford's report was developed is described and the conclusions of that report regarding costs presented;
- My key observations from the costs shown in Exhibit 6;
- A review of paragraph 4.3(a)(iii) Mr Offen's report; and
- Conclusions.

3.1 Exhibit 6

Figure 1 overleaf presents Exhibit 6 of Mr Stanford's report.

The source and reference of the report is stated in Mr Stanford's report as the Bureau of Resources and Energy Economics, The Australian Energy Technology Assessment, presentation to the Economic Club of Canada, July 2012, http://www.bree.gov.au/documents/presentations/aeta-31july.pdf

Exhibit 6 is taken out of the presentation slides. The slides note the "Release of AETA Report and AETA Model 31 July 2012". The full report is entitled "Australian Energy Technology Assessment 2012" (AETA) and was prepared by the Australian Bureau of Resources and Energy Economics (BREE). AETA 2012 report did not contain Exhibit 6. AETA 2012 report is referred to later in my report.

Two issues are discussed in this section relating to Exhibit 6, these being the definition of the costs shown in Exhibit 6 and the assumptions that underpin the costs shown.

3.1.1 LCOE

Although not stated in Mr Stanford's report, the costs shown in Exhibit 6 are Levelised Cost of Energy or LCOE. This is stated in the presentation slides from which the Exhibit is taken[9].

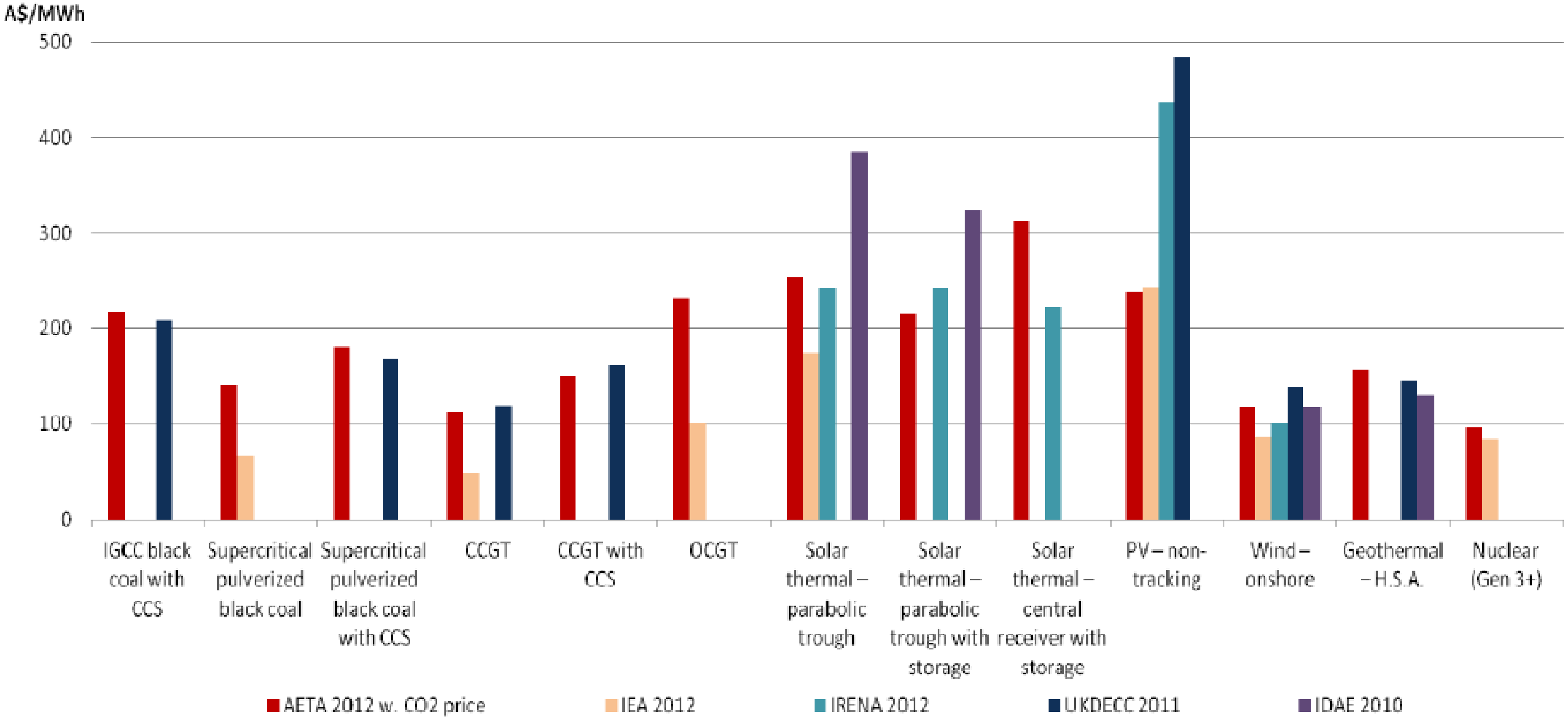
LCOE is *"a long term cost concept which accounts for all the resources and physical assets required to yield a stream of electricity output. The LCOE represents a "break-even" value that a power provider would need to charge in order to justify an investment in a particular energy project"* [10].

In the Australian Energy Technology Assessment 2012 (AETA) report, Section 2.4 "Caveats on the use of LCOE", the following is stated:

[9] The Australian Energy Technology Assessment, 31 July 2012, The Economic Club of Canada Ottawa, Canada21 February 2012. Professor Quentin Grafton.

[10] http://large.stanford.edu/courses/2010/ph240/vasudev1/

Figure 1 **Exhibit 6 from Mr Stanford's Report**



Note: IGCC = Integrated Gasification Combined Cycle; CCS = Carbon Capture and Storage; CCGT = Combined Cycle Gas Turbine; OCGT = Open Cycle Gas Turbine; HSA = Hot Sedimentary Aquifer

"The AETA LCOEs are restricted to only utility-scale or large scale technologies. Consequently, small-scale technologies (e.g. non-tracking photovoltaics, fuel cells, co-generation, and trigeneration) that may be relevant to distributed generation are not include in the AETA 2012 analysis, LCOE cost estimates associated with distributed photovoltaics are likely to differ substantially from utility-scale photovoltaic systems as a result of differences in component costs (e.g. capital costs, operating and maintenance costs) and performance characteristics (e.g. capacity factor).[11]"

3.1.2 Assumptions

Mr Stanford's report did not state the underlying assumptions of the costs presented in Exhibit 6. In particular there were no explicit assumptions presented relating to the cost of fuel. This is a critical assumption which may account for over 50% of the costs of generation, depending upon the technology and fuel.

I do note that slides of the presentation referred to above stated that:

- AETA was developed to be consistent with the Australian Energy Market Operator's (AEMO) National Transmission Network Development Plan (NTNDP), and its 'planning scenario'.
- Key assumptions include: (1) economic growth of 2.5%; (2) \$23/tonne CO_2e- e leading to a 5% reduction in CO_{2e} by 2020, and 80% by 2050; (3) AUD moving to peak of 1.13 USD/AUD by 2016-17 and low of 0.86 USD/AUD by 2031-32.
- Capital costs are provided on the basis of an Nth-of-a-kind (NOAK)[12] plant in Australia and at a utility-scale.

3.2 Context of Exhibit 6

The source of Exhibit 6 is a slide presentation by BREE to The Economic Club of Canada[13]. The BREE presentation provides Exhibit 6, titled "Comparison with international studies, current costs".

I am inclined to assume that these comparisons were presented to illustrate the relative costs between international studies.

Mr Stanford failed to list or comment on the key findings of the presentation, which were presented in the slides as follows:

- *"Estimated costs of solar photovoltaic technologies have dropped dramatically in the past two to three years as a result of a rapid increase in the global production of photovoltaic modules.*
- *Differences in the cost of generating electricity, especially between fossil fuel and renewable electricity generation technologies, are expected to diminish over time.*
- *By 2030 some renewable technologies, such as solar photovoltaic and wind onshore, are expected to have the lowest LCOE of all of the evaluated technologies.*
- *Among the non-renewable technologies, combined cycle gas (and in later years combined with carbon capture and storage) and nuclear power, offer the lowest LCOE cost competitive with low cost renewable technologies.*

[11] The Australian Energy Technology Assessment 2012, BREE.

[12] Nth of a kind refers to mature commercial power plants.

[13] < http://www.bree.gov.au/documents/presentations/aeta-31july.pdf>

- *For some technologies, LCOE is projected to increase over time due to: projected weakening of the Australian-dollar exchange rate, rising carbon price and cost escalation factors".*

3.3 Key Observations

As described in the previous chapter, the cost structures of generators depend on a number of issues and are sensitive to the assumptions made regarding these issues. As noted above, these assumptions were not stated in Mr Stanford's report. Because of this, it is not possible to reply on the costs shown for the purposes of determining the relative economics of the generator types shown.

Noting this reservation, my key observations from Exhibit 6 are as follows:

- That Exhibit 6, in BREE's presentation to the Economic Club in Canada, is titled "Comparison with international studies, current costs". In his report, Mr Stanford does not state that these costs are "current costs" and in his discussion the implication is that these are future costs.
- Of the six non-renewable technologies (ignoring nuclear that is dealt with separately) four of these have assumed CCS. However CCS is unproved on a commercial scale and its viability is unknown. Consequently the costs shown for the generators with CCS are without a proper commercial basis.
- The remaining non-renewable technologies of Exhibit 6 are supercritical pulverised black coal, CCGT and OCGT. We have previously noted in Section 2.2 that OCGT is designed to meet peaking demand periods and not for base load or intermediate energy production and thus is not considered any further in this report.
- As shown by both IEA and AETA, CCGT is cheaper than supercritical pulverised black coal with or without a carbon price. *Mr Stanford notes in his report that both "coal and gas provide the most efficient solution to electricity generation".* With a rapidly expanding market for international gas (through shale gas in the USA, Australia, China etc.) CCGT technology could continue to be a preferred option to reduce the levels of CO_{2e} emitted by coal.
- The thermal solar costs appear high, although the relativity of these having the highest cost accords with my understanding. The IEA 2012 estimates (presented as one of the five estimates in Exhibit 6) appear reasonable for this technology.
- PV costs (which are discussed in Section 3.5) have shown significant cost reductions over the past 10 years and 2012 cost estimates are more reliable.
- Wind costs have shown reductions in recent years and the figures shown are higher than my understanding of the costs in Australia. However the high exchange rate has assisted in this and the numbers reflect the greater certainty in wind costs.
- The IEA 2012 figures have wind generation only slightly higher than supercritical pulverised black coal.
- Nuclear costs are very dependent on the infrastructure in place and have a number of issues associated. What can be said is that nuclear does offer an option other than coal generation although the viability of this is uncertain.

3.4 Mr Offen's report

Paragraph 4.3(a)(iii) of Mr Offen's report refers to cost comparison estimates from the World Coal Institute on the relative costs of coal generation to solar generation and wind generation.

While the World Coal Institute is not an independent party and would be expected to support coal generation, the indicated ranking of coal, solar and wind generation costs (based on no carbon price) is consistent with my understanding.

However the relativity of costs as described:

> "however in many countries coal remains the cheapest source of fuel for power generation by a considerable margin"

is not consistent with my understanding and is also not supported by Exhibit 6 of Mr Stanford's report that shows IEA 2012 estimates of supercritical pulverised black coal (without a price of carbon emissions) of about $70/MWh compared to CCGT costs of less than $50/MWh and wind generation of about $90/MWh. This illustrates the uncertainties in relative cost estimates.

The paragraph also notes that it would take a:

> "material increase in the price of coal to change this equation".

Apart from the cost relativities noted in the paragraph above, the comment omits that coal generation cost increases can also occur due to CO_{2e} emissions policy.

Further the paragraph does not recognise the massive increase in gas resources in recent years and the associated increase in gas (as LNG) trade expected to occur. This will compete with coal for power generation. The cost estimates in Exhibit 6 of Mr Stanford's report have gas CCGT generation costs as lower than black coal generation. However as previously noted this depends on the cost of coal and gas that will be produced in the future, and the infrastructure available to transport coal and gas to power stations.

Consequently, the key message of the paragraph that coal will remain the lowest cost generation option and thus the favoured option for development in the future is not sufficiently established.

While cost estimates do have coal generation lower than renewables and for many situations currently the lowest cost option, the strategy for many nations is a complex consideration of cost, fuel mix, security and environmental issues. While coal is expected to play a part in this, these factors are indicating a decline in its growth from simple analysis.

3.5 Reasonableness

In considering the issue of reasonableness I address the following two questions:

- Do the costs presented in Exhibit 6 reasonably reflect what the costs of these technologies will be over the next 30 years?
- Is the context that the costs appear to have been used in Mr Stanford's report, which is as a metric of likely generators to be developed, reasonable?

3.5.1 Reasonable reflection of costs

Section 2 of this report presents the key factors that comprise LCOE for generators. This demonstrated the sensitivity of generator costs to the assumptions used in the studies listed in

Exhibit 6, particularly fuel costs. This point is supported in the Australian Energy Technology Assessment report 2012 (AETA) by BREE that noted in its key findings:

> *"it is difficult to compare costs across these studies because the technical and economic assumptions can vary substantially and are not always transparent or fully documented"*

The costs of Exhibit 6 are reported for studies that were undertaken by international organisations over the period 2010 to 2012. Over this time period there have been significant developments in the energy sector which could have significantly changed the basis of the assumptions that underpin the presented costs.

Moving forward, particularly over 30 years, the spread of conceivable assumptions is wider than the conceivable spread when considering "current costs".

Taking a medium time outlook, it is possible to develop conceivable scenarios of capital, coal and gas costs, discount rates, and where appropriate carbon emission costs that would have costs for generators as presented in Exhibit 6, but excluding generators with CCS and the extremely high PV costs. It is also possible to develop conceivable scenarios of the same factors as above that would have costs for generators different than as presented in Exhibit 6. The outcomes of these scenarios depend on the assumptions made at the time.

Over the long term, particularly 30 years, it is most likely that generation costs, and the relativity of costs between different generation technologies will change. This was evident in the AETA 2012 report that showed projections of generator technology costs over the period 2013 to 2050. A sample of these projections is shown in Figure 2 overleaf. The projections shown have pulverised supercritical black coal costs remaining unchanged (when carbon emission costs are not considered), CCGT costs changing slightly; and solar using parabolic technology and solar photovoltaic showing significant decreases in costs.

Reliance on generation costs over an extended period requires that the underpinning assumptions and how these may change over the period be stated and understood. As the costs presented in Exhibit 6 of Mr Stanford's report do not satisfy this requirement, it is not reasonable to rely on these costs as reflective of generator technologies over the 30 year period.

3.5.2 Context as a metric of new generator development

As noted in Section 2, there are many issues that comprise an investment decision to develop a new power station, or indeed the policy by government regarding the most appropriate power stations to develop.

Environmental and carbon emissions may be the leading policy issue in this regard. The IEA in its recent report "Tracking Clean Energy Progress"[14] supports this by saying:

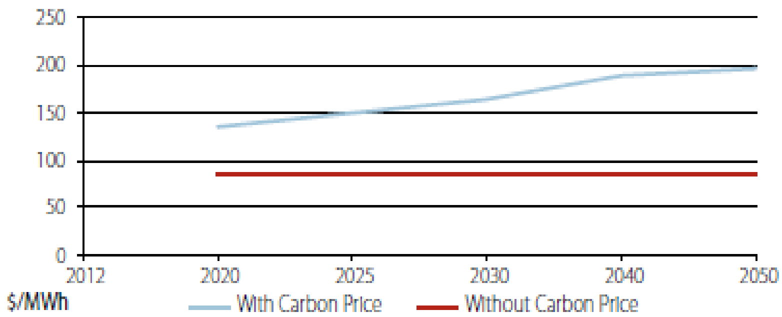
"It is currently difficult to envisage a future in which coal is not used to meet growing power demand – not only in non-OECD regions, but also in many OECD countries. In regions where the demand for electricity is rising, availability and cost of alternative fuels or other low-carbon sources of power will affect the decision to reduce generation from coal-fired plants. In a truly low-carbon future, however, coal cannot be the dominant energy source."

This illustrates that great care needs to be taken when drawing conclusions about what type of generation will be preferred or operating over the next 30 years.

[14] http://www.iea.org/media/etp/Tracking_Clean_Energy_Progress.pdf

Figure 2 LCOE Projections taken from the report Australian Energy Technology Assessment 2012

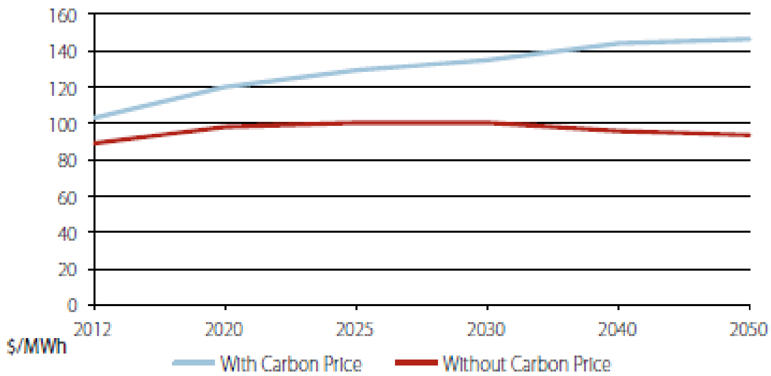
Figure 4.9: Pulverised coal supercritical plant based on bituminous coal, LCOE, NSW



Pulverised Black Coal Supercritical

Without carbon costs, costs stay relatively constant over time.

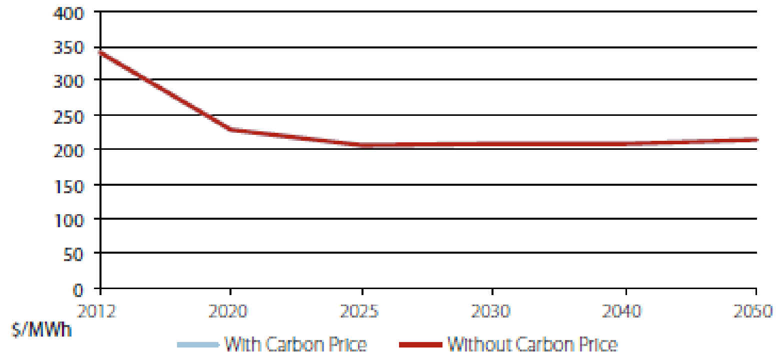
Figure 4.16: Combined cycle plant burning natural gas, LCOE, NSW



CCGT

Without carbon cost, costs stay relatively constant over time. The changes are likely due to gas costs.

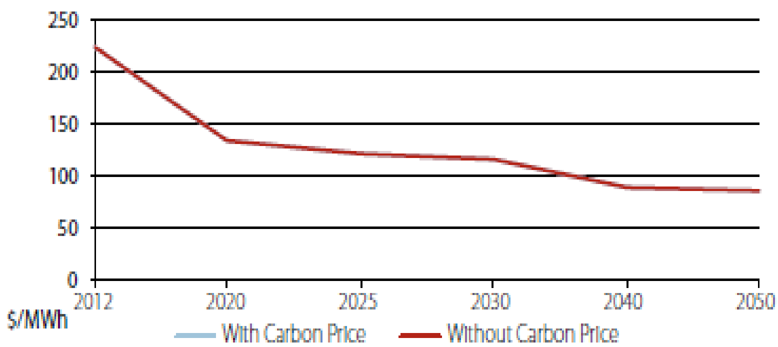
Figure 4.22: Solar thermal plant using parabolic trough technology with storage, LCOE, NSW



Solar thermal using parabolic technology

Costs decrease significantly over time.

Figure 4.26: Solar photovoltaic - non-tracking, LCOE, NSW



Solar photovoltaic

Costs decrease significantly over time.

4. Question 2 – Renewable Generator Costs

Whether the cost of generating wind and solar power is decreasing? If so, at what rate?

To address the matter of wind and solar generation cost reductions I reviewed empirical evidence of cost reductions since 1998 and assessments of cost projections that are based on historical evidence of cost changes.

4.1 Historical Prices

The historical pattern of wind and solar generation costs over the past 10 years has been different:

- Wind generation costs have shown both increases and decreases due to factors that have included the high demand for wind turbines. Over this period the technology has continued to improve with wind turbines increasing in efficiency and capable of operating in regions of lower wind (through increased size of blades). In Australia wind costs have substantially decreased over the past 3 years.
- Solar power costs, particularly Photovoltaic (PV) has shown substantial cost decrease understood to be due to improved technology and economies of scale.

I note that within Australia, the cost of these technologies (as with many other assets that have import components) have been influenced by Australia's exchange rate.

There is a substantial body of empirical evidence to support the cost patterns described. I illustrate this through figures shown in two reports by the US Department of Energy:

- Photovoltaic (PV) Pricing Trends: Historical, Recent, and Near-Term Projections November 2012[15] (Based on research at Lawrence Berkeley National Laboratory (LBNL) and the National Renewable Energy Laboratory (NREL)); and
- 2011Wind technologies Market Report, Lawrence Berkeley National Laboratory August 2012

These graphs of historical trends for PV and wind turbines are shown in Figure 3 and Figure 4 respectively below. They show (the actual costs are not the issue here rather the cost movements):

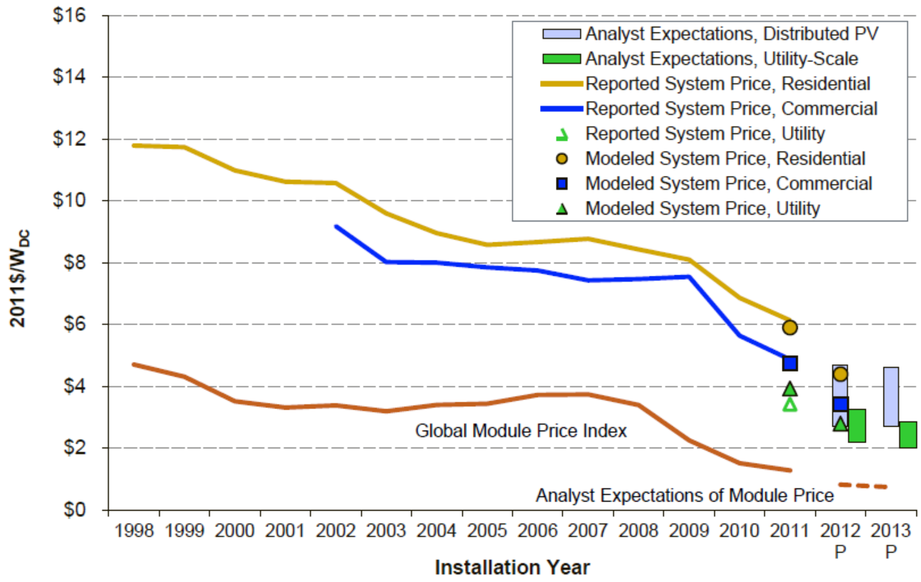
- PV costs decreasing by about 50% over the period 1998 to 2011;
- Wind generation costs increasing over the period 2001 to about 2007 after which they decreased.

I note that the cost reduction for PV systems is most likely conservative. The AETA 2012 report noted that:

"the cost of photovoltaic modules has fallen by approximately 50 per cent over the past 2–3 years. At present, modules comprise of approximately one-half of the capital cost of photovoltaic systems"

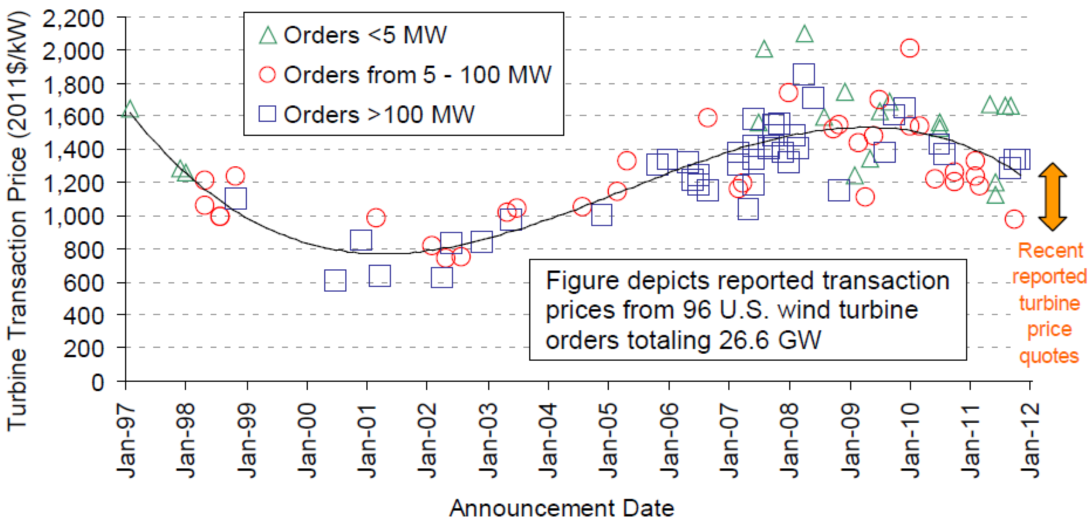
[15] http://www.nrel.gov/docs/fy13osti/56776.pdf

Figure 3 **Historical PV Costs**



Source: US Department of Energy

Figure 4 **Turbine transaction prices in the USA**



Source: US Department of Energy

4.2 Recent Movements and Projections of Wind and Solar Generation

To consider the rate of cost reductions in wind and solar technologies moving forward, I present figures presented in the report “Renewable Energy Technology Cost Review” dated March 2011 developed by the Energy Research Institute, University of Melbourne.

This report states in the executive summary:

“This paper has undertaken a review of current and future costs of three forms of renewable energy technology, comparing data from a range of international and Australian-specific studies, taking care to

compare data on the same basis of financial assumptions (discount rates) and resource quality. The purpose was to compare both the current costs, along with the rate of decrease, and the reason for differences between the studies."

To address this matter, Figure 5, Figure 7Figure 6 and Figure 7 below respectively show the figures from that report on projected PV, concentrating solar thermal and wind generation costs. Of note is that the solar technologies show expected substantial cost reduction whereas the wind cost reductions are moderate.

Figure 5 PV LCOE Projections

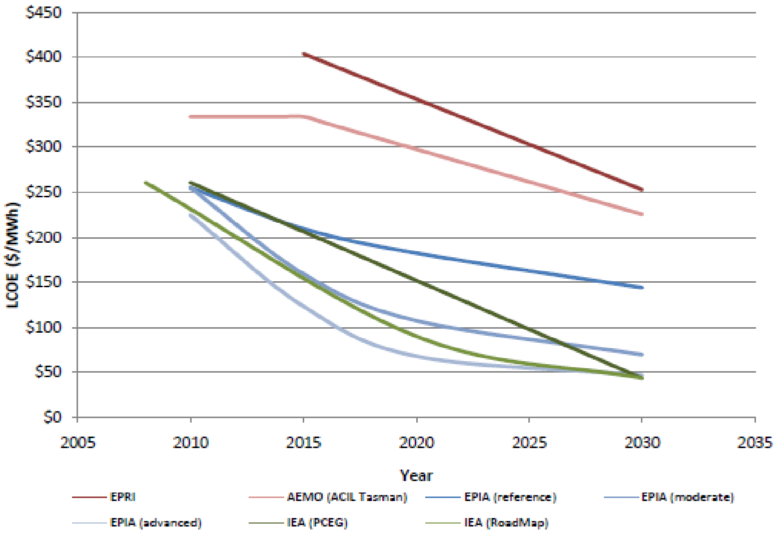


Figure 14: Comparison of PV LCOE's between different cost projections

Source: Energy Research Institute, University of Melbourne

Figure 6 Concentrating Solar Thermal

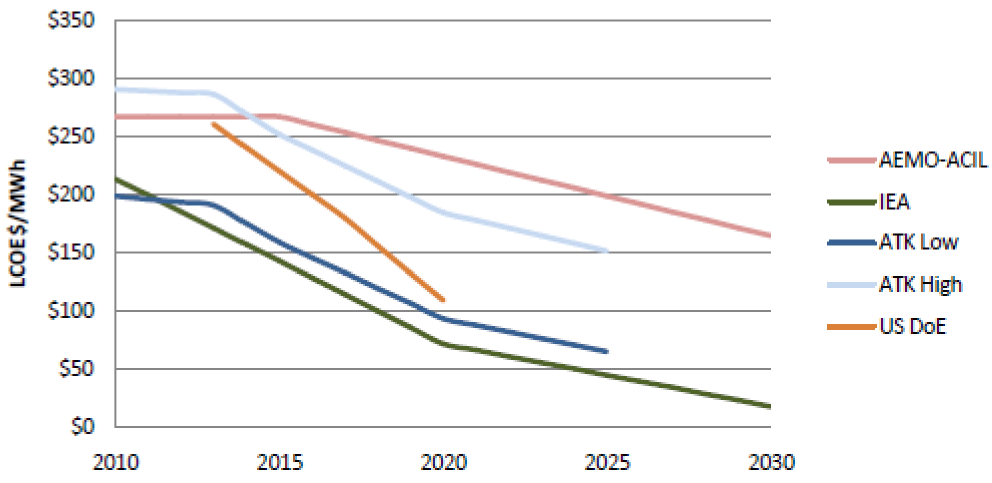
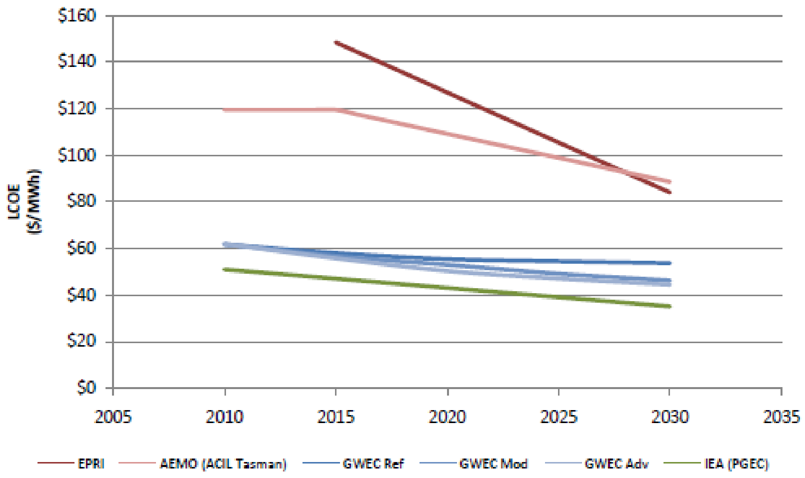


Figure 3: CST cost projections, at Direct Normal Irradiation of 2400 kWh/m2/yr.

Source: Energy Research Institute, University of Melbourne

Figure 7 Wind Generation LCOE Projections



Source: Energy Research Institute, University of Melbourne

This general trend and assessment of technological improvements is also supported in the AETA report, which states:

"Technological improvement and reductions in the cost of plant equipment and operation are likely to have the largest influence on pricing trends for generating technologies over the period 2012 to 2050".

4.3 Conclusions

From this I conclude that historical evidence and research supports that wind and solar generation costs have and are expected to decrease in the future. Wind costs reductions may be moderate but PV and solar technology costs are expected to show continuing and substantial cost decreases.

This reduction in renewable generation costs was also the conclusion of the AETA 2012 report. Figure 2 of this report presented a sample of four generation technology costs over the period 2013 to 2050.

5. Question 3 – Bloomberg Article

Whether you agree with the statement by Bloomberg New Energy Finance that unsubsidised renewable energy is now cheaper than electricity from new-build coal-fired and gas-fired power stations in Australia?

Under the current capital and fuel costs in the Australian electricity markets as published by AEMO[16] has coal and gas generation at a lower cost than renewable generation (wind and solar).

The Western Australian electricity market that operates in the South West Interconnected System (SWIS) has similar capital cost structures as in the National Electricity Market (NEM) and fuel costs which may be slightly higher.

On this basis I do not agree that unsubsidised renewable energy, in particular wind generation and solar, is now cheaper than electricity from new-build coal-fired and gas-fired power stations in Australia.

However the following point of clarification is added. The article by the Bloomberg New Energy Finance team (BNEF) is principally about what would most likely be developed, and as noted previously (in Chapter 2) this is a different question to a comparison of costs. The article in question says:

"New coal is made expensive by high financing costs. The study surveyed Australia's four largest banks and found that lenders are unlikely to finance new coal without a substantial risk premium due to the reputational damage of emissions-intensive investments – if they are to finance coal at all"[17].

The position of the banks reflects the uncertainty future policy and in particular carbon price, and also in my view a wariness of public reaction to the development of a new coal fired power station with increasing debate on carbon emissions concerns.

[16] http://www.aemo.com.au/Electricity/Planning/Related-Information/2013-Planning-Assumptions

[17] http://about.bnef.com/press-releases/renewable-energy-now-cheaper-than-new-fossil-fuels-in-australia/

6. Question 4 – Black Coal Generation

Whether black thermal coal is currently the cheapest or most attractive form of power generation internationally?

If the answer to question 4 is 'yes', under what conditions, if any, would black thermal coal cease to be the cheapest or most attractive form of power generation?

The issues of this chapter relate to:

- The current position of coal generation with respect to other technologies;
- Whether coal generation is the most attractive technology internationally; and if so
- Under what conditions would this change.

These issues are considered in turn below.

6.1 Relative Cost of Coal Generation

A consideration of the cost of coal generation compared to other technologies requires assumptions of fuel technology used, capital costs, fuel costs and fuel availability at the power station. A scenario of conceivable cost assumptions for black coal generation and CCGT generation and the resulting LCOE for each is shown in Table 1 below. No carbon price has been assumed. This shows black coal generation having a high capital cost but a lower fuel cost than CCGT generation. Under the assumptions shown, a carbon price over $12/tonne CO_{2e} would result in CCGT having a lower cost than the coal plant.

Table 1 Scenario of Power Station Cost Assumptions

	Black Coal	CCGT
Capital cost ($/kW)	2,500	1,300
Economic life years	30	30
WACC	9%	9%
Fuel cost $/GJ	4	8
VOM	5	4
Efficiency	41%	50%
Capacity Factor	90%	90%
LCOE	$71/MWh	$77/MWh

Table 1 is not intended to show that black coal is lower cost than CCGT. On the figures presented in Exhibit 6 discussed earlier in this report CCGT had a lower cost than the coal generation shown. The intention is to show that there is uncertainty in relation to the cost of coal generation compared to CCGT technology, and indeed all the estimates shown.

Other issues that would impact the relative costs shown above are the risks inherent in developing coal generation and the infrastructure to deliver coal or gas to power stations.

What can be said is that on a fuel outlook that has coal at less than $US100/tonne, black coal generation is likely to be the lowest cost generation option, although it may not be very much cheaper compared to other technologies such as CCGT .

6.2 Attractiveness

As discussed in Chapter 2, there are many issues which comprise the investment decision in generation. Issues include:

- Risk and uncertainties with regard to issues such as:
  - the imposition of carbon price;
  - technological change;
  - the move to decentralised and smart power grids;
- Fuel supply security;
- Financing;
- Risk of public reaction and associated risks and costs.

Evidence from Government and commentators is that momentum is developing for increased international action on carbon emissions. Recent articles / speeches that support this include:

The Economist in its 29 June 2013 issue advocating that:
"Current environmental policies will not keep the rise in global temperatures to below 2°C—the maximum that most climate scientists think safe. A carbon tax, if stiff enough, could. Big polluters should assume that such a tax will one day arrive, and start planning for it now."[18]

President Obama, in his recent speech on 25 June 2013, said:

"Today, I'm calling for an end of public financing for new coal plants overseas unless they deploy carbon-capture technologies, or there's no other viable way for the poorest countries to generate electricity. And I urge other countries to join this effort."[19]

I also note that as communities become more aware of the effect of carbon emissions on society their propensity to resisting developing new coal fired power plants is likely to become stronger and governments' responses would be to further regulate to reduce emissions. For example, the Chinese emissions trading scheme, announced recently, is the Government's response to the high levels of pollution measured in Chinese cities and the anticipated burden on future health issues. As communities become more aware of the effect of carbon emissions on society their propensity to resisting developing new coal fired power plants would become stronger and governments' responses would be to further regulate to reduce emissions.

6.3 Current Trends

There is much literature regarding the development of different types of power stations such as coal, gas, wind and solar. My understanding is that all technologies are being developed and that it is uncertain what the trend will be in say 15 years from now.

In a presentation to the press in London on 12 November 2012, the International Energy Agency presented the graph shown in Figure 8 below[20]. This shows the projected change in generation types over the period 2010 to 2035. While coal is playing a major part particularly

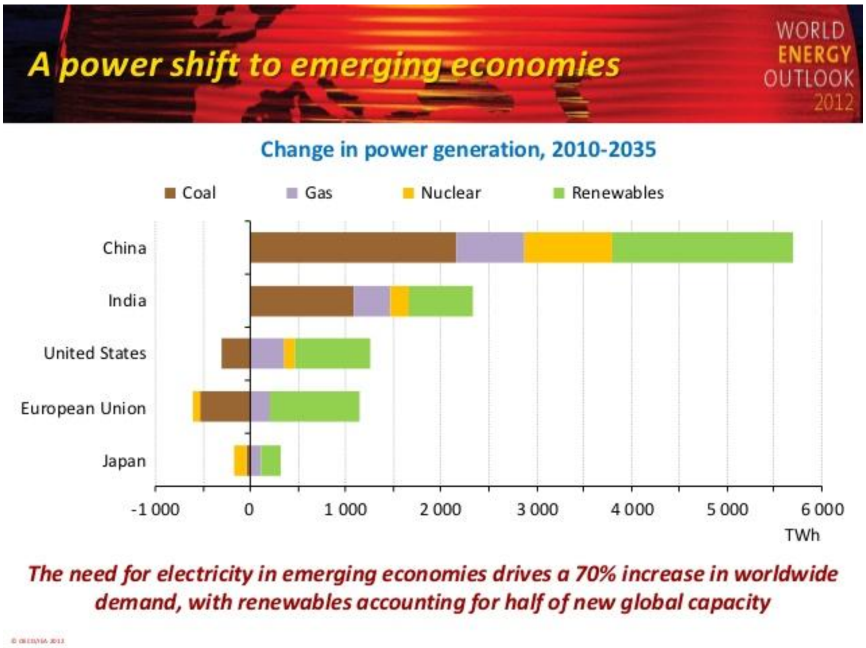
[18] The Economist - edition 29 June.

[19] http://www.whitehouse.gov/the-press-office/2013/06/25/remarks-president-climate-change

[20] http://www.slideshare.net/internationalenergyagency/world-energy-outlook-2012-presentation-to-press

in China and India, it decreases in the United States and the European Union. Also note that China and India also have substantial developments of renewables, nuclear and gas generation.

Figure 8 Change in Generation Mix – IEA 2012



In his report, Mr Stanford states that:

"new coal generators (some of them using very high emissions lignite) are being built in Germany in order to replace nuclear power for base load duty".

A quick review of the current coal fired generators being constructed in Germany shows that the majority of these generators are replacements for old inefficient plants by new ones with significant reduction of carbon emissions. Table 2 provides a list of these new power plants with comments indicating their roles.

Table 2 Germany's new coal plants

Operator	Location	Date due	Comments
GDF	Wilhelmshaven	2013	Ultra-supercritical coal fired unit of 731 MW. New high efficient (46%) plant that allows decommissioning of highly polluting old existing coal plants.[21]
Steag	Duisberg	2013	Co-generation power plant unit 10. On the 10th of June 2013 a first synchronisation with the converted power plant unit was successfully completed and electricity with a capacity of 175 MW was fed into the grid.[22]
E.ON	Datteln	2013	Datteln 4 will replace some very old power plants such as Datteln 1-3 and Shamroc. Datteln 4 will operate significantly more efficiently and cost-effectively and with greater environmental compatibility, saving more than 1 million tonnes of carbon

[21] http://www.gdfsuez.com/wpcontent/uploads/2012/12/GDF_SUEZ_Analyst_Pack_Major_projects_under_construction.pdf

[22] http://www.steag.com/walsum+M52087573ab0.html

			dioxide emissions per year.[23]
RWE	Hamm	2013	The most advanced plants of their kind worldwide, they will replace the 160-megawatt units commissioned in 1962/63 and expand the capacity of the site. The new plant will require 20% less coal. Per kilowatt hour of produced electricity, less greenhouse gases will be emitted: some 2.5 million tons of CO_{2e} per year compared with older plants. [24]
Vattenfall	Hamburg	2014	Vattenfall invests to enhance efficiency and reduce CO_{2e} emissions in current plants but will not build any new plants without commercially proven CCS. In June 2011, Germany's parliament's decided that all 17 of the country's nuclear power plants are to be closed by 2022 at the latest.[25]
GKM	Mannheim	2015	Following closure of Units 3 and 4, the new plant, unit 9, will technically and economically safeguard the long-term energy supply for the people in the region and also forms the basis for expanding the district heat network. The highly modern 911 MW coal unit on the east of the company site will go into operation at the end of 2013.[26]

6.4 Conclusions

The risk of developing black coal generation compared to lower carbon emitting technologies will likely be viewed differently by different parties. The issues that would influence such judgements have been addressed earlier in this report.

However on the calculated cost, the following would make coal more expensive than CCGT plant based on the assumed assumptions used in Table 1 above:

- A moderate carbon price of about $12/tonne; or
- An increase in the WACC of the coal plant of 3% or an increase in capital costs of over $500/kW; or
- Reduction in gas price of over $1/GJ; or
- A combination; of these or some other factors.

This illustrates by way of example the sensitivities associated with such assessments.

For reasons of uncertainty regarding environmental policy (including carbon emission costs), commodity prices (such as coal and gas), new technology developments, energy efficiency and future electricity demand, developers of new generation (be they private investors or government) undertake scenario analysis to ascertain how investments will perform under a range of uncertain outlooks. Such analysis is likely to show coal generation being viable in many of the "business as usual" scenarios but with limited viability in other scenarios that incorporate rapid technology development and/or greater environmental constraints.

[23] http://www.eon.com/en/about-us/structure/asset-finder/datteln4.html

[24] http://www.rwe.com/web/cms/en/348148/rwe-technology-the-power-plant-specialist-in-the-rwe-group/construction-projects/new-build-projects/westphalia/

[25] http://www.vattenfall.com/en/germany.htm

[26] GKM_Block_9_Folder_GB(1).pdf

7. Summary of conclusions

In summary, my conclusions in respect of each of the questions asked are as follows:

1) Whether the relative costs of energy sources expressed in Exhibit 6 of Mr Stanford's report and paragraph 4.3(a)(iii) of Mr Offen's report are reasonable?

I do not consider the relative costs of electricity generation expressed in Exhibit 6 of Mr Stanford's report as reasonable. The key reasons for this are that Mr Stanford's report does not state the underpinning assumptions that underpin the presented costs and does not consider in any way how these might change in the future. I do note that the presentation slide stated that these costs were "current costs" which was not stated in Mr Stanford's report.

Further, Mr Stanford's report implicitly assumed these costs can be used as a metric of favoured generation development when there are many other factors that will influence this such as environmental risk and supply security.

2) Whether the cost of generating wind and solar power is decreasing? If so, at what rate?

A review of these costs shows that wind generation costs have varied and are now reducing. Solar generation costs have and are projected to decrease significantly. The report (Australian Energy Technology Assessment 2012) that contained the data in the presentation slide showing Exhibit 6 shows solar generation costs decreasing significantly in the future.

3) Whether you agree with the statement by Bloomberg New Energy Finance that unsubsidised renewable energy is now cheaper than electricity from new-build coal-fired and gas-fired power stations in Australia?

Based on current coal costs and government policy I do not agree that unsubsidised renewable energy, in particular wind generation and solar, is now cheaper than electricity from new-build coal-fired and gas-fired power stations in Australia.

However I also do not believe that new coal generation is currently viable in Australia. The reasons for this include environmental policy risk, market risk, and public reaction.

4) Whether black thermal coal is currently the cheapest or most attractive form of power generation internationally?

I do not believe in the premise of the question that there is a cheapest and most attractive form of generation.

On current international coal costs and environmental policies, coal generation is amongst the lowest cost generation options. However developments such as the advent of shale gas and an increasing international move to constrain carbon emissions is and will increasingly impact the risk and acceptability of coal generation. Plausible outlook scenarios can have coal generation lower cost or higher cost than competing technologies (depending on assumptions such as gas costs and carbon emission costs or policy).

What I believe will occur is that coal generation will continue in the energy mix including new build generation, but that this will abate over the 30 year period being considered.

5) If the answer to question 4 is 'yes', under what conditions, if any, would black thermal coal cease to be the cheapest or most attractive form of power generation?

While I did not answer 'yes' to the above question, there are conceivable scenarios of commodity cost and environmental policy positions where this may or may not be the case, noting that economics of coal versus other generation is likely to be country specific.

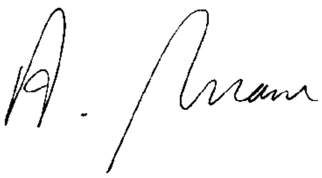
7.1 Expert's statement – Additional facts

I am not aware of any further readily ascertainable additional facts that would not assist me to reach a more reliable conclusion.

7.2 Expert's confirmation

I confirm the following:

(a) the factual matters stated in this report are, as far as I know, true;
(b) I have made all enquiries that I consider appropriate;
(c) the opinions stated in this report are genuinely held by me;
(d) the report contains reference to all matters I consider significant; and
(e) I understand my duty to the court and have complied with the duty.



Antoine Nsair

8. Appendix1 Antoine Nsair Curriculum Vitae

Antoine Nsair – Curriculum Vitae

BSc (University of Melbourne)

MSc Statistics (La Trobe University) *MJA Senior Associate*

Antoine Nsair has over 32 years of experience in the energy sector. During this period he held senior management positions and was involved in the development and implementation of the National Electricity Market and the Victorian Gas Market. Antoine was a partner and director of McLennan Magasanik Associates (MMA) (2000-2009), where he provided advice to senior executives, in government and privately owned organisations, on matters relating to forecasting demand and investment in the electricity, gas and water industries in Australia and Singapore. Prior to joining MJA Antoine was an associate with IES (2010-2011).

Antoine held executive positions on two leading energy companies, AGL and TRUenergy as head of energy trading and a member of the financial risk management committee.

Recent projects include:

- Led a team of experts in providing advice to the Queensland Gas Commissioner in undertaking a comprehensive report on the east Australian gas market review.
- Advised state and territory regulators on electricity, gas and water demand forecasts and the impact of demand management programs in setting prices. Clients included IPART, ICRC, ESC (Victoria), QWC, and the Victorian water utilities.
- Developed statistical models to forecast energy and maximum demand for the Victorian electricity system.
- Over the last 2 years, Antoine has been advising investment banking corporations, hedge fund managers and investors on the Australian gas and electricity markets with specific focus on Alinta Energy's assets and its gas contracts and prices. The advice also included matters relating to the refinancing of generation assets and the Australian Government's Clean Energy policy.
- Provided independent advice to the Australian Energy Market Operator (AEMO) on the cost projections for fuels supplied to individual NEM generators under five economic and environmental scenarios.
- Led MMA's teams to provide strategic advice and due diligence services to investors and financial institutions in the merger and acquisition of energy assets in Australia and Singapore. Clients included, amongst others, Singapore Power International, Hongkong Electric, Meridian Energy, Sime Darby Berhad (Malaysia) and Brascan Investment (Canada).
- Provided full support to Singapore Power International on the acquisition and sale of TXU assets worth over $5 billion, and the joint purchase of Alinta Energy assets with BBI worth over $13 billion.
- Undertook energy market studies advising clients (mainly generation companies) on the dynamics and uncertainties surrounding the Australian Government's introduction of the Carbon Pollution Reduction Scheme (CPRS) and the expanded renewable energy target. Clients included generation companies in Queensland and Victoria including renewable energy generation companies.

- Advised clients on identifying business opportunities in the national electricity market (NEM) and gas markets.
- Supported financial institutions and energy market participants in providing market studies and revenue projections for the purpose of refinancing debt.
- Provided advice to one of the bidders for the Victorian desalination plant on the electricity market and strategies to manage the plant's power procurement strategies including interruptibility and trading of renewable energy certificates (RECs). Advice was also provided to the successful bidder for the South Australian desalination plant.
- Led a major study of supply and demand of the Australian gas market with focus on the eastern states of Australia.
- Undertook a study for the Australian Geothermal Energy Association (AGEA) on the costs associated with developing geothermal power plants from pilot to demonstration to commercial stages for the different geographical sites.
- Provided industry overview studies for new market entrants to better understand the risks faced by participants in the electricity and gas markets.