Submission

No 27

INQUIRY INTO THE ECONOMICS OF ENERGY GENERATION

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Australian Government

Nuclear-based science benefiting all Australians

21 February 2012

The Committee Manager
Public Accounts Committee (PAC)
Parliament House
Macquarie St
Sydney NSW 2000

Attention: Vicki Buchbach (pac@parliament.nsw.gov.au)

Dear Ms Buchbach

RE: Public Accounts Committee Inquiry into the Economics of Energy Generation

Please find attached the Australian Nuclear Science and Technology Organisation's submission to the Public Accounts Committee Inquiry into the Economics of Energy Generation.

We would like to thank the Committee for the opportunity to contribute to this important subject. We would also like to thank Dr Groves for the extension of the deadline by a week for our submission.

Please do not hesitate to contact me if the Committee has any questions regarding this submission.

Yours sincerely

Dr Adi Paterson
Chief Executive Officer

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ANSTO Submission to the Public Accounts Committee Inquiry into the Relative Economics of Energy Generation for NSW

Contents

1 Executive Summary

A secure energy supply is characterised by good adequacy, reliability and affordability. It should be environmentally sustainable, and have minimal adverse health effects. This is best achieved through the use of a diverse mix of low carbon and low pollution energy sources.

The main energy challenges are to provide a secure and reliable source of energy to keep up with the increasing demand at affordable prices, while urgently reducing greenhouse gas emissions to limit the effect of climate change. There is, and will continue to be, a direct link between Gross Domestic Product growth and energy requirement growth in resource based economies. Australia remains a resource based economy.

New South Wales is heavily reliant on fossil fuels, in particular coal, for the generation of its base load electricity supply. According to the Australian Bureau of Statistics, carbon emissions from electricity grew from 106.2 million tonnes equivalent emissions in 1999, to 121.7 million tonnes in 2009. Over the same period, emissions in the state from industry, agriculture and waste management have decreased.

This heavy dependence on fossil fuel sources also exposes the state to price fluctuations and supply difficulties. This concern will be enhanced as Australia continues to offer more of its energy resources for export.

At present the shortfall between New South Wales electricity generation and demand is being met by electricity imports from Queensland and Victoria. Any increased load on regional interconnectors, in an effort to meet growing consumption, will require investment for upgrades and maintenance and incur increased transmission losses. This restricts any potential increase of imports into New South Wales and reduces the cost effectiveness of expanding generation facilities interstate to service itss growing demand.

Limited low carbon emission generation technologies are available for reliable base load supply of electricity that are cost comparable with the currently installed high emission fossil based portfolio. These include hydroelectricity generation and nuclear power. Gas turbine based technologies offer a competitive, intermediate solution with lower carbon emissions, facilitating incrementally stricter emission targets for 2020 and 2050. However, the use of gas cannot deliver the high carbon cuts currently being talked about for the latter part of that period.

International experience has demonstrated that nuclear power plants are a proven technology as part of the energy mix that can provide low carbon electricity generation, in a reliable and affordable manner. This proven experience has to be assessed against risk perceptions following the Japanese earthquake and tsunami. In this context a number of NSW overseas trading partners are continuing with new programmes and lifetime extensions for their nuclear reactor fleets. Considered international experience suggests that exploration of nuclear power generation within the NSW energy mix would: increase diversity of supply; accelerate and leverage the government's objective of carbon dioxide emission reduction; mitigate future trade risk in a "carbon penalising" trade regime globally; and achieve this without major impact on economic prosperity.

By comparison with hydropower and nuclear low carbon technologies such as solar PV, solar thermal and wind power are restricted by cost, efficiency and intermittency issues. Given international experience to date, in aggregate, these technologies will not achieve penetration of more than 15-20%. At this level of penetration the countries that have adopted these technologies are backed up by hydro, gas and load-following nuclear plants that enhance security of supply. All countries with high solar and wind penetration are in the upper quartile of global domestic and industrial energy costs.

Clearly energy diversification with optionality of using a combination of mature and emerging alternative sources can provide the benefits of emissions reductions and energy security.

In this report we conclude that:

1. Current trends in global and domestic energy demand and consumption are expected to continue. These rates of increase are, however, unsustainable, and threaten both security of energy supply and climate stability.
2. A secure energy supply is characterised by good adequacy, reliability and affordability. It must also be environmentally sustainable, and have minimal adverse health effects. This is best achieved through the use of a diverse mix of low carbon and low pollution energy sources.
3. Most developed economies and a number of developing economies include nuclear power in their long-term energy security strategy. Australia is one of very few OECD countries not utilising nuclear power.
4. All OECD countries (except Australia, New Zealand, Israel and Iceland) that are not utilising nuclear power can and do import nuclear power from contiguous economies that have nuclear power. Australia will not have this option available to it – a significant negative for energy security, if the intention is to remain a leading economy.
5. NSW currently relies almost exclusively on fossil fuels,especially coal for its electricity supply. A lack of diversity and current dependence on sources with high greenhouse gas emissions in general makes future energy supply inherently insecure as well as lacking in optionality and diversity. It is worth noting that the total cost of energy supply becomes more vulnerable when a price on carbon dioxide emissions is introduced. (including in NSW)
6. The current policy of pursuing clean coal and renewables is a necessary strategy in the light of the climate change challenge. However, renewables cannot yet provide early or proven solutions to the problems NSW faces. Affordable clean coal being available in a short time frame is not supported by the science, or the technological maturity of the technologies, or the required regulatory assurance. A balanced consideration of worldwide evidence is that clean coal will not be economical in the required timeframe. The assumptions that underpin policy optimism in this regard therefore cannot be sustained.
7. Nuclear power generation is a mature, proven technology that has provided base load power in a number of countries for 50 years. It has a number of advantages such as fuel price stability, low operating costs, low emissions and waste and, a secure fuel supply. As demonstrated elsewhere in the world,

nuclear power has much to offer in the way of achieving a diverse energy mix and contributing to medium to long term energy security.

8. The nuclear power industry in the developed world is the only electricity generator that currently pays for its full lifecycle costs, including the cost of managing the waste it produces.
9. Consideration of nuclear power should be considered on a full evidence-based examination of the available technology along with a range of other technologies using established levelised cost analysis and properly pricing carbon within the analysis and the attendant consideration of the safety of third generation nuclear plants.
10. Despite its maturity, it is clearly recognised that there a number of important public concerns raised about nuclear, including waste, proliferation and safety. These issues have been extensively examined in many countries through comprehensive studies.
11. Active public engagement and debate, transparent, clear and factual information in other countries have been shown to significantly allay public concerns. Independent, strong regulators are also seen to be key to public confidence.
12. Concerns are also raised about the cost of nuclear power, due to its requirement for high initial capital investment. This requires special funding mechanisms and government support to reduce the risks from delays and provide incentives for investment. This is no different to the support given to other forms of energy production. Nevertheless, appropriate accounting for greenhouse gas and other emissions has made nuclear a competitive option in relation to existing coal and natural gas plants and a much better low carbon source.
13. While there are a number of ways to provide a secure and diverse energy mix all will require reducing reliance on current fossil fuel technologies. and nuclear power, in combination with renewable energy technologies, does satisfy the criteria for being considered a key technology.
14. Energy security, from a trade and economic point of view will be at risk without active consideration of nuclear energy given : the future cost of carbon is not known and all renewable options are intermittent low power density sources that cannot be relied on for energy intensive processes. This includes transport and logistics infrastructure, national defence facilities/deployment, and economic extraction of natural resources, which form the bulk of our trading income.

2 Introduction

As New South Wales moves towards a low carbon economy, decisions should be made on the basis of technological, economic and environmental evidence. In order to ensure a secure and reliable supply of energy from optimal sources, policy makers should evaluate all available technologies.

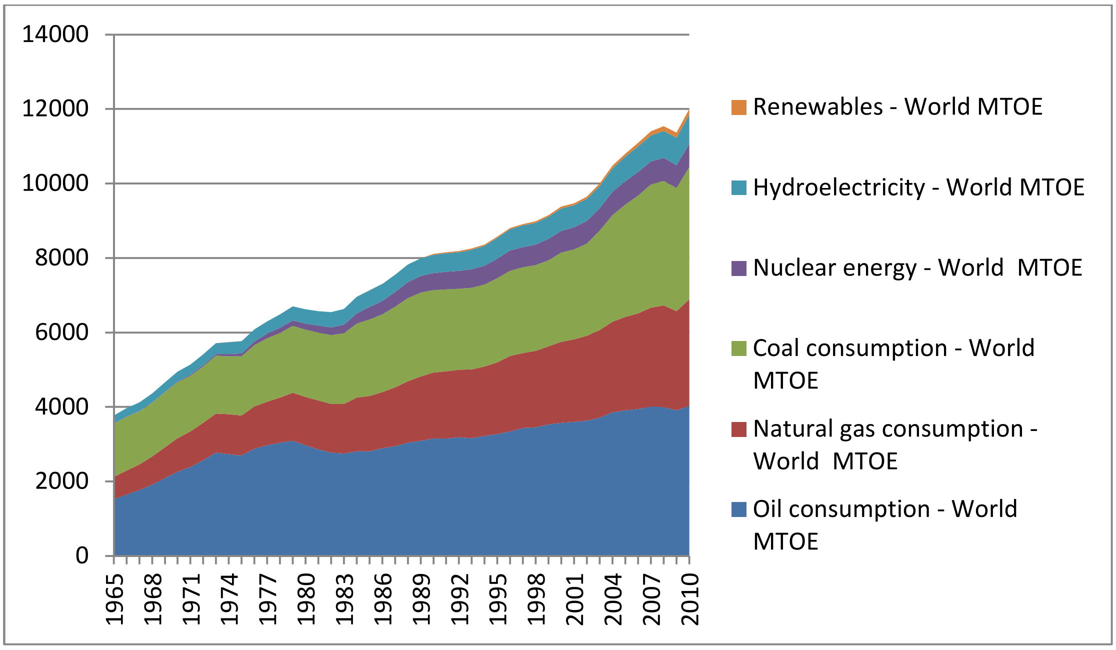
At present, New South Wales is highly dependent on fossil fuels. This lack of diversity has the potential to put its energy security under stress , as the dominance of coal as an energy single source, exposes the state to price fluctuations (in relation to carbon dioxide emissions). This concern could be enhanced as Australia continues to offer more of its fossil resources for export with the potential for importing "carbon penalties" from other jurisdictions.

The development of established and emerging alternatives to high emitting fossil fuel technologies could secure the state's energy supply while providing a cleaner source of energy. With the implementation of emissions abatement policies, such cleaner technologies will also become more economically competitive.

3 Growth of energy consumption

Globally, energy demand is increasing. This increase will inevitably continue if countries are to be afforded the right to economic prosperity or maintenance of their standard of living. Forecasts of energy consumption by the OECD's International Energy Agency predict that the strongest growth to 2030 will occur in Asia and the Middle East, as those regions' populous developing countries continue to industrialise.[1]

Figure 1: Global primary energy consumption by source (MTOE)[2]



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[1] IEA (2009) *World Energy Outlook 2009*, p. 76
[2] BP (2011) *BP Statistical review of world energy*. Accessed 30 January 2012: http://www.bp.com/assets/bp_internet/globalbp/globalbp_uk_english/reports_and_publications/statistical_energy_review_2011/STAGING/local_assets/pdf/statistical_review_of_world_energy_full_report_2011.pdf

Table 1: Primary energy demand by region (Mtoe) [3]

	1980	2000	2007	2015	2030	2007-2030*
OECD	4,050	5,249	5,496	5,458	5,811	0.2%
North America	2,092	2,682	2,793	2,778	2,974	0.3%
Europe	1,493	1,735	1,826	1,788	1,894	0.2%
Pacific	464	832	877	892	943	0.3%
Non-OECD	3,003	4,507	6,187	7,679	10,529	2.3%
E. Europe/Eurasia	1,242	1,008	1,114	1,161	1,354	0.9%
Asia	1,068	2,164	3,346	4,468	6,456	2.9%
China	*603*	*1,105*	*1,970*	*2,783*	*3,827*	*2.9%*
India	*207*	*457*	*595*	*764*	*1,287*	*3.4%*
ASEAN	*149*	*389*	*513*	*612*	*903*	*2.5%*
Middle East	128	378	546	702	1,030	2.8%
Africa	274	499	630	716	873	1.4%
Latin America	292	457	551	633	816	1.7%
World**	7,228	10,018	12,013	13,488	16,790	1.5%

**Compound average annual growth rate*
***World includes international marine and aviation bunkers, which are not included in region totals*

While a number of countries in these regions of most rapid growth are developing nuclear power, the globe will remain highly dependent on fossil fuels for the foreseeable future. The fact that the world's most rapid growth in energy consumption is occurring within our own region, highlights the importance of diversification in NSW's future energy supply. Without a diversified energy portfolio, New South Wales risks exposure to price growth and competition for supply within the region.

Dependence on fossil fuels for energy supply – for both primary use and electricity generation – leaves the state vulnerable to increased cost from the implementation of climate change policy and exposure to international fossil fuel markets. The lack of energy resource diversity in New South Wales and across all the National Electricity Market jurisdictions, enhances the state's exposure to price volatility, external shocks and supply issues.

4 Energy Security

The federal Department of Resources, Energy and Tourism (DRET) conducted a National Energy Security Assessment, released in 2009 [4], which defined energy security as the adequate, reliable and affordable supply of energy to support the functioning of the economy and social development, where:

- Adequacy is the provision of sufficient energy to support economic and social activity;
- Reliability is the provision of energy with minimal disruptions to supply; and

[3] IEA (2009), p. 76
[4] DRET (2009) *National Energy Security Assessment 2009.*

- Affordability is the provision of energy at a price which does not adversely impact on the competitiveness of the economy and which supports continued investment in the energy sector.

In addition to the above points, it is also necessary to include environmental impact and public health and safety as a part of the assessment criteria.

The National Energy Security Assessment 2011 (NESA 2011), also conducted by DRET, concluded that the security of Australia's electricity and natural gas energy is *moderate*, with liquid fuel security rated as *high trending to moderate*.[5] A rating of *moderate* indicates that "the economic and social needs of Australia are being met. However, there could be a number of emerging issues that will need to be addressed to maintain this level of security."[6] Expected price increases in all three categories are highlighted by NESA 2011 as significant factors in achieving less than optimal security ratings.

Liquid fuel security is expected to come under pressure from increased demand straining infrastructure and high crude oil prices.[7] Natural gas is likely to face price increases once the domestic market is exposed to the international market with the establishment of coal seam gas (CSG) and liquefied natural gas (LNG) exports from Australia's east coast, due to commence in 2014-15.[8] Electricity prices will continue to rise with increased demand and the implementation of climate change policies.[9] Further to this, NESA 2011 rates Australia's electricity affordability in the short, medium and long term as *low*, meaning that "the economic and social needs of Australia are not being, or might not be met".[10]

NESA 2011 also warned that volatility of gas supply to electricity generators could threaten the reliability of electricity supply, in which case the reliability rating would be downgraded to *low*.[11]

New South Wales is connected to the National Electricity Market's (NEM) grid, which traverses the Australian Capital Territory, NSW, Queensland, South Australia, Tasmania and Victoria. In 2009-10, the state imported 7,978 GWh via interconnectors at the Victorian and Queensland borders, with the majority of imported supply sourced from Queensland.[12] A threat to reliability of supply in Victoria or Queensland should therefore also be interpreted as a threat to supply in New South Wales.

The Australian Energy Market Operator (AEMO) regional outlooks identify the timing of low reserve condition (LRC) points, which "indicate when reserve margins

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[5] DRET (2011) *National Energy Security Assessment 2011*. Accessed 30 January 2012: http://www.ret.gov.au/energy/Documents/Energy-Security/nesa/National-Energy-Security-Assessment-2011.pdf
[6] Ibid, p. 3
[7] Ibid, p. 8
[8] Ibid, p. 34
[9] Ibid, p. 55
[10] Ibid, p. 3
[11] Ibid, p. 55
[12] AEMO (2011) *NTNDP Maps*. Accessed 30 January 2012: http://www.aemo.com.au/planning/0410-0085.swf

will potentially fall below minimum reserve levels (MRL). LRC points … indicate when the power system is falling below long-term system reliability standards."[13]

AEMO predicts, assuming medium economic growth, that:[14]

- Queensland requires additional investment by 2014-15 (reliance on Queensland for electricity supply is high risk)
- Victoria and South Australia require additional generation investment by 2014-15
- New South Wales requires additional generation investment by 2018-19

5 The need to target baseload technologies

Electricity demand is generally categorised into baseload, intermediate load and peak load. In the medium term, baseload demand does not change significantly over time and is defined as the minimum amount of power that an electricity utility or distribution company must always make available to its customers.[15] Intermediate load does vary but is predictable and influenced by time of day such as weekday mornings and evenings. Peak load is much less certain and is often influenced by climatic conditions that change demand for building heating and cooling.

Different generators service the three different loads. An efficient mix of generation is one which minimises the total cost of meeting the demand. The shape of the demand profile is a key consideration. For example, a relatively flat demand profile implies a greater role for baseload generation, while a very peaky demand profile implies a greater role for peaking generation. In Australia in 2009 baseload plants provided 60% of the peak load and 76% of total energy.[16]

6 Fit-for-service (FFS) technologies for baseload supply

Not all low-carbon generating technologies are suitable for baseload plants. The US Energy Information Administration (EIA) defines baseload plants as facilities that operate almost continuously, generally at annual utilization rates (capacity factors) of 70% or higher.[17] Nicholson *et al.* similarly developed a comprehensive set of selection criteria.[18]

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[13] AEMO (2011) *Electricity Statement of Opportunities for the National Electricity Market 2011, Revision 2*, p. 7-1(213). Accessed 30 January 2012: http://www.aemo.com.au/planning/0410-0079.pdf
[14] Ibid
[15] Nicholson M, et al., How carbon pricing changes the relative competitiveness of low-carbon baseload generating technologies, Energy (2010), doi:10.1016/j.energy.2010.10.039
[16] Ibid
[17] US Energy Information Administration. Annual energy outlook, http://www.eia.doe.gov/oiaf/aeo/electricity_generation.html; 2010.
[18] Nicholson M, *et al.*, How carbon pricing changes the relative competitiveness of low-carbon baseload generating technologies, Energy (2010), doi:10.1016/j.energy.2010.10.039

For a technology to be considered fit-for-service (FFS) as a baseload generator it needs to be scalable, dispatchable without large storage and have a reliable fuel supply, low (L) or moderate (M) emissions intensity and a high capacity factor.[19] The technologies that score well enough to meet the FFS criteria are pulverised fuel black coal with carbon capture and storage (PF Coal/CCS), integrated gasification combined cycle coal with CCS (IGCC/CCS), combined cycle gas turbine with CCS (CCGT/CCS), nuclear power, and solar thermal with thermal storage and/or hybrid gas (STE). Engineered geothermal systems (EGS) could also qualify, but EGS is only at the pilot plant stage of development and therefore lacks adequate reliable cost data.

Technologies that do not meet the FFS criteria according to Nicholson are PF Coal, IGCC, CCGT, Biomass, conventional Geothermal, Wind, Solar PV, Tidal and Wave. Hydroelectricity is also disqualified in Australia due to low scalability and a low capacity factor.

7 New South Wales

7.1 The current situation

By far the largest proportion of energy consumed in NSW is for electricity production. According to the Australian Bureau of Statistics, carbon emissions from electricity production grew from 106.2 million tonnes equivalent emissions in 1999, to 121.7 million tonnes in 2009.[20] Over the same period, emissions in NSW from industry, agriculture and waste management decreased.[21]

At present New South Wales has installed capacity to generate approximately 18,365 MWe:[22]

- 13,993 MWe (76.2 %) is generated by the burning of fossil fuels – either coal or gas
- 4,046 MWe (22.0 %) is generated by hydroelectric plants
- 266 MWe (1.4 %) is accounted for by wind farms
- The balance is generated by other small (mostly renewable) technologies e.g. bagasse.

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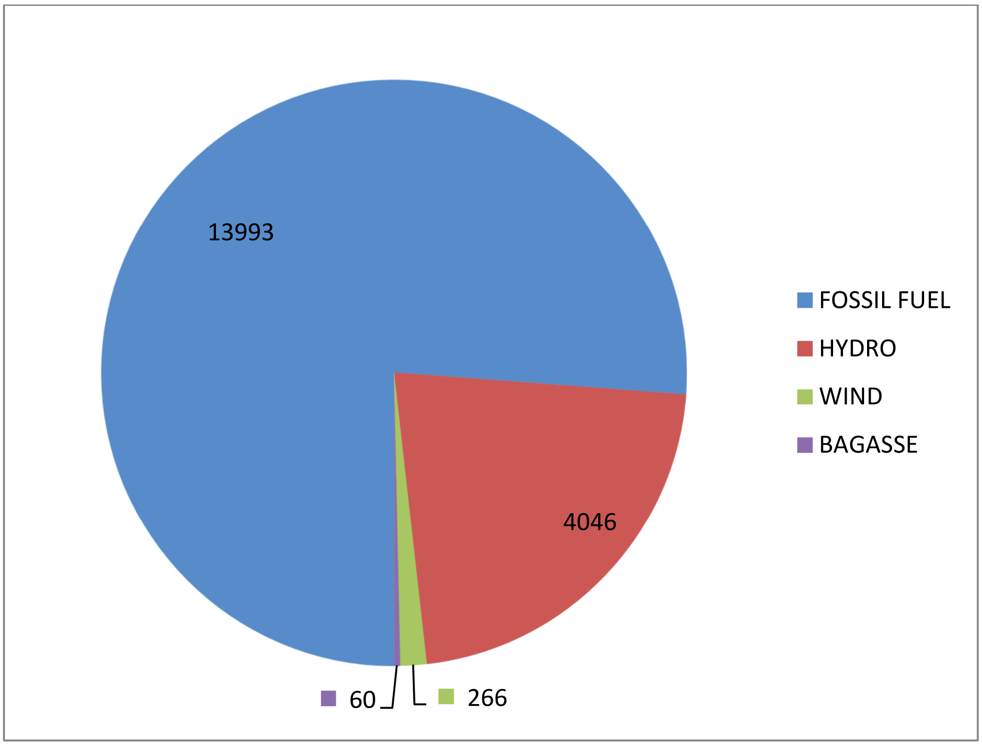
[19] Nicholson M, *et al.*, How carbon pricing changes the relative competitiveness of low-carbon baseload generating technologies, Energy (2010), doi:10.1016/j.energy.2010.10.039

[20] ABS (2011) *1367.0 – State and Territory Statistical Indicators, 2011: Carbon Emissions*. Accessed 31 January 2012: http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/1367.0~2011~Main%20Features~Carbon%20Emissions~2.39

[21] Ibid

[22] NSW Trade and Investment (2011) *Electricity Generation*. Accessed 30 January 2012: http://www.trade.nsw.gov.au/energy/electricity/generation

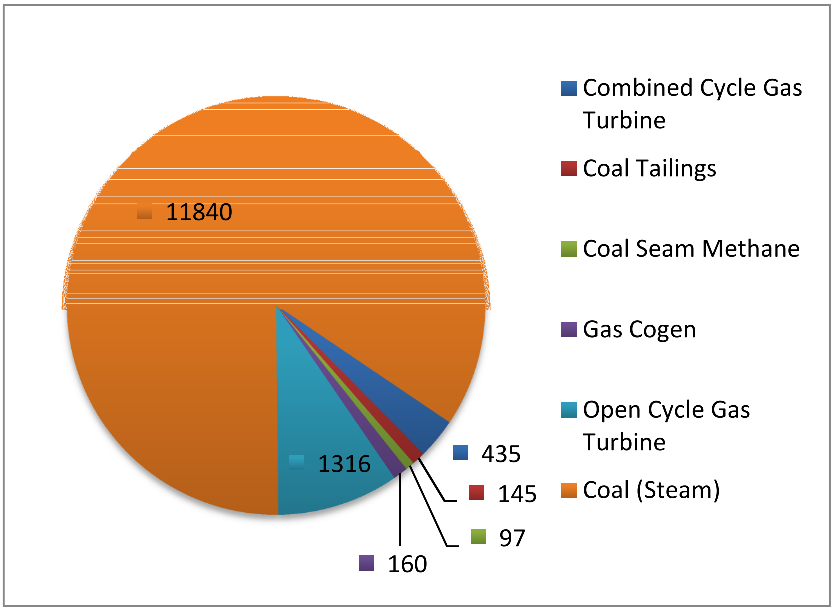
Figure 2: NSW installed capacity for electricity generation (MWe)



Of the 13,993 MWe capacity provided by fossil fuels:[23]

- 11,985 MWe (85.6 %) comes from coal
- 2,008 MWe (14.4 %) comes from natural gas or coal seam methane

Figure 3: NSW installed capacity for electricity generation from fossil fuels (MWe)



[23] Ibid

It is important to note that these figures represent generation capacity – that is, the power output that would be achieved if all generation plants operated simultaneously at full capacity - and not electricity supplied.

In practice, electricity generated by renewable sources in Australia in 2009-10 made up only 8.3 % of total electricity generated, despite comprising 18.4 % of total installed capacity.[24] This is because the majority of demand is serviced by baseload sources. Currently gas plants tend to service peak demand and provide "spinning reserve" for intermittent renewables such as wind.

In 2008-09, 4.0 % of primary energy consumption in NSW was generated by renewable sources, while 55.8 % came from coal, and 37 % from petroleum products.[25] NSW was responsible for 27 % of Australia's energy consumption.[26]

While abundant coal reserves in NSW provide a cheap and reliable source of fuel, this dependency is reflected in NSW's carbon emissions. NSW is a major greenhouse gas emitter at approximately 23 tonnes CO_2 equivalent per person per year [27], compared to Victoria's 23 tonnes CO_2[28], Queensland's 43 tonnes CO_2[29], Western Australia's 36 tonnes CO_2[30], South Australia's 19 tonnes CO_2[31] and Tasmania's 17 tonnes CO_2.[32]

7.2 Sourcing Energy Interstate

The NEM consists of five interconnected regions – New South Wales, Queensland, South Australia, Tasmania and Victoria. This allows for the export and import of electricity across state borders to ensure a reliable supply that can most efficiently met peak demands.

Interconnectors ensure variability in demand across all regions can be serviced. The Queensland to New South Wales Interconnector and the Victoria to New South Wales Interconnector (via the Snowy Hydro system) are the two major pathways for New South Wales to source energy from the NEM. New South Wales is a net importer of electricity, and in 2009-10 imports supplied 8,000 GWh of electricity equating to approximately 10 % of the state's total consumption.[33]

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[24] Energy Supply Association of Australia (ESAA) (2011) *Annual Review 2010 – 2011*, p. 9. Accessed 30 January 2012: http://www.esaa.com.au/Library/PageContentFiles/f8856ad0-b504-4c00-9dae-1243808afbd6/20111121__esaaAnnualReview2010_2011.pdf
[25] Department of Resources, Energy and Tourism (DRET) (2011) *Energy in Australia 2011.* Accessed 1 February 2012: http://www.ret.gov.au/energy/Documents/facts-stats-pubs/Energy-in-Australia-2011.pdf
[26] Ibid
[27] NSW Trade and Investment (2011) *Greenhouse gas.* Accessed 30 January 2012: http://www.trade.nsw.gov.au/energy/sustainable/greenhouse-gas
[28] Queensland Government (2008) *ClimateQ: Towards a Greener Queensland.*
[29] Ibid
[30] Ibid
[31] Ibid
[32] Ibid
[33] DRET (2011) *Energy in Australia 2011*

There are three critical factors that determine the scale and direction of energy flow through regional interconnectors: cost of generation, infrastructure capacity and energy demand growth in each region.

New South Wales Treasury has forecast energy demand in Queensland to grow at 3.5 % per annum for the period leading up to 2017, surpassing the forecast growth rate of 1.7 % for NSW. [34] To service this accelerating demand, energy that may have previously been exported to the state would no longer be available, or will be significantly more expensive. Similarly, increasing energy consumption in Victoria, South Australia and Tasmania will place greater demand on the interconnectors that form part of the Snowy Hydro system. The Snowy Hydro plants have typically generated 4,800 GWh annually with the majority supplied to New South Wales. [35] Ensuring fluctuations in peak demand across the state can be met will depend on the its ability to source electricity affordably from adjacent jurisdictions. Consideration should be given to the long term sustainability of electricity imports to New South Wales as regional energy demand grows.

A study conducted by ACIL Tasman estimates that the price of natural gas is approximately 30 % lower and coal prices 15 % lower in Queensland than in New South Wales. [36] Energy providers typically supply users in regions with higher prices by sourcing from regions of lower cost generation. This will provide a continued incentive for energy input to the state until the price differential narrows.

Capacity limits and maintenance costs of existing infrastructure will act as a barrier to increasing the energy loads between regions. Capacity limits on interconnectors in the Tamworth/Armidale area (275 kV lines), the Lismore area (132 kV lines) and Mudgeeraba & Mullumbimby areas (110 kV lines) make expansion of generating facilities in Queensland for the purpose of supplying New South Wales less feasible. [37] These energy imports will have a greater risk of being 'constrained off' due to failures in existing infrastructure. New South Wales can import a maximum load from Queensland at any point in time of approximately 1300 MWe and from Victoria (via the Snowy Hydro interconnector) of approximately 1100 MWe. [38] Accurate forecasting of demand is required to ensure that supply and cost is not affected by these infrastructure limitations.[39]

Given the stae's above OECD average carbon emissions, and the pressing need to diversify its energy portfolio, it is necessary to strongly consider alternative, low carbon emitting options for the replacement of existing, and installation of new generating capacity.

The Australian government has set a Renewable Energy Target of generating 20 % of Australia's electricity using renewable technology by 2020.[40] No country is known to

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[34] AEMO (2011) *Electricity Statement of Opportunities.*
[35] DRET (2011)
[36] ACIL Tasman (2009) *Fuel resource, new entry and generation costs in the NEM.*
[37] AEMO (2011) *Interconnector Quarterly Performance Report.*
[38] Ibid
[39] DRET (2011) *Energy in Australia 2011*
[40] Department of Climate Change and Energy Efficiency (DCCEE) (2011) *Renewable Energy Target*. Accessed 1 February 2012: http://www.climatechange.gov.au/government/initiatives/renewable-target.aspx

have demonstrated renewable generation for base load power with the exception of hydroelectricity, which is at, or near capacity in Australia. Low efficiencies and intermittent generation from wind and solar remain problematic. It is not generally known by most policy makers that intermittent supply has to be fully backed up with an alternative. In Australia this is usually a gas plant maintained as a “spinning reserve”. In Europe, for example wind intermittency is backed up by hydro and nuclear plants. A key principle in energy security is fit-for-service (FFS) base load supply, as discussed in section 6 above. In the current mix fossil fuels (coal and gas) and hydro provide this base load. Of these hydro is low carbon. Wind and solar have not been demonstrated in mature cost effective technologies to be FFS.

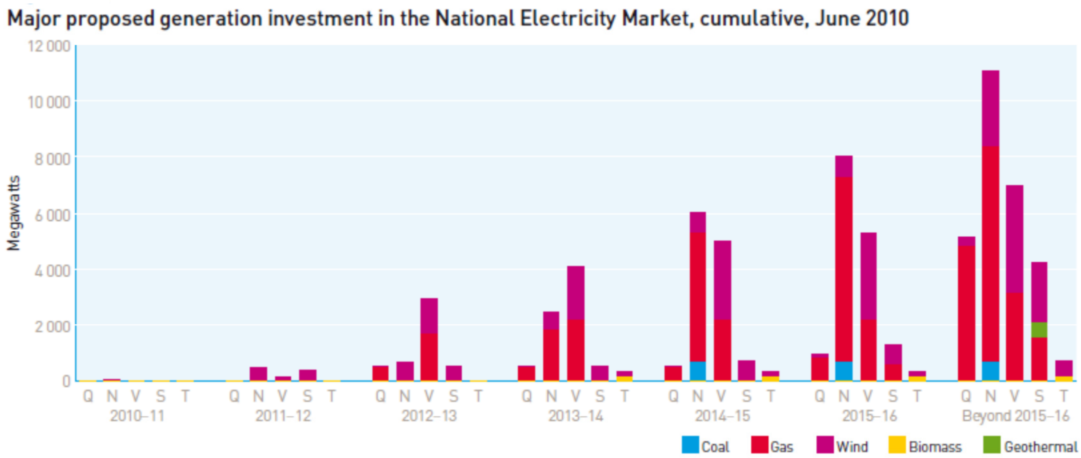
As New South Wales moves towards a low carbon economy, a diversified mix of energy technologies will be needed to ensure energy supply is continuous and reliable.

Reliability of supply refers to the capacity of the generating technology to consistently meet base load demand and service a portion of intermediate demand. Those technologies with high capacity factors and able to operate independent of seasonal influences are considered suitable for base load supply. Gas fired, coal fired, nuclear and hydro power plants are all examples of widely implemented FFS base load supply technologies.

Peak demand fluctuates and is dependent on seasonal variations in heating and cooling. Solar and wind power are notionally operated “continually” but are only able to generate electricity cyclicly, influenced by climatic conditions, resulting in poor overall capacity factors. Electricity generated from these sources is able to augment the base load supply but cannot be relied on to meet peak demand.

7.3 Future investment strategy

The graph below[41] clearly indicates that the proposed future generation investment strategy for NSW (indicated as N in the legend) is heavily biased towards gas and wind. The options and economics are explored below.



Source: AEMO.

8 The options

Coal-fired generators are not considered in this report as the Terms of Reference indicate an examination of alternative energy sources is required. As such, natural gas, hydroelectricity, wind and nuclear power are discussed.

8.1 Natural gas

8.1.1 Combined Cycle Gas Turbine in base-load

Combined Cycle Gas Turbines (CCGT) are widely employed domestically and internationally as a base load electricity supplier. Queensland, Western Australia and South Australia all have large existing operations for CCGT generation accounting for 70 %[42] of Australia's CCGT capacity. The ability to add turbine 'blocks' to upscale the size of generation output and capacity factors of approximately 90 % make CCGT an attractive base load supply alternative. Carbon emissions will form a key aspect of decision making with respect to future electricity generation and CCGT on average emits up to 400 kg of CO_2 / MWe output.[43] A US Energy Information Administration report estimated that the levelised cost of electricity generation from CCGT turbines is US$18 / MWeh.[44] To reduce the carbon emissions from CCGT turbines a Carbon Capture and Storage (CCS) system must be installed which escalates the cost to US$35 / MWeh.[45] Due to the continuous nature of CCGT operation, the costs associated with fuel use are lower than Open Cycle Gas Turbines (OCGT). Despite

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[41] Australian Energy Regulator *State of the Energy Market 2010*, p41
[42] DRET (2011) *Energy in Australia 2011.*
[43] Ibid
[44] US Energy Information Administration (EIA) (2010) *Annual Energy Outlook 2011.*
[45] Ibid

this, fuel costs account for 60 – 85%[46] of total generation costs. This makes the economic viability of CCGT vulnerable to gas price fluctuations and supply reliability. With significant increases in demand for Liquefied Natural Gas (LNG) exports, the price of domestically supplied gas may be determined by foreign market forces.

8.1.2 Open Cycle Gas Turbine for peaking

OCGT is a peak demand supply technology that usually accompanies the construction of a CCGT plant, but remains on stand-by for periods of increased demand. Queensland, Western Australia and South Australia account for 65 % of Australia's installed capacity of OCGT generation.[47] Due to the nature of OCGT generation – single turbine with no ability to capture exhaust heat – the capacity factor for this technology is lower 30 % compared to CCGT.[48] The levelised cost of electricity generation from OCGT turbines has been estimated at US$46 / MWeh. The lower efficiency of OCGT leads to an estimated emissions rate of 550 kg of CO_2 / MWeh.[49] OCGT generators can be retrospectively converted to CCGT if demand is forecasted to remain at a consistently higher level. However, OCGT's are designed for their duty cycle and not for continuous operation meaning a conversion to CCGT would result in a series of sub-optimal generators.[50] The fuel supply and pricing shock influences on economic viability for OCGT mirror that of CCGT.

8.1.3 Reducing the carbon footprint of gas

Carbon capture and storage (CCS) technology offers the prospect of lowering CO_2 emissions from existing fossil fuel based energy production. However, the technology is yet to be proven, except in specific applications. Backward integration of CCS technology into existing plants remains a significant challenge. In the US a CCS status report revealed that without significant government incentive schemes and support, installation of CCS with power plants is unlikely.[51] Further, CCS fails to remove various other pollutants produced by the burning of fossil fuels. CCS also fails to address the lack of diversity of energy supply in NSW.

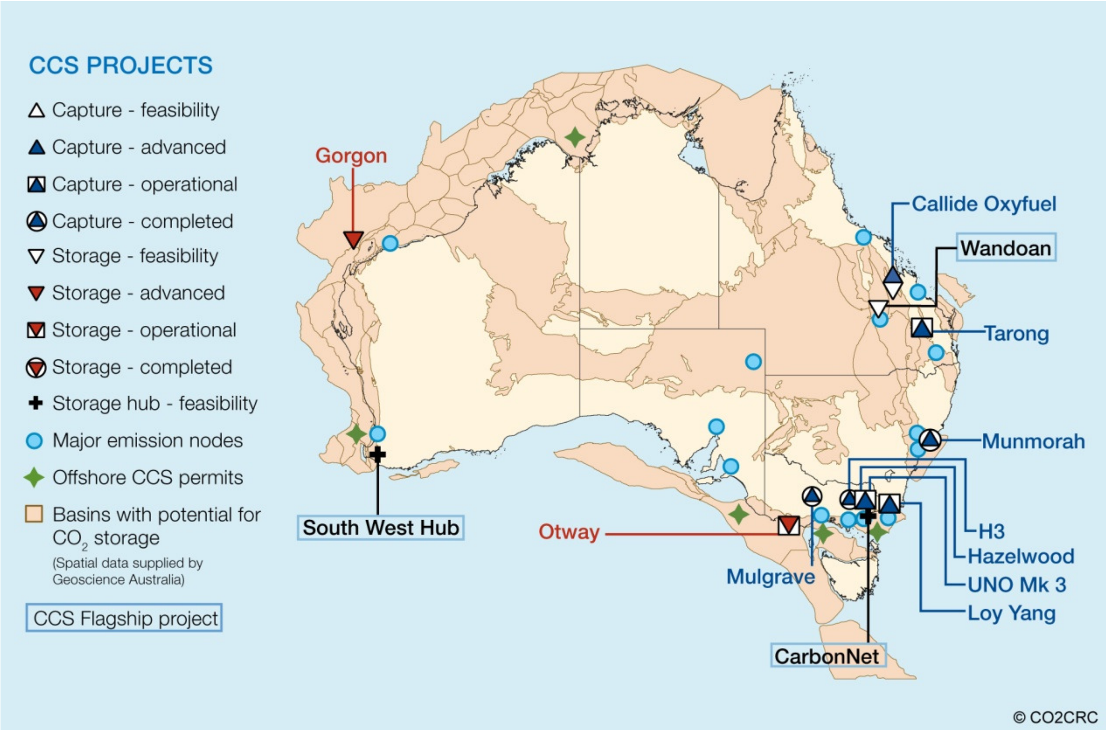
At present, no large scale commercial CCS operations exist in Australia – see figure 5, with overseas CCS operations focused on industrial applications rather than power generation.[52] However, a number of pilot scale projects are ongoing, including the Cooperative Research Centre (CRC) for Greenhouse Gas Technologies'(GGT) CO_2CRC Otway Project. The Otway Project is the world's largest research and geosequestration demonstration project.[53]

The results of this and other studies underway across Australia will provide a greater understanding of CCS technology, and whether it is able to provide solutions to the

[46] Connell Wagner (2007) *New South Wales Power Generation and CO_2 Emissions Reduction Technology Options.*
[47] DRET (2011)
[48] US EIA (2010)
[49] International Energy Agency (2010) *Gas-Fired Power.*
[50] Connell Wagner (2007)
[51] Global CCS Institute (2011) *The Global Status of CCS: 2011.*
[52] Ibid
[53] CRCGGT (2011) *CO_2CRC Otway Project*. Accessed 31 January 2012: http://www.co2crc.com.au/otway/

problem of emissions from energy production. In any event these technologies can be considered to be technically immature and of uncertain cost for planning initiated in this decade.

Figure 5: Current and Proposed CCS Projects in Australia[54]



8.2 Hydroelectricity

In 2009-10, 5.6 % of electricity generated for the NEM was generated by hydroelectric plants.[55] However, given the substantial environmental impact of large dams and the lack of suitable areas for development, expansion of hydroelectricity production in New South Wales is unlikely.[56] Hydroelectricity is also disqualified as a FFS baseload option in Australia due to poor scalability and a low capacity factor.[57]

[54] CO_2CRC (2011). Accessed 30 January 2012: http://www.co2crc.com.au/images/imagelibrary/gen_diag/AusMapProjects_2012_v5.jpg
[55] ESAA (2011), p. 9
[56] Roarty, M. (2000); *Renewable Energy Used for Electricity Generation in Australia,* Science, Technology, Environment and Resources Group. Accessed 31 January 2012: http://www.aph.gov.au/library/Pubs/rp/2000-01/01RP08.htm#therenew
[57] Nicholson M, et al., How carbon pricing changes the relative competitiveness of low-carbon baseload generating technologies, Energy (2010), doi:10.1016/j.energy.2010.10.039

8.3 Wind

At present, Capital Wind Farm, near Bungendore in the state's south east, is the state's largest wind farm by generating capacity. The installed generating capacity of the 67 turbines at Capital Wind Farm totals 140.7 MWe.[58]

As wind is an intermittent resource, wind farms will not generate at full capacity. An estimate of the levelised cost of generation with wind power was given at US$84 / MWeh[59] for on-shore farms and US$210 / MWeh[60] for off-shore farms. Capital Wind Farm's operator, Infigen Energy, quotes a capacity factor for the farm of 36 %.[61] However, an analysis of the farm's output by windfarmperformance.info using data provided by AEMO indicates that the farm's capacity factor for 2010 was 26.7%.[62] That is, in 2010, Capital Wind Farm averaged an output of 37.6 MWe.

A major expansion of wind power in the state is already underway. According to New South Wales Trade & Investment, wind farm projects with development approval are predicted to add an additional 2,419 – 2,439 MWe of installed (nameplate) wind capacity.[63] The biggest of these by installed capacity will be the Silverton Wind Farm at Broken Hill, which will have a nameplate capacity of 1,000 MWe.[64]

However, as evidenced by the state's largest wind farm to date, wind power is intermittent. "Spinning reserve" gas plants or diversion of hydro baseload is required to provide a reliable service. The effect of this situation is well understood in the global setting. Countries with high wind penetration have higher costs than countries that depend on FFS low carbon sources such as hydro and nuclear. Wind investments will tend to increase consumer electricity costs relative to trading partners who opt for FFS options.

8.4 Nuclear

Like renewable technologies, nuclear technology is constantly developing. Concerted international effort on design of future Generation IV fission plants promises to produce safer and more efficient designs than previously available. Despite the impact of the Fukushima accident, construction of new nuclear plants is continuing around the world. In our immediate region, China, India, South Korea, Taiwan, and Vietnam are continuing to increase installed nuclear capacity through the construction of new plants. China has twenty-six nuclear power reactors under construction, India has six,

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58 Infigen Energy (2011) *Renewable Power Ventures*. Accessed 31 January 2012: http://www.infigenenergy.com/rpv.html
59 EIA (2010)
60 Ibid
61 Infigen Energy (2011)
62 Miskelly, A. (2012) *Wind Farm Performance* Accessed 31 January 2012: http://windfarmperformance.info/
Data for *Wind Farm Performance* calculations sourced from AEMO (2010) *NEXT_DAY_ACTUAL_GEN series*. Accessed 31 January 2012: http://neMWeeb.com.au/Reports/ARCHIVE/Next_Day_Actual_Gen/
63 NSW Trade and Investment (2011) *Electricity Generation*
64 Ibid

South Korea has five, and Taiwan has two.[65] Vietnam has signed contracts with Russia and Japan to be provided with four new reactors by 2022.[66]

In Australia, the hurdles to nuclear development are social, political, legislative, and economic, rather than technological. Being the world's largest exporter of coal, Australia has had, to date, little economic incentive for nuclear power investment. This could change with the implementation of carbon abatement policies across federal and state jurisdictions.

According to the Prime Minister's *Uranium Mining, Processing and Nuclear Energy Report* (UMPNER) from 2006, nuclear power would become economically competitive with conventional coal-based electricity at low to moderate prices for carbon dioxide emissions – at approximately A$15-40/t CO_2-e.[67] This is dependent on investors' perception of risk, and the specific technology employed. The federal "carbon price" to be introduced 1 July 2012 will be fixed at A$23/t CO_2-e for the first three years of operation. This falls within the range which UMPNER described as producing an economic environment in which nuclear can compete with fossil fuels.

A single nuclear power plant in New South Wales would be a relatively large investment for existing utility companies. . In general global experience has shown that nuclear plants become more economical in aggregate if a larger number of plants are built and operated.

In terms of economic optionality, nuclear plants have high capital costs and very low operating costs. This has provided a massive advantage to countries that built plants in the 1970s and early 1980s which are now undergoing power uprates and lifetime extensions. The incremental cost of capital does not impact the already low cost of electricity produced. For this reason South Korea, France and the United States currently enjoy a lower cost of electricity (domestic and industrial) than New South Wales.

Nuclear energy is cheaper to generate than most renewable sources and benefits from low price sensitivity to fuel variations. With increasing exposure of NSW's fossil fuel resources to growing demand in the region, the stability of nuclear power pricing make it attractive for achieving overall energy security.

Australia is the world's third largest producer of uranium, and therefore an Australian nuclear power industry could maintain a secure and reliable local source of nuclear fuel should the industry become further developed. . The, the UMPNER Report concluded that "*the challenges associated with the required investment levels and access to enrichment technology are very significant*."[68] Any development of enrichment facilities would face significant geopolitical and economic barriers.

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[65] IAEA (2012) *Nuclear Power Plants Information: Under Construction reactors by Country.* Accessed 31 January 2012: http://www.iaea.org/cgi-bin/db.page.pl/pris.reaucct.htm
[66] World Nuclear Association (2012) *Nuclear Power in Vietnam.* Accessed 31 January 2012: http://world-nuclear.org/info/vietnam_inf131.html
[67] Department of the Prime Minister and Cabinet (DPMC) (2006) *Uranium Mining, Processing and Nuclear Energy – Opportunities for Australia?* p. 55. Accessed 31 January 2012: http://www.ansto.gov.au/__data/assets/pdf_file/0005/38975/Umpner_report_2006.pdf
[68] DPMC (2006) p. 33.

However, even without the development of local processing capabilities, the energy density of uranium means that it is easy to accumulate sufficient stocks of fuel to provide energy security.

8.4.1 Nuclear power technology is mature and widely implemented

Nuclear power has been providing electricity since the 1950s. According to the International Atomic Energy Agency (IAEA), 30 countries worldwide are currently operating 435 nuclear reactors for the purpose of electricity generation.[69] A further 63 new nuclear power plants are under construction in 14 countries.[70]

The United States possess the largest nuclear power capacity, with 101.2 GW installed.[71] In regards to adequacy of energy supply, one need look no further than France, the world's fifth largest economy, with 74.1 % of its electricity supply sourced from nuclear power reactors.[72]

In terms of reliability, global average availability of nuclear power currently stands at approximately 83 %, although three countries (the Netherlands, Slovenia and Finland) achieve more than 95 % availability, with another six countries achieving more than 90%. [73]

Between 1990 and 2004, 57 % of the growth in nuclear output was not from building new reactors, but from increasing availability of existing reactors and power uprates.[74]

In terms of affordability, while nuclear power involves very high capital costs, in established nuclear markets, operational and maintenance costs are very low. In addition, the price of nuclear power is very stable when compared to power generated by fossil fuels, due to the low price sensitivity associated with the uranium fuel.

Most significantly, nuclear power is a mature technology – it has a proven track record in many countries around the world, including the leading economies. North America and Europe lead the world in the use of nuclear power in terms of proportion of primary energy consumption. This is reflected in the comparison of primary energy consumption between OECD and non-OECD countries. The use of nuclear, with its high capital costs and requirement for advanced technological expertise is largely confined to the OECD, BRIC (Brazil, Russia, India & China) and former Soviet states.[75]

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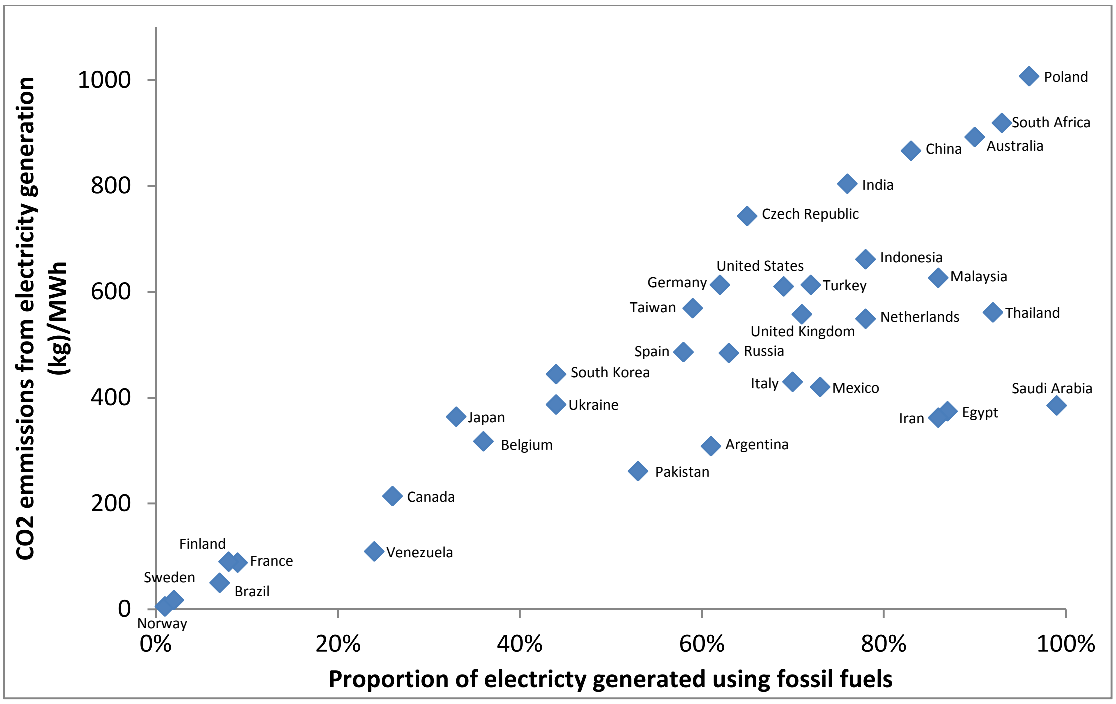
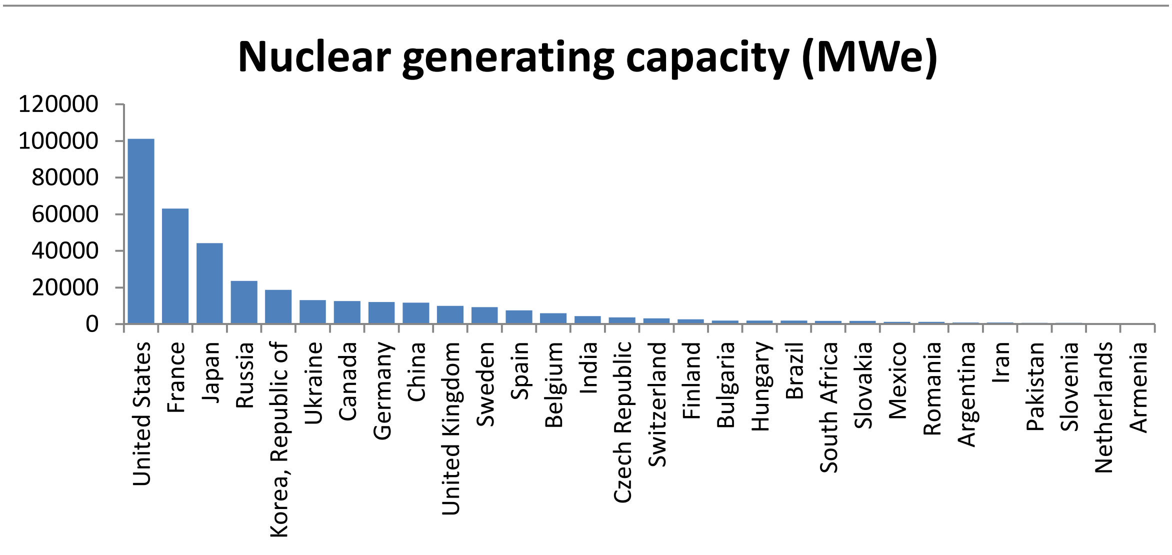
[69] IAEA (2012) *Power Reactor Information System.* Accessed 30 January 2012: http://www.iaea.org/programmes/a2/index.html
[70] Ibid
[71] Ibid
[72] Nuclear Energy Institute (2011) *World Statistics*. Accessed 30 January 2012: http://www.nei.org/resourcesandstats/nuclear_statistics/worldstatistics/
[73] OECD Nuclear Energy Agency (2007) *Nuclear Energy Data*
[74] OECD Nuclear Energy Agency (2008) Nuclear Energy Outlook
[75] BRIC refers to the emerging economies of Brazil, Russia, India and China, all of whom operate nuclear power reactors

Figure 6: The relationship between fossil fuel electricity generation and CO_2 emissions, 2007



Of the 34 OECD countries, 18 operate nuclear power reactors.[76] Only four of the remaining 16 do not import electricity produced in jurisdictions operating nuclear power reactors – Australia, Iceland, Israel, and New Zealand.

Figure 7: Nuclear generating capacity of all countries operating nuclear power reactors[77]



Internationally, efforts are underway to further improve the standards of nuclear power generation technology. The International Framework for Nuclear Energy Cooperation (IFNEC) and the Generation IV International Forum (GIF) are two

[76] IAEA (2012)
[77] Ibid

international programs aiming at developing future technologies that directly address issues such as efficiency, waste generation, health and safety and non-proliferation. Although it is unlikely to be a reality until at least 2030, the development of Generation IV reactors has the potential to greatly extend the lifetime of fuel deposits, increase energy output and offer greater proliferation and physical protection capability. Most reactors currently in operation are Generation II light water reactors, with most new reactors to be Generation III or Generation III+ (there are currently four Generation III+ reactors under construction).[78] While not available now, advances in nuclear power technology will further improve the viability of nuclear within a diverse energy mix.

8.4.2 Public Concerns

The nuclear power debate in Australia can best be described as a political issue rather than a technological, economic or resource issue. The success of any nuclear power industry within Australia will depend on acceptance by the general public. Nuclear power remains a sensitive topic within many sections of the community. Research conducted by the OECD Nuclear Energy Agency indicates that acceptance of nuclear power increases proportionally with knowledge and experience of the industry. [79] The problem is lack of knowledge and engagement with community stakeholders.

Despite strong anti-nuclear sentiment within Australia, there are signs that the general public are willing to discuss the possibility of nuclear development as part of a rational debate into the enrgy mix. A McNair Gallup poll from 2007 indicated that support for nuclear power had increased to 41 %, up from 34 % in a similar poll in 1979.[80] Opposition had also decreased from 56 % to 53 %. Even at the height of the Fukushima accident, in April 2011, a poll conducted by the Lowy Institute for International Policy indicated that 35 % of Australians continued to support the local development of nuclear power.[81]

Several key events can be identified as having contributed to the development of Australian society's attitude to nuclear power. These events include the nuclear weapons testing at Maralinga/Emu Field in the 1950s; the Ranger Uranium enquiry in the 1970s; the decision made in the early 1980s to restrict uranium mining; continued nuclear weapons testing in the South Pacific in the 1980s and 1990s; and the Three Mile Island and Chernobyl accidents, in 1979 and 1986 respectively. We can now add to this list the ongoing situation in Fukushima. Discussions of the nuclear industry in Australia are invariably framed within the context of these events, whether accurate or specific details are known or not, and irrespective of technological progress since they occurred.

Australia maintains and continues to develop a strong relationship with uranium mining, but personal interaction with any form of nuclear industry, particularly in the eastern states, remains distant and infrequent aside from international news media and popular fiction.

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[78] OECD Nuclear Energy Agency (2008) Nuclear Energy Outlook
[79] Ibid
[80] McNair Ingenuity Research (2007) Support for Nuclear Power in Australia
[81] Lowy Institute for International Policy (2011) *Australia and the World: Public Opinion and Foreign Policy*

The climate change issue has meant nuclear power has returned into policy debates. A number of key environmental opinion leaders have publicly reconsidered deeply held attitudes against nuclear power in light of the need to reduce greenhouse gas emissions. Adverse reaction to the Fukushima accident has not been insignificant, but major policy shifts have been limited to few countries. In countries like the US, UK and France, governments have maintained strong support for their local nuclear industries. There, governments recognise that nuclear power provides domestic energy security in the present situation of rising oil and coal prices, with the added benefit of negligible carbon emissions.

9 Conclusion

A more diverse combination of traditional technologies, such as advanced coal and gas, and mature alternative technologies, such as nuclear and wind, would form a secure and reliable energy mix for New South Wales.. Developing technologies with few medium-large scale operations in Australia, such as geothermal and tidal, should also be the subject of further research and development. Current development operations in other jurisdictions, such as the geothermal pilot projects in South Australia, should be monitored for future results.

Technologies that allow reliable base load supply with a reduced greenhouse gas output can secure a large portion of the state's energy mix. With the adoption of a price on carbon emissions, advanced technologies will become more economically competitive.

While difficult to effectively retrofit to power stations at present, CCS is a promising technology for lowering emissions on a large scale as evidenced in its use in industrial processes globally. Generation III nuclear reactors are also capable of providing a reliable, low cost base load supply, with significantly reduced emissions.

To meet peak fluctuations and supply smaller scale operations/communities, the more established renewable technologies can be implemented. Capacity factor limitations and transmission inefficiencies associated with photovoltaic and wind power make their application most suitable for a distributed supply network. Further, to successfully integrate these into the NEM grid, forecasting of base load and peak should t be consistently accurate, with the intermittent nature of the technologies not allowing for on-demand generation.

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1. Current trends in global and domestic energy demand and consumption are expected to continue. These rates of increase are, however, unsustainable, and threaten both security of energy supply and climate stability.
2. A secure energy supply is characterised by good adequacy, reliability and affordability. It should also be environmentally sustainable, and have minimal adverse health effects. This is best achieved through the use of a diverse mix of low carbon and low pollution energy sources.

3. Most developed economies and a number of developing economies include nuclear power in their long-term energy security strategy. Australia is one of very few OECD countries not utilising nuclear power.
4. All OECD countries (except Australia, New Zealand and Iceland) that do not have nuclear power can and do import nuclear power from contiguous economies that have nuclear power. Australia will not have this option available to it – a significant negative for energy security, if the intention is to remain a leading economy.
5. New South Wales currently relies almost exclusively on fossil fuels,especially coal, for its electricity supply. This lack of diversity and current dependence on sources with high greenhouse gas emissions makes the state's future energy supply inherently insecure and without the flexibility of both optionality and diversity. NSW total cost of energy supply becomes more vulnerable when a price on carbon dioxide emissions is introduced.
6. The current policy of pursuing clean coal and renewables is a necessary but not necessarily a sufficient strategy in the light of the not insignificant climate change challenge. Renewables cannot yet provide early or proven solutions to the problems New South Wales faces. Affordable clean coal being available in a short time frame is not supported by the science, or the technological maturity of the technologies, or the required regulatory assurance. The assumptions that underpin policy optimism in this regard cannot be sustained. A balanced consideration of worldwide evidence is that clean coal will not be economical in the required timeframe.
7. Nuclear power generation is a mature, proven technology that has provided base load power in a number of countries for 50 years. It has a number of advantages such as fuel price stability, low operating costs, low emissions and waste volume and, for New South Wales in particular, a secure fuel supply. Nuclear power has much to offer in the way of achieving a diverse energy mix, and thus, contributing to medium to long term energy security.
8. The nuclear power industry in the developed world is the only electricity generator that currently pays for its full lifecycle costs, including the cost of managing the waste it produces.
9. Nuclear power merits serious consideration as part of the energy mix options for the state. The consideration should be based on a full evidence-based examination of the available technology along with a range of other technologies using established levelised cost analysis and properly pricing carbon within the analysis and the attendant consideration of the safety of third generation nuclear plants.
10. Despite its maturity, it is clearly recognised that there a number of important public concerns raised about nuclear, including waste, proliferation and safety. These issues have been extensively examined in many countries and by many studies.
11. Active public engagement, transparent, clear and factual information and engaged debate have been shown in other countries to significantly allay public concerns. Independent, strong regulators are also seen to be key to public confidence.
12. Concerns are also raised about the cost of nuclear power, due to its requirement for high initial capital investment. This requires special funding mechanisms and government support to reduce the risks from delays and provide incentives for investment. This is no different to the support given to

other forms of energy production. Nevertheless, appropriate accounting for greenhouse gas and other emissions has made nuclear a competitive option in relation to existing coal and natural gas plants and a much better low carbon source.

13. While there are a number of ways to provide a secure and diverse energy mix for New South Wales, all will require reducing reliance on current fossil fuel technologies, and nuclear power, in combination with renewable energy technologies, satisfies the criteria for being considered a key technology.
14. New South Wales energy security from a trade and economic point of view could be at risk if all options are not actively considered. This is significant given the future cost of carbon is not known and all current renewable options are intermittent low power density sources that cannot be relied on for energy intensive processes such as transport and logistics infrastructure, national defence facilities/deployment, and economic extraction of natural resources, which form the bulk of our trading income.