Global Change Institute

The University Of Queensland
AUSTRALIA

Meeting the challenge of change

DELIVERING A COMPETITIVE AUSTRALIAN POWER SYSTEM

Part 1: Australia's global position
November 2011

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Historically Australia’s ample supply of coal has underpinned its power system. Competing countries however have used a variety of different energy sources and, as a result of this diversity, many have a more resilient power system to provide future electrical power.

This report looks at Australia’s global position with respect to itsresource-rich competitors.

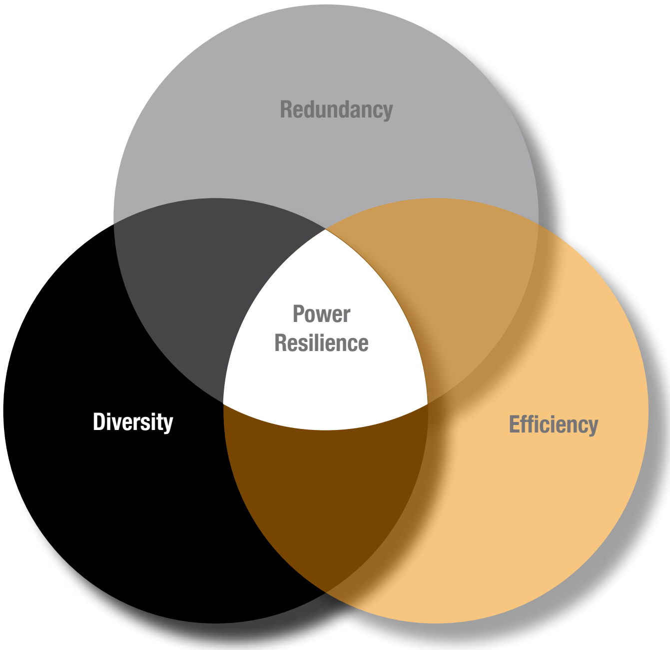


TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 OBJECTIVES AND KEY MESSAGES

Australia's dominant energy supply resource has historically defined the structure of its stationary power generation and consumption. A plentiful local energy resource supply by way of coal has underpinned the international competitiveness of Australia's power system, bringing investment, particularly in power intensive industries. Competing countries with scarce energy resources and vulnerable to international energy markets have had to adapt by investing in efficiency, technology and diversification throughout the energy transformation chain to meet demand. These investments have prepared them for a future where fossil-fuel based primary energy supply may be constrained and/or global environmental policies may constrain or force adaptation of the power system and power intensive industries.

In a three step process we will provide a series of papers entitled "Delivering a Competitive Australian Power System."

- In stage one, we analyse Australia's current global position with respect to its resource rich competitors.
- In stage two we will seek to establish a target position in 2035 for the Australian power economy to remain competitive.
- In stage three we will examine the possible routes to reach the target position.

Traditionally power economy analysis has been conducted on a detailed, bottom up approach based on complex, regional, supply and demand projections. This analysis seeks to deviate from bottom up analysis to provide a strategic, national (top down) analysis of the power economy over long time frames.

To do this we have compared the Australian power economy, not to other OECD countries, but to countries that also have natural resources for sale on the global market; but importantly resources that need to be processed using significant amounts of power.

In 2008, metals processing and fabrication in Australia:

- consumed 27% of Australian power,
- employed 151,000 people, and
- contributed 2% to GDP.

so it

- represents the biggest sector for the power economy,
- is an important contributor to the economy as a whole, and
- can be used as an indicator of power economy performance.

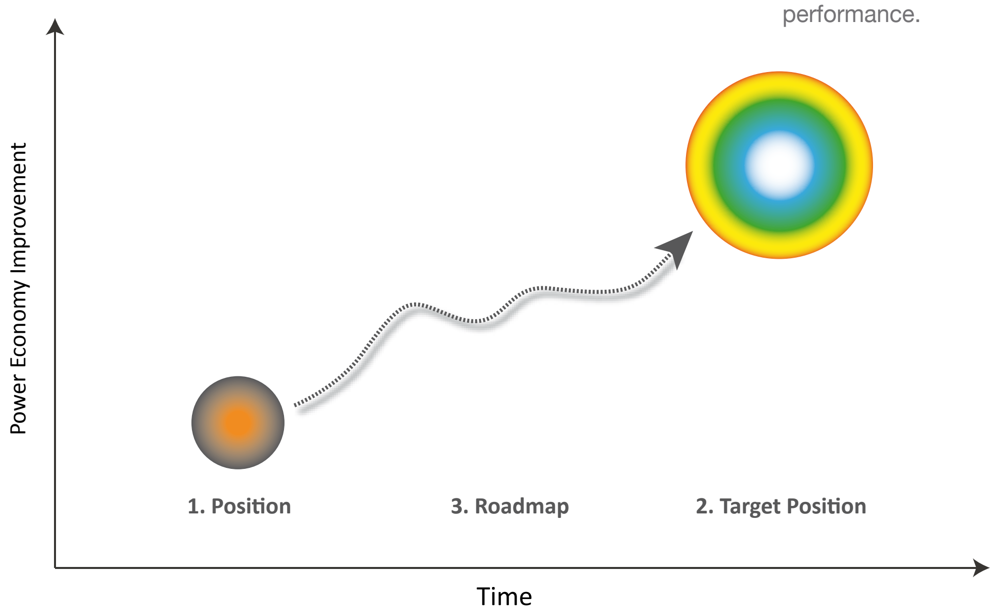


FIGURE 1: DELIVERING A COMPETITIVE POWER SYSTEM: THE THREE STAGES

To assist in the complex analysis, we define and construct a holistic parameter we term the "Power Economy Resilience Index." This index allows us to compare in a systematic and rational way the efficiency, diversity and security of national power systems. The Power Economy Resilience Index also allows us to consider Australia's future position with respect to its competitors.

The key findings of this first report are:-

- In most cases a country's power economy reflects its historic inheritance in terms of local natural resources. However, some countries have experienced problems as a result of insufficient supply which have caused them to diversify and enhance their infrastructure leading to greater resilience.
- For good reasons, Australia has historically sought competitive advantage for its power economy by harnessing its abundant supply of coal for power generation, which attracted substantial investment in power hungry metals processing industries like aluminium, which in turn part funded power infrastructure for future decades.
- Since 1990 though, Australia has shed 53,000 jobs from the metals processing and fabrication sector and lost global market share in metals processing, to countries with more resilient power economies.
- With increased global demand for energy and concerns over carbon emissions, Australia's power system now presents a risk to current consumers and future investors because of its fossil fuel reliance.
- Australia has one of the least resilient power economies of any of its global competitors and the step-changes required to improve this are not in evidence.

The consequences of these findings are:

1. Australia could continue to lose market share and shed jobs from the metals processing and fabrication industry to our resource rich competitors, and
2. Australian electricity users could experience large increases in price as a result of a lack of resilience.

To avoid these consequences, transformation of the power economy is not merely a desired, but a necessary, condition for the continued economic and social prosperity of this country.

2 THE AUSTRALIAN ECONOMY TODAY

With its wealth of natural resources and resilient economy, Australia considers itself to be the "lucky country". Between 1990 and 2008 real GDP has grown by a yearly average of 3.4% fed by mean yearly real export growth of 5.3%. Vast deposits of mineral resources: 19% of the world's bauxite reserves, 17% of the world's iron ore reserves, 13% of the world's copper reserves and 12% of the world's gold reserves, have boosted exports and generated wealth for development and stability.

Whilst Australia has increased its copper and iron ore mining ahead of the global average, its performance on the processing of copper, iron and aluminium is less stellar. Copper and steel production has been virtually stagnant since 1990, with aluminium production growing but lagging behind world production growth. It would be reasonable to expect Australia to lose market share to developing countries in labour intensive industries, but it is less reasonable to see reduced market shares in capital intensive industries with predominantly export outputs. Is Australia utilising its metal[1] ores and other mineral resources to build a robust power economy?

Securing energy intensive industry investment however requires a reliable, affordable electricity backbone. As a developed country, Australia would be expected to satisfy this requirement but an analysis of other countries' electricity backbones will provide clues as to the competitiveness or otherwise of Australia's power economy.

2.1 COMPARING AUSTRALIA'S ECONOMIC PERFORMANCE TO RESOURCE-RICH COMPETITORS

To establish whether Australia's economic resilience is a matter of luck or design, it is helpful to compare its performance over the last 18 years with countries that have similar natural resource wealth. We will compare the performance of Brazil, Canada, Chile, China, India, Russia[2] , South Africa and the United States to understand how they have fared over the same period. Whilst many countries experienced a rocky start

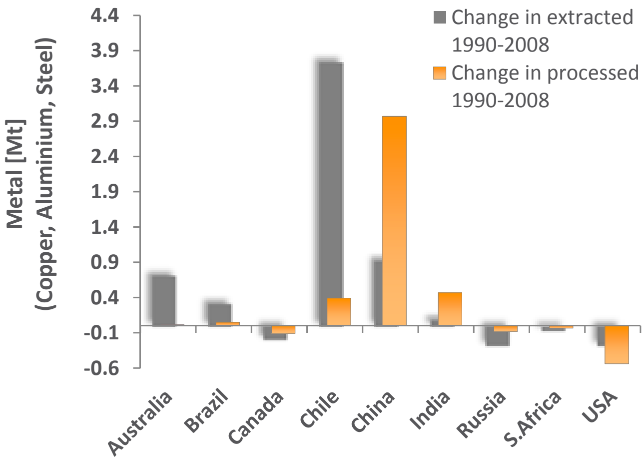


FIGURE 2: METALS MINING AND PROCESSING

Source: (USGS 2011)

Country	Bauxite	Iron Ore	Copper
Australia	2.6%	0.3%	0.2%
Brazil	3.3%	2.2%	1.0%
Canada	3.8%	-0.3%	-1.2%
Chile	-	3.2%	0.8%
China	16.6%	11.3%	6.0%
India	6.3%	7.8%	5.8%
Russia	1.0%	-4.9%	0.1%
South Africa	9.8%	-0.7%	-1.7%
United States	-2.3%	-0.4%	-1.9%
World	4.0%	2.5%	1.1%

TABLE 1: ANNUAL GROWTH IN METAL REFINING 1990-2008

Source: (USGS 2011)

[1] We look at metal ores rather than all mineral resources because we are comparing the performances of the energy-intensive metals processing sector

to the 1990s, Brazil, India and Russia may have had higher levels of turmoil, but they have recovered to end the period with strong growth. China, India and Chile would appear to be the stand-out performers in the group, while Canada and the US lagged in 2008 as a result of the Global Financial Crisis. Export growth tracks consistently above each country's GDP growth, underpinning GDP performance.

A trend towards decreased labour intensity has not increased unemployment, but there has been a shift away from manufacturing (high employment) to mining (low employment) and the financial intermediation sector (medium employment). To illustrate, in 1990 1.2 million people (15% of the work force) were employed in the manufacturing sector earning revenue of AU$74 thousand per person ($2008), but that shrunk to 1.1 million people (10% of the work force) and AU$99 thousand per person ($2008) in 2008. Conversely, mining employment has increased from 89,000 in 1990 (1% of the work force) to 133,000 in 2008 (still 1% of the work force) with a GDP contribution of AU$673 thousand per person ($2008).

By comparison Brazil, Chile and South Africa have increased their manufacturing employment while Russia and the US have decreased it although all countries[3] (except Russia) show a trend to decreasing labour intensity, in particular a shift of employment away from agriculture.

At US$47,890 per person in 2008, Australia has the highest GDP per capita of the competitor countries identified. This represents an annual increase of 2.1% since 1990. China's GDP/person grew by 9.6% per annum, India's by 4.47%, Chile's GDP by 4%, Brazil's by 2.72% and Russia's by 2.28% over the same period so Australia was at the lower end of GDP per capita growth. Competition from China and India, where GDPs/person are US$3,400 and US$1,070 per person respectively, is fierce as they seek to win global production capacity through substantially lower labour costs. To remain competitive, Australia will need to offer technological superiority to counteract its higher labour costs.

	GDP Growth	Export Growth
Australia	3.4%	5.3%
Brazil	3.0%	7.3%
Canada	2.6%	4.5%
Chile	5.5%	7.8%
China	10.5%	18.3%
India	6.3%	12.0%
Russia1	2.0%	4.5%
South Africa	2.9%	4.6%
United States	2.8%	5.8%

TABLE 2: AVERAGE YEARLY GROWTH (1990-2008)

Source: (IMF 2011)

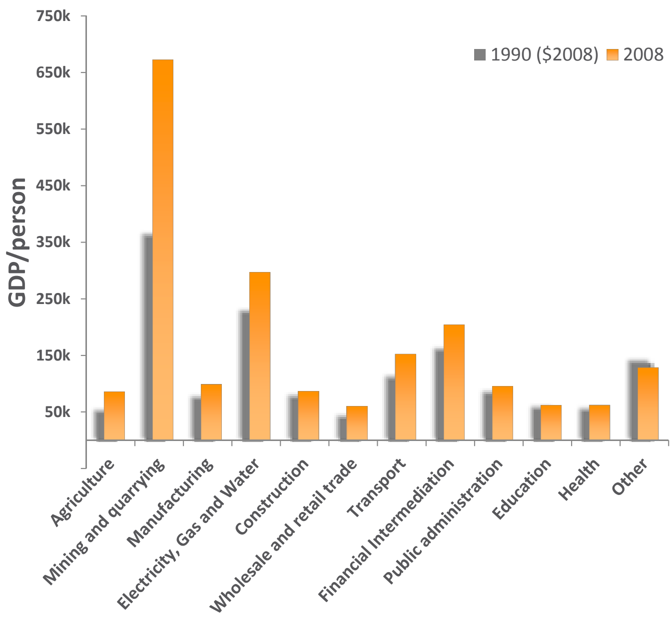


FIGURE 3: GDP PER PERSON 1990 VS. 2008

Source: (UNData 2011)

[2] Russian data is based on the period from 1992 to 2008 due to lack of data for 1990 and 1991.
[3] Employment by industry sector data is not available for China and India

2.2 COMPARING AUSTRALIA'S ENERGY CONSUMPTION TO RESOURCE-RICH COMPETITORS

Australia has increased its demand for energy between 1990 and 2008 from 5 to 6 tonnes of oil equivalent (toe) per person per year which is more than 3 times higher than the average for the rest of the world. Brazil, Chile, China and India have all grown at more than that, but their demand remains substantially lower than Australia's. All countries have reduced the energy intensity of their GDP but those reductions remain under whelming when compared to the average reduction by China, India and Russia[4].

Every country's energy use reflects its historic inheritance in terms of local natural resources. However, some countries have experienced problems as a result of insufficient supply which have caused them to diversify and enhance their infrastructure for greater security of supply.

2.3 COMPARING AUSTRALIA'S METAL RESOURCE UTILISATION TO RESOURCE-RICH COMPETITORS

When it comes to major metal deposits, Australia leads the world. India and China have modest deposits of many of the metals, and yet, perhaps because they are starting from a low base, they have shown greater export growth over the period than more resource-rich countries like Australia.

There are many reasons behind China and India's apparent robust economic performance, but activity in the metals processing industries might provide an indicator of their economic management.

The metals processing industry however requires substantial quantities of electricity at affordable prices. Australia considers itself fortunate to have deposits of coal which have underpinned a reliable, affordable electricity system. Metals processing consumed 24% of all electricity consumed in Australia in 1990 and 27% in 2008. But what has happened to our competitors

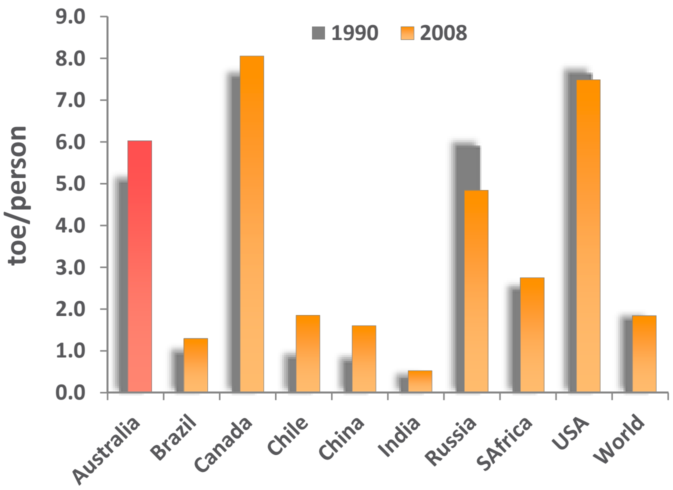


FIGURE 4: ENERGY CONSUMPTION PER CAPITA

Source: (IEA 2010), (IEA 2010)

Country	Bauxite	Iron Ore	Copper	Gold
Australia	19%	17%	13%	12%
Brazil	12%	18%	-	4%
Canada	-	3%	1%	2%
Chile	-	-	24%	4%
China	3%	8%	5%	4%
India	3%	5%	-	-
Russia	1%	16%	5%	11%
South Africa	-	1%	-	13%
United States	-	2%	6%	6%

TABLE 3: SHARE OF GLOBAL METAL DEPOSITS

Source: (USGS 2011)

[4] Russian data based on period from 1992 to 2008

over the same period[5]? Canada and Russia increased metal processing consumption to 13% and 12% of all power consumed; Brazil, South Africa and the USA have decreased metal processing consumption as a percentage of total electricity consumed, partly because commercial and residential consumption have grown proportionately more than metals processing since 1990; and China increased metals processing consumption from 12% to 20% using 607TWh more in 2008 than in 1990. That's a voracious appetite for metals processing and power by a labour-intensive country still developing its power infrastructure.

In 1998 the Productivity Commission produced a report on the impact of microeconomic reform on the aluminium industry (Productivity Commission 1998). The report included the results from a survey of firms which indicated that environmental regulations including hazardous waste, air emissions, water emissions and land rehabilitation would have a negative impact on the industry (Productivity Commission 1998). A concern with environmental constraints would go some way to explaining the loss of market share to developing countries, but any business contemplating a long-term investment in a country would have

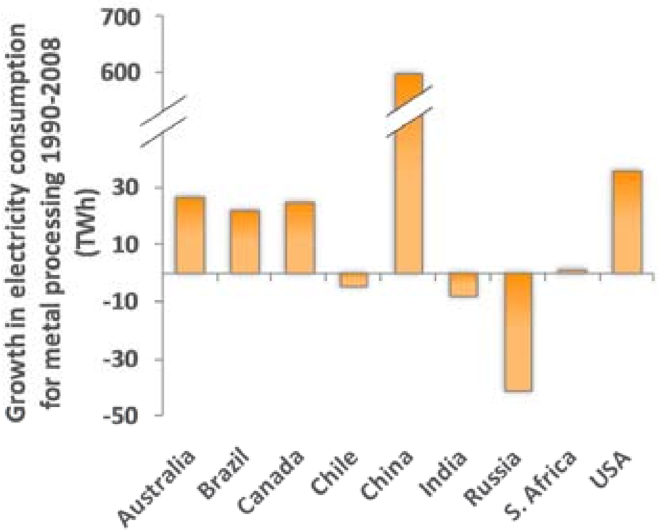


FIGURE 5: GROWTH IN ELECTRICITY CONSUMED FOR METALS PROCESSING

Source: (IEA 2010), (IEA 2010)

to consider the risk of environmental constraints re-appearing as large developing economies mature.

Despite the potential for environmental concerns, the oil shock of the 1970s and the prospect of a resources boom drove substantial investment in power infrastructure in Australia: Loy Yang in Victoria to service Alcoa's aluminium plant at Portland; Eraring, Bayswater and Mt Piper to service the expected boom in New South Wales; Gladstone, Tarong and Callide to service Queensland's projected requirements. Whilst the timing of those power stations may have initially resulted in excess capacity for the late 1980s and early 1990s, they have serviced, and continue to service, the power economy well. Although the public may have paid for at least some of that infrastructure by way of excess capacity and subsidised tariffs (Simshauser 2001), the benefit has been employment, investment and the funding of base-load power for the economy as a whole. Attracting resource-based investment to Australia has been good for the economy, increased employment and built an electricity backbone.

In summary, China is not only providing affordable labour resources for manufacturing, it is also building its electricity backbone for capital intensive industry based on Australian resources. Australia can either lose capital- and power-intensive industries to developing countries where the power systems are still being developed or it can invest in a resilient, technologically advanced and competitive power economy that makes it logical to avoid the heavy costs of transporting ores across the globe. What would energy intensive industries require from the power economy to invest in Australia?

[5] Electricity industry consumption data for India and Chile is not available or unreliable.

3 THE AUSTRALIAN POWER ECONOMY TODAY

Resilience is the ability to withstand external shocks like interruptions to the supply of fuels, policy that might seek to reduce pollution, or unexpected surges in demand. Because of the fundamental importance of electricity to the economy, the electricity system must be resilient. Measuring the resilience of a power economy is complicated, however from a high level perspective, a resilient power economy should have a mix of fuel types that are able to withstand shocks from fuel supply or emission constraints, be efficient in producing power, provide security for the economy, and be affordable. To this end, quantifiable measurements of resilience in electricity supply are: the quantity of non-renewable fuel used; the quantity of emissions produced; the diversity of the type of fuel used; the efficiency of generation, transmission and distribution; the proportion of supply external to the country; the availability of electricity for use; and price. These high level measures allow concrete comparisons without having to understand the plethora of different policies pursued by each of the competitor countries. An overview of Australia's power economy comparative[6] resilience follows in which we develop a new overall measure that we call the Resilience Index which accounts for all these first order influences (see Appendix B: Building a Resilience Index for the power economy for more detail on the index).

3.1 ENERGY MIX IN POWER GENERATION

3.1.1 Non-renewable fuel used in generation

In 2008, Australia used 284 tonnes of oil equivalent (toe) non-renewable energy per Gigawatt hour (GWh) of electricity consumed which is higher than the world usage of 210 toe/GWh. The usage of non-renewable energy has increased since 1990 when it was 258 toe/GWh. The Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), points to an ageing power generation fleet with reducing efficiencies as the probable cause of this increased usage (ABARES 2011). The increased usage also indicates a declining ability to withstand shocks from global non-renewable fuel shortages and substantial price increases in the event of constrained international supply.

Figure 6 provides a comparison of non-renewable fuel usage in electricity consumption between the competitor countries.

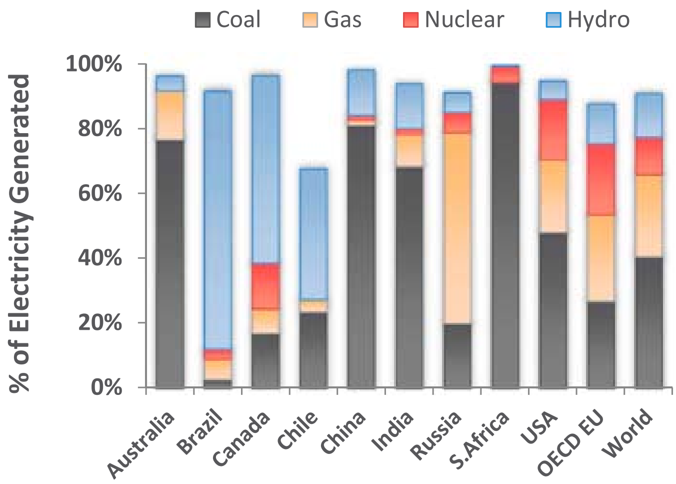


FIGURE 6: GENERATION MIX

Source: (IEA 2010), (IEA 2010)

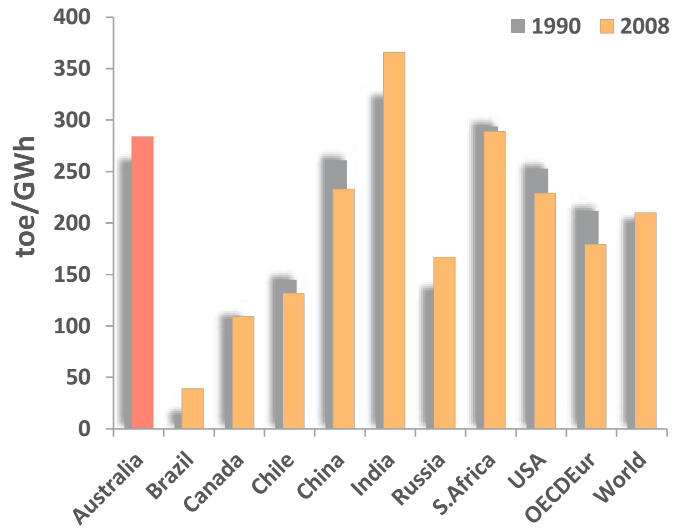


FIGURE 7: NON RENEWABLE ENERGY USE FOR ELECTRICITY CONSUMPTION

Source: (IEA 2010)

[6] We compare Australia to its resource rich competitors, but for reference purposes we have included OECD Europe. Historically, OECD Europe has processed much of the world's metal resources, and more recently it has invested heavily in diversifying its supply of power, so it serves as a useful reference point for power economies.

The standout performer in the group would be Brazil where only 39 toe are used per GWh consumed. Brazil has 85GW of hydro-electric power which generates 80% of its electricity, providing considerable resilience to non-renewable fuel shocks. Canada and Chile generate 58% and 41% of their electricity from hydro-electricity, also providing them with the ability to withstand non-renewable fuel shocks. To ensure reasonable comparisons between countries, heat generated for consumption from combined heat & power and pure heat plants has been converted to GWh to provide a notional total for electricity generation and consumption[7]. The IEA considers heat to be a very efficient form of energy (IEA 2011) and as a result Russia uses only 167 toe/GWh of power consumed. China has made efficiency improvements to its fleet of thermal generators which have reduced the average usage to 233 toe/GWh. Reliance on a high proportion of coal in electricity generation makes India, South Africa and Australia more vulnerable to non-renewable fuel price shocks.

3.1.2 Carbon intensity of generation

Australia has increased its emissions of carbon dioxide from electricity generation from 811g/KWh in 1990 to 882g/KWh in 2008 which is considerably more than the world average of 500g/KWh in 2008. This reflects the increased fuel usage in the generation of electricity from coal as highlighted in Figure 8.

As can be seen when comparing Figure 7 to Figure 8, countries that have a low use of non-renewable fuels logically have low carbon dioxide emissions from their electricity generation. These two indicators both measure the mix of generation but are included separately because a potential fuel constraint and a potential emission constraint would be two completely different shocks to the system.

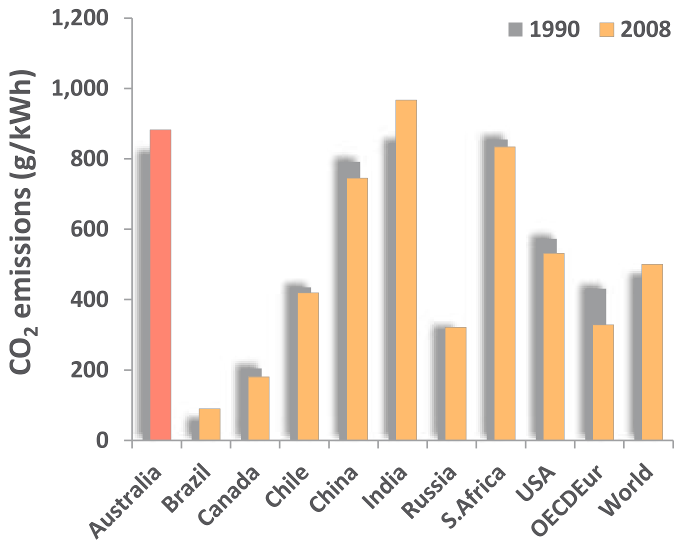


FIGURE 8: CO_2 EMISSIONS FROM ELECTRICITY GENERATION

Source: (IEA 2010)

[7] This is particularly important for Russia, as two-thirds of their power consumption is in the form of heat rather than electricity. All power generation and consumption data in the paper include the notional adjustment to include heat power.

3.1.3 Diversity of Generation

The probability that the next watt of electricity will be generated from a different fuel type is a measure of diversity in the generation of electricity. Because of its high proportion of coal in the electricity mix, in 2008 the probability that the next watt would be from a different fuel type in Australia, was 0.39 (in 1990 it was 0.37). This change reflects the increased proportion of gas, and the arrival of wind, into the energy mix.

Where Brazil has an enviable supply of renewable electricity, its diversity of generation in 1990 was 0.14. The risk associated with a low diversity of generation was thrown into stark relief in 2001 when the Brazilian Government declared a major energy supply crisis as a result of a prolonged drought which severely depleted hydro-electric reservoir levels and threatened electricity supply. A power rationing program was instituted from May 2001 to February 2002 and consumption remained depressed until 2003 (IEA 2006). As a result Brazil has invested in natural gas generation which has increased diversity to 0.36. Australia too experienced reductions in electricity supply in 2007 as a result of drought: Snowy Hydro became severely constrained and some coal-fired generation was scaled-back because of an inadequate supply of water.

South Africa is another country that has extremely low diversity of generation being almost entirely dependent on coal, with only 5% of generation from nuclear. What Australia and South Africa can learn from Brazil's experience is that no matter how effective the supply of electricity may be, if there are few alternatives, the system is compromised. Australia needs to transition away from high reliance on fossil fuels to improve the diversity of its power economy.

3.2 EFFICIENCY

3.2.1 Generation Efficiency

Australia's efficiency in producing electricity (and heat) from coal, oil and gas in 2008 was 34% which was less than the world average of 42%. Australia's generation efficiency has deteriorated from 36% in 1990 as a result of an ageing fleet.

Figure 10 provides a comparison of the generation efficiency in producing electricity (and heat) from coal, oil and gas of the

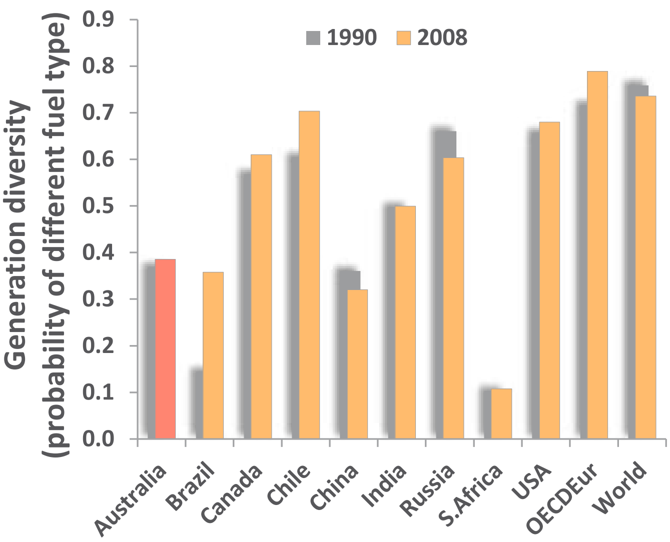


FIGURE 9: DIVERSITY OF GENERATION

Source: (IEA 2010)

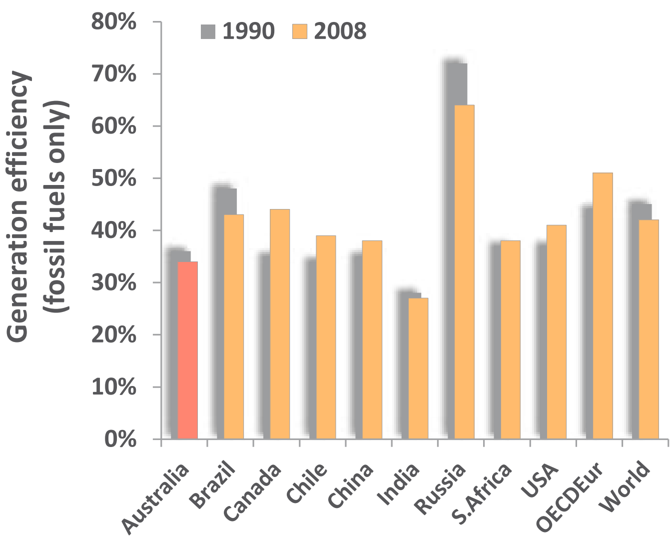
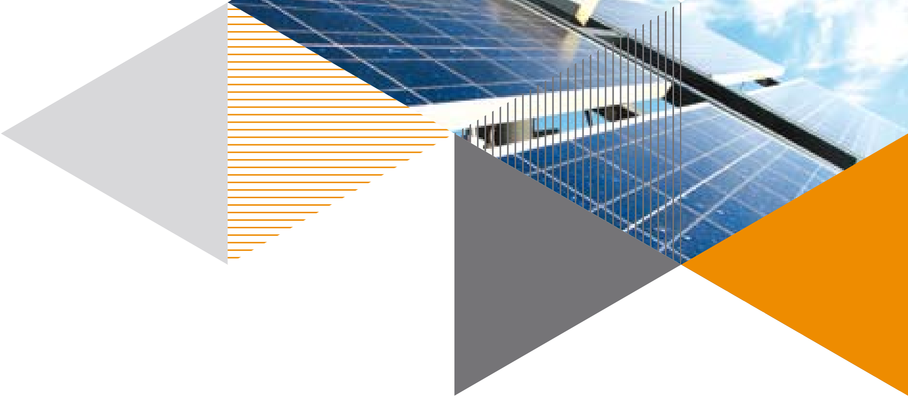


FIGURE 10: FOSSIL FUEL GENERATION EFFICIENCY

Source: (IEA 2010)



competitor countries. All countries have improved the efficiency from fossil fuel generation over the 18 year period except Brazil, India, Russia and Australia. Russian generation is very efficient at 64% efficiency in 2008 because it recovers heat in the generation process to make the conversion to electricity more efficient. It also generates heat as a source of power which increases the efficiency of generation to 80-90% by eliminating losses in the conversion of energy. Australia could be missing efficiency benefits from recovering and using heat. There are many opportunities for recovering heat, particularly at the 5-10MW scale which could have a substantial impact on efficiency. China has seen improved efficiency from fossil fuel generation which reflects programs like the Large Substitute for Small Program, which are modernising and improving the efficiency of the fleet. India's fossil fuel based generation efficiency at 27% would reflect the low gross coal plant efficiency in the Indian generation fleet (IEA 2011).

3.2.2 Own use, transmission and distribution efficiency

Australia has a landmass of 7.68 million km2, serviced by 80,539 kms of transmission and 832,819kms of distribution lines supporting generation of 55 GW and a supply of 257 TWh. There is a complex relationship between geography, settlement, source of electricity supply and the transmission and distribution of that supply. Whilst Australia is a continent in its own right, it is smaller than the landmasses of Brazil, Canada, China, Russia and the USA. Australian load centres are very distant from each other with a large, low energy density rural load complicating the transmission and distribution infrastructure requirements.

2008		Supply	Trans km	Dist km
	mill km2	TWh	(000s)	(000s)
Aus	7.7	257	81	833
Bra	8.5	507	203	1582
Can	9.1	619	188	1162
Chile	0.7	61	16	119
China	9.3	3489	992	12100
Ind	3.0	839	280	5674
Rus	16.4	1021	510	2148
SA	1.2	252	28	626
USA	9.1	4378	1235	9645

TABLE 4: LANDMASS, SUPPLY, TRANSMISSION, DISTRIBUTION

Source: (ABS Energy Research 2010; IEA 2010; IEA 2010; World Bank 2011)

Chile has a particularly complex geography being only 175km at its widest point. India has a relatively small landmass with a very large population. The complexities make comparison of the transmission and distribution complex, and yet there is a relationship between electricity supplied and geometry/architecture of transmission and distribution lines. It is interesting to note, that in 1990 Australia had 457km of transmission lines for every TWh supplied, whereas in 2008, this figure was 313km. Some of the other countries have experienced similar declines except for Canada and Russia where there is very little decline and an increase, respectively. The average across the group in 2008 is 305km of transmission lines per TWh supplied. The data for distribution presents a similar picture.

In terms of power system delivery efficiency, Australia loses some 18% of electricity between electricity generation and consumption: 7% is used by generators, 4% is used in mining and refining fuels and 7% is lost in transmission and distribution[8].

Comparing Australia's transmission losses to the larger countries in Figure 12, we find that Brazil loses 15% through old and poorly maintained transmission and distribution systems with high losses and power theft, Canada loses 8% (including transmission for export to the USA), China loses 5%, and the USA loses 6%. Russia loses 8% through transmission and distribution, even though it sprawls across 11 time zones providing opportunities for spreading the impact of demand peaks and thus reducing generation requirements (IEA 2005). India's losses are complex and multi-faceted including theft through illegal tapping, faulty meters, overloading distribution at peak demand and a very high ratio of low voltage to high voltage line kilometres (IEA 2011).

[8] 7% loss through transmission and distribution is thought to be lower than generally accepted losses. This could be as a result of the IEA reporting a total for the country including embedded generation which has no loss from transmission and distribution

A lack of adequate investment in transmission has been blamed for, or implicated in, more than one severe failure in electricity supply in the competitor countries. The blackout in the USA in 2003 was blamed on inadequate adherence to reliability standards possibly as a result of reduced investment in the networks (IEA 2007). The electricity crisis in Brazil in 2001 after a sustained period of drought may have been exacerbated by old and poorly maintained transmission lines that were unable to reroute electricity from hydro-electric facilities less affected by the drought. The power shortages in China between 2002 and 2005 may have been worsened by grid bottlenecks from limited transmission capacity between regional grids, weakness in transmission of bulk power at local levels, and weak interconnection. India continues to experience outages, not only as a result of transmission inadequacies but it is a part of the mix.

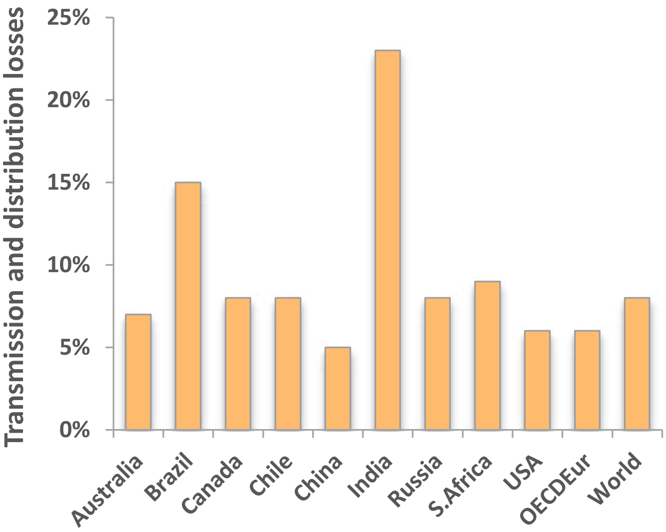


FIGURE 12: TRANSMISSION AND DISTRIBUTION LOSSES 2008

Source: (IEA 2010), (IEA 2010)

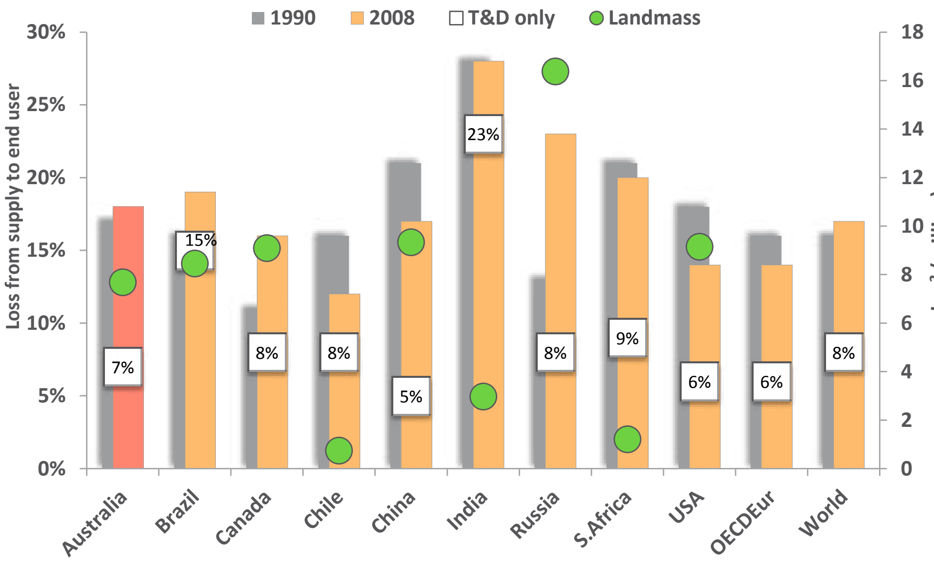
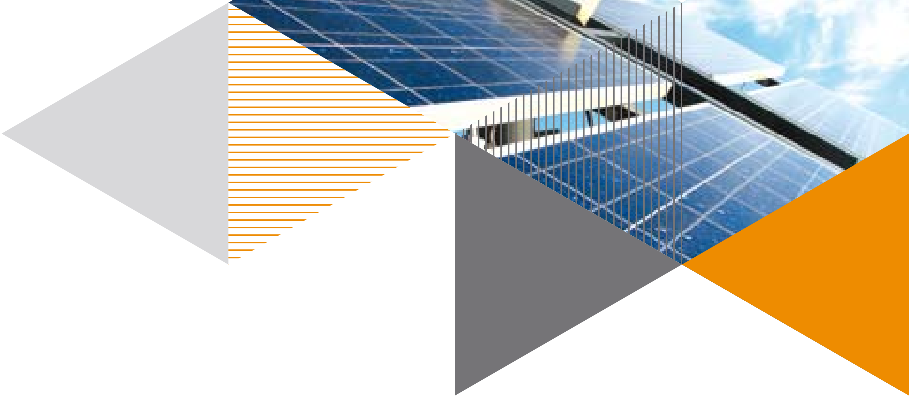


FIGURE 11: ELECTRICITY LOST OR USED BY ENERGY INDUSTRY

Source: (IEA 2010)



3.3 SECURITY

3.3.1 Reliance on imports of fuels for electricity or actual electricity imported

Being a rather large island with most of the fuel inputs for electricity generation locally available, Australia has no real security of supply issues. In 2008 Canada exported 58 TWh of electricity (9% of its generation) to the United States, and sees electricity as a valuable source of revenue. Russia and South Africa also export electricity to neighbouring countries although a smaller proportion than does Canada.

On the other extreme, Chile imports coal and gas for its electricity generation and electricity from Argentina. There has been diversification from hydro power after a prolonged 40 year drought reduced reservoir levels and resulted in outages and rations of electricity from 1998 to mid 1999. The move to gas has not been without its troubles as gas is imported from Argentina and that supply has been constrained since 2004. As a result Chile is constructing LNG terminals, in the hope of gaining security of import for gas for generation.

India too has to import coal and gas for generation and electricity from Bhutan and Nepal. Coal imports are expensive for India but cheaper than transporting coal across the continent which can add $30/tonne to the price. With few resources to power the continent, Europe imports coal, gas and oil for generation and electricity from Russia. Brazil imports electricity from Paraguay and gas from Bolivia. Brazil too has sought to decrease its reliance on hydro-electricity by increasing its gas generation. However, Bolivia has run short of gas for its own requirements and all but ceased exports to Brazil, so Brazil is developing its gas fields to supply its gas generation.

Australia's security of supply is dependent on the continued use of fuels priced at domestic levels. In the event of substantial escalation of international prices, it will become increasingly difficult to maintain domestic prices and thus affordable electricity. And whilst certain coal deposits may be considered to be 'stranded' at current world prices, their potential for exploitation and sale will be affected by what other countries are prepared to pay for them. Thus, the strategic security of supply will decrease as global fuel prices rise.

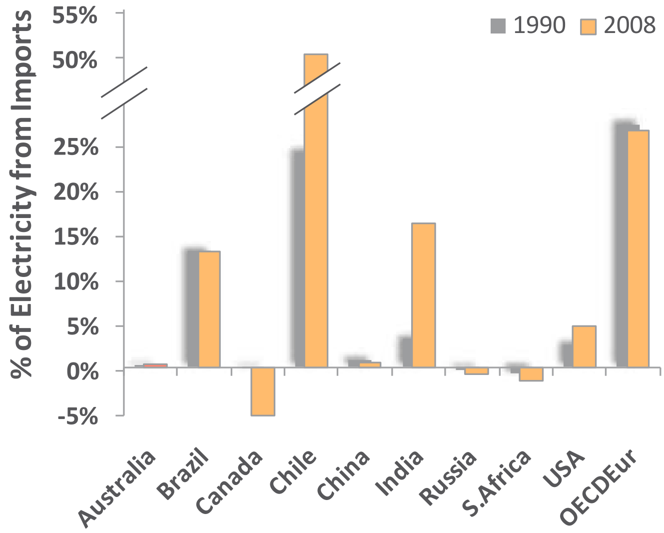


FIGURE 13: PERCENTAGE OF ELECTRICITY SUPPLIED (GENERATED PLUS IMPORTED) FROM IMPORTED SOURCES

Source: (IEA 2010)

3.3.2 Redundant power for use in GDP

When countries experience electricity shortages, economic impacts are felt. It is with this in mind, that this indicator of redundancy is used as a measure of resilience; that is the spare capacity in the electricity system to fuel the economy. Unusually, this measure reflects positively for economies which have a high component of spare electricity capacity within GDP, and negatively for economies with a small amount of spare electricity for every dollar earned. This is because electricity will fuel growth and if electricity is squeezed, growth may be reduced.

As can be seen from figure 14 Russia has a large quantity of spare capacity. Lenin is reputed to have said that Communism is "Soviet power plus the electrification of the whole country." Massive investment in electrification and free provision of utilities, led to very large consumption of power. However, the introduction of charges for the use of utilities after 1990 has substantially reduced power consumption and increased efficiency.

In 1990, South Africa had a high level of spare capacity, which had substantially declined by 2008 as a result of its failed market reforms (see section 4.4 for more detail). China also has a high component of spare capacity to fuel GDP. Studies have found unidirectional causality in China between electricity consumption and GDP over the periods 1971-2000 and 1978 -2004 (Shiu and Lam 2004; Yuan, Zhao et al. 2007). So China's high level of spare capacity has served its growth targets well.

Chile's experiences in 1999 provide an interesting and insightful example of the relationship between GDP growth and power system capacity. Over the 18 year period 1990 to 2008, the only year that Chile's economy descended into recession was in 1999 after an hydro-electricity crisis in 1998 that followed 40 years of drought. Figure 15 shows GDP growth and TWh growth in Chile since 1990. The coupling of GDP growth to electricity growth appears to uncouple after the 2004 electricity crisis which followed restricted supply of gas from Argentina. This should be understood in the context of resilience measures adopted by Chile after 1999 which included a requirement for generators to have diesel-generated back-up units, and financial encouragement of industrial customers to install back-up diesel generation (IEA 2009). Chile's experience with electricity supply constraints is a good illustration of the importance of having sufficient generation for economic needs.

As an energy source, electricity is effective, efficient and clean, and investment in electricity infrastructure should be planned to cover more than historical levels of consumption growth, allowing for the migration of all sectors of the economy to the use of electricity as the primary source of energy. As an example, the transportation sector offers the potential to migrate much of the asset base to electrification in the years to come; China has started the migration with fast rail links between cities. For this reason, economies will require increasing quantities of KWhs for every dollar of GDP earned, despite efficiencies gained through supply and demand management. With a requirement to increase consumption of electricity in different sectors of the economy, efficiency will be critical to optimise investment in the power infrastructure.

Resilience and the power economies

In the previous sections Australia has been compared to other countries on quantifiable measurements of resilience in electricity supply. In summarising, the following observations can be made about the Australian power economy:

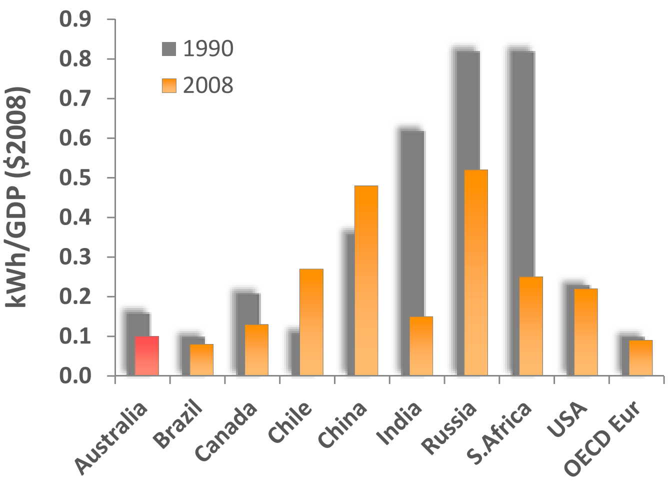


FIGURE 14: SPARE ELECTRICITY FOR USE IN EARNING INCOME

Source: (IEA 2010)

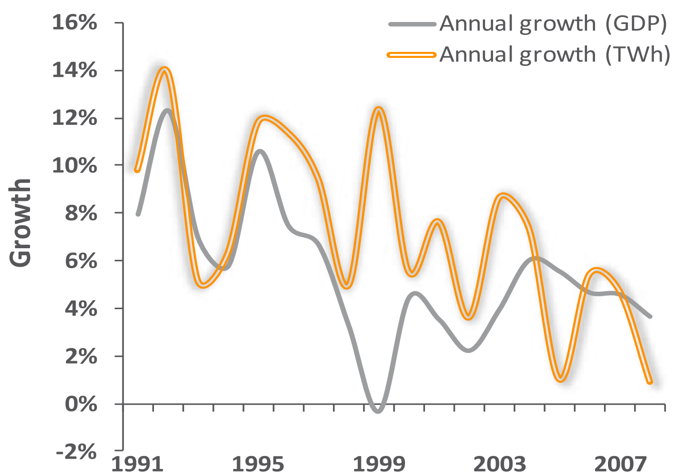


FIGURE 15: CHILE GROWTH GDP VS TWH

Source: (IEA 2010), (IMF 2011)

- It uses more fossil fuels in the generation of every KWh than the world average, making it vulnerable to global energy price increases. Only India and South Africa use more fossil fuels in generation.
- It emits more carbon dioxide emissions in the generation of every KWh than the world average, making it vulnerable to carbon emission mitigation policies. Only India emits more carbon dioxide from generation.
- It has a low diversity of generation, making it vulnerable to energy supply constraints. Brazil, China and South Africa have lower diversity of generation.
- Its efficiency in generating power from fossil fuels is lower than the world average, with only India less efficient in generating power from fossil fuels.
- Its transmission and distribution system is more efficient than the world average, with only China, USA and OECD Europe having more efficient distribution systems.
- It has little reliance on imports for the generation of electricity and no reliance on imported electricity, making it secure from external supply disruptions, although this security will be impacted as global fuel prices rise.
- Unlike China, Russia and the USA, Australia has low levels of spare capacity to fuel GDP which could indicate an inability to service unplanned growth in electricity requirements.

3.4 COST OF ELECTRICITY TO INDUSTRY

With the de-regulation of much of Australia's electricity system in 1998, data pertaining to costs, investments and prices has not been collected nationally. ABARES calculate country aggregated price based on IEA estimations from 2004 extrapolated using Australian Bureau of Statistics (ABS) electricity price indices. Indeed IEA estimations are subject to substantial variations in the historical data which the IEA state is as a result of switching between several sources. For the purposes of this paper, the price of electricity to industry has been calculated using 1990 as a base year (when a weighted average national price was readily available through the Electricity Supply Association of Australia, ESAA) and extrapolated to 2008 using the ABS Producer Price Index or electricity.

Figure 16 shows relatively flat nominal weighted average national electricity prices for industry in Australia between 1990 and 2007, with a sharp increase in 2008. However, if the prices are adjusted for inflation, then there is a fall in prices between 1990 and 2008.

Whilst there was a small improvement in the US/AUS exchange rate between 1990 and 2008 there was a substantial deterioration in the rate from 1998 to 2003 when electricity would have been considerably cheaper relative to world prices. Comparing prices in US$ therefore to some extent masks domestic trends but global firms will look to the price of electricity in US$ to establish competitiveness, as profits will be reported in US$. For this reason, 2008 prices are compared to 1990 real prices at the 2008 exchange rate.

Figure 17 provides a summary of the weighted average national price of electricity to industry for Australia's resource-rich competitors. The source of most of the data, the IEA, recommends caution with respect to data quality. Despite this the comparative data provides an indication of how energy-intensive firms may view the Australian power economy viz-a-viz other resource-rich countries.

Prices for electricity in Russia have soared from a negligible price in 1990, reflecting Russia's moves to monetize utilities and reform the electricity sector by creating competitive wholesale and retail sectors. Chile and Brazil have also experienced

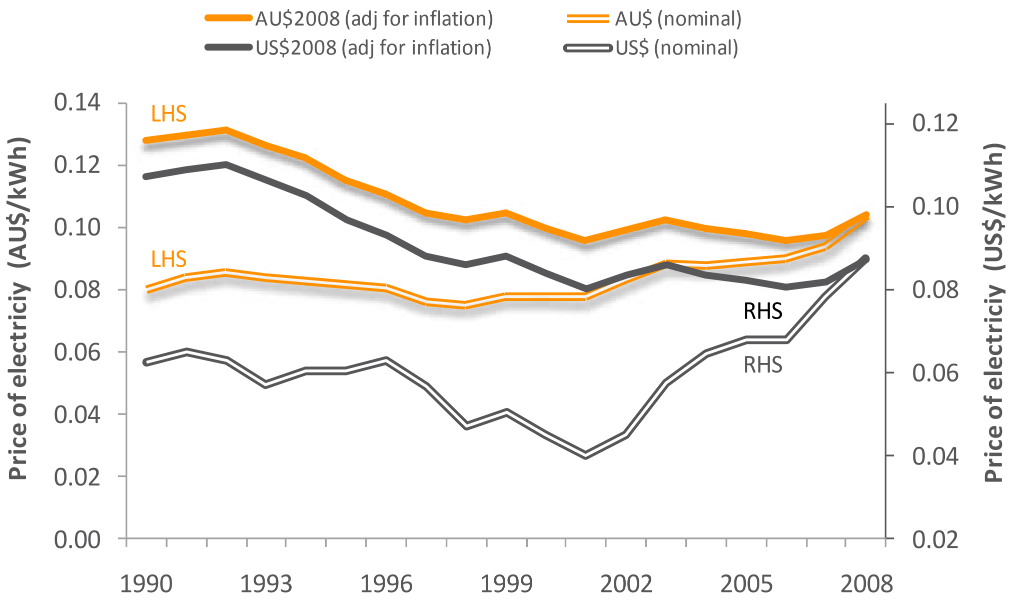
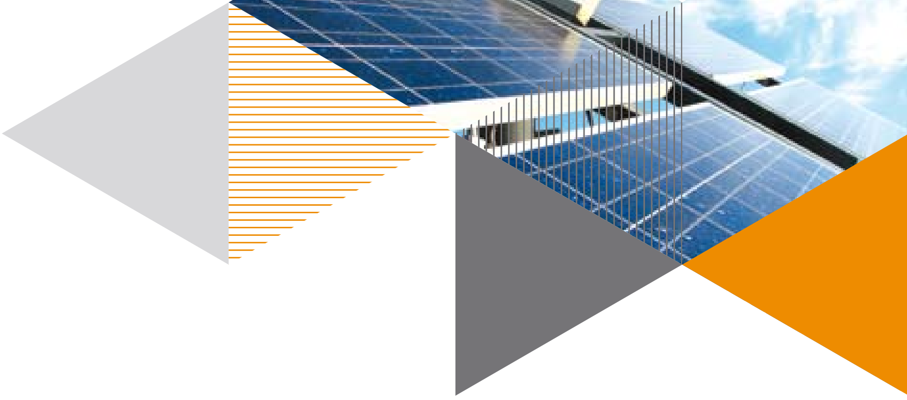


FIGURE 16: AUSTRALIAN COST OF ELECTRICITY TO INDUSTRY

Source: (ESAA 1994), (ABS 2011), (IMF 2011)



sharp increases in electricity price having had to contend with electricity rationing during droughts, currency turmoil and inflation as a result of uncertainties regarding gas supplies from Argentina and Bolivia. Also, the IEA reports that 40% of the average Brazilian electricity bill is for taxes and special charges to cover the cost of extending electrification to all households (IEA 2006). Europe has experienced an increase in prices but has diversified the supply and decreased the emissions intensity of its electricity supply. China is starting to experience rises in price which may accelerate if coal cost increases and massive investment in electricity infrastructure start to be passed through to customers.

Australia, India, South Africa and the US prices have been relatively stable or even decreasing with little change to their generation mix and efficiency. By comparison, South America has had to respond to fuel supply constraints and Europe has been responding to the risk of future carbon constraints. For instance whilst Australia has increased its carbon intensity from 811g/KWh in 1990 to 882g/KWh in 2008, OECD Europe has decreased its carbon intensity from 431g/KWh to 328g/KWh. South America and Europe may be better prepared

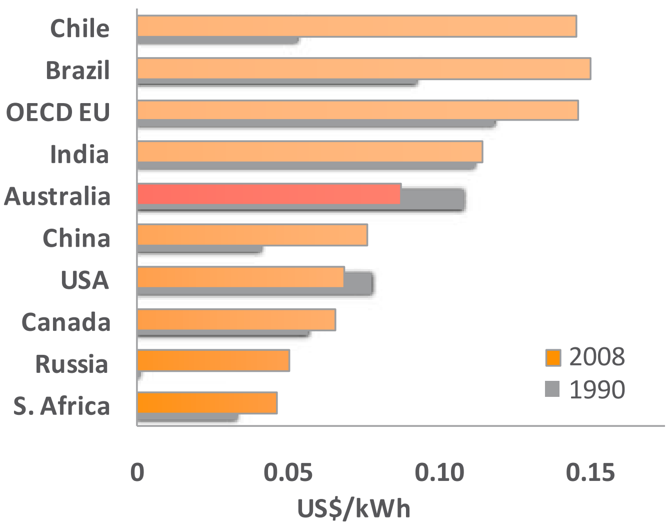


FIGURE 17: COST OF ELECTRICITY TO INDUSTRY

Source: (IEA 2011), (IEA 1998), (ESKOM 2008), (ABS 2011), (ABS 2011), (IMF 2011)

for future uncertainties regarding fuel costs and carbon constraints as a result of their experiences over the last 18 years. Canada has invested in its natural resources to deliver low-cost, diversified and affordable electricity despite its largely regulated power system (generation is deregulated in Alberta, and is subject to contract guarantees and fixed prices in Ontario and fully regulated in all other provinces). Reflecting the competitiveness of its power to industry, it has maintained its market share of aluminium smelting even though it has no deposits of the metal in the country. Notably, Australia and the US's reduced real price of electricity to industry, has not resulted in a marked increase in energy-intensive electricity consumption.

3.5 COMPETITIVENESS OF THE POWER ECONOMIES

How resilient a power economy is, will dictate how prepared it is to meet challenges and opportunities, and its future potential to compete. Non-renewable fuel used, carbon intensity, diversity of fuel type, efficiency in generation, efficiency in supply from generation to consumption, reliance on imports and spare electricity capacity (the measures mentioned above) have been incorporated into a composite index, called the Power Economy Resilience Index. As all the indicators are viewed as equally important in measuring an electricity system's resilience, so they have not been weighted (more detail is provided in Appendix: Building a Resilience Index for the power economy)

Effectively the Power Economy Resilience Index measures the quality of the power production system, and coupled with the price of the service provided, allows measurement of the competitiveness of the power economy. Plotting the Resilience Index as a function of the average cost of electricity to industry provides a simple graphical representation of the competitiveness of the power economies.

With reference to Figure 18, it appears reasonable to draw the following conclusions:

- Russia has the most competitive power economy from amongst the competitor countries. Unlike much of the rest of the world, it has not invested heavily in coal-fired generation and has a large and reliable supply of gas to meet its generation needs. Russia has also gained efficiency benefits from using heat as

- a source of power. However, Russia's power infrastructure is aged and in need of renewal (IEA 2005).
- Canada also offers a competitive power economy. It has increased resilience from fossil fuel price spikes and supply uncertainty and it has achieved that resilience at very affordable prices.
- The USA too offers a competitive power economy because it has a diverse supply of electricity coupled with reasonable levels of capacity to fuel the economy.
- Chile and OECD Europe are resilient but their cost reduces their competitiveness.
- South Africa offers the most competitively priced electricity system amongst the group, but it comes with resilience warnings for any investor.
- It would seem that Australia's power system today is neither very resilient nor competitively priced.

There are a few interesting comparisons to consider. The first is that Russia offers the most competitive power economy from a largely non-competitive institutional structure, compared to Chile which offers resilience, but at a cost, from a competitive market structure. The second is that the USA and China have similar levels of competitiveness but have fundamentally different market and institutional structures. Whilst Canada and Russia have similarly affordable, (largely) publicly owned electricity systems in large, cold landmasses, their generating fleets are vastly different with Canada gaining its resilience from hydro-electricity and Russia gaining its resilience from

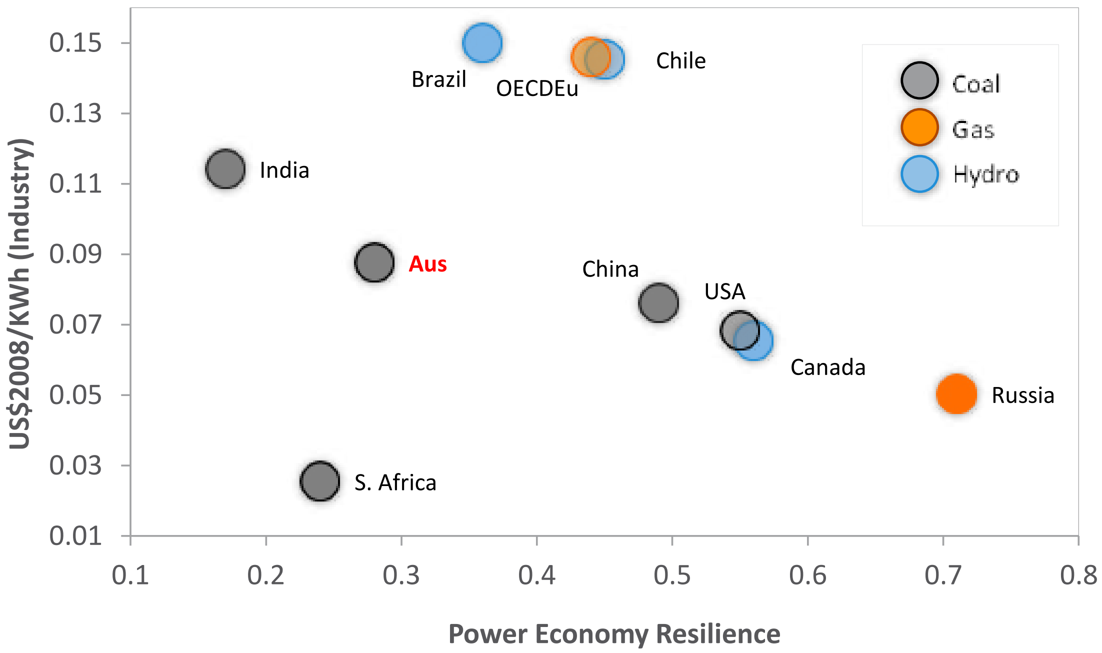


FIGURE 18: ELECTRICITY COMPETITIVENESS COMPARISON 2008

Source: (IEA 2010), (ESKOM 2008), (IEA 2011), (ESAA 1994), (ABS 2011), (IMF 2011) gas generation and efficient use of heat as power. It would seem that there is more than one path to competitive resilience. Which is the best path for Australia to follow to improve its competitive resilience?

In order to validate the competitiveness of each power economy, Figure 19 offers further evidence of each country's ability to attract energy-intensive industry. Global market share gap is defined as the difference between the global market share of the metal mined and the global market share of the metal processed. For example in 2009, Australia mined 33% of global bauxite but processed 5% of the world's aluminium, allowing a market share gap of 28% for aluminium processing.

Countries that process more of a metal than they mine could then be assumed to be attractive to metals processing investors. Figure 19 shows that Canada, Russia, China and the USA process more aluminium than they mine, which supports the findings presented in Figure 18 that those countries offer competitive power economies. Brazil and Chile have substantial market share gaps which bears out the findings that they are reasonably resilient but expensive. India shows a lack of competitiveness with only copper producing a negative market share gap. South Africa shows a negative market share gap for aluminium which reflects its low price. Australia shows little evidence of ability to attract energy-intensive industry.

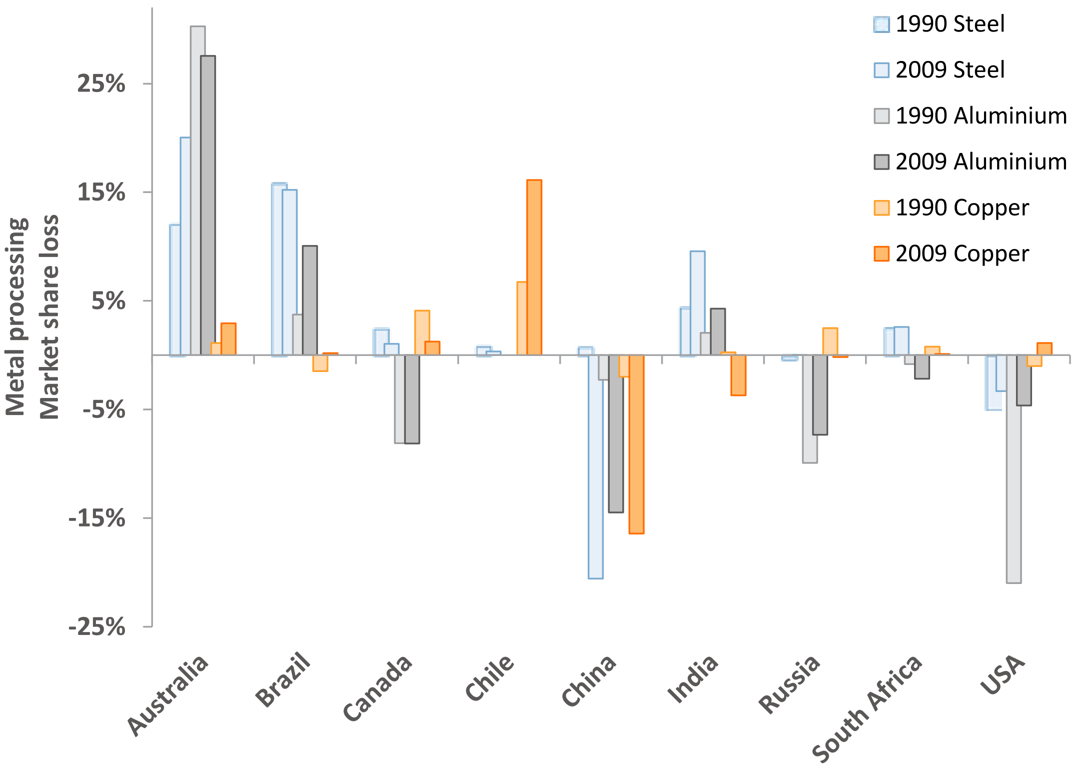


FIGURE 19: GLOBAL MARKET SHARE GAP (MINED VS. PROCESSED)

Source: (USGS 2011)

4 KEY DRIVERS OF THE PAST AND THE FUTURE

Using the same source of data, the IEA, for the resilience index calculation and the weighted average price of electricity to industry it is relevant to understand the direction of change from 1990 to 2008, assuming the same methodology.

Figure 20 provides a summary of the relative competitiveness of each country in 1990 and the shift in competitiveness to 2008. Russia's apparent reduced resilience should be treated with caution due to Russian data quality issues in 1990, however it can be noted that the monetisation of utilities has brought Russian power prices more into line with the rest of the competitor countries. Most countries have achieved modest increases in resilience at an average annual price increase of less than 2% except for Brazil, China and Chile where the price increase was 2.7%, 3.4% and 5.7% respectively.

The USA improved its resilience through improved generation, transmission and distribution efficiency as well as improved diversity whilst also reducing the price. Chile's loss of resilience is due to its increased dependence on imported sources for electricity, India's loss of resilience is due to its decrease in efficiency of generation coupled with increased dependence on imported sources for electricity, and Australia's reduced price has come at the cost of resilience as a result of generation efficiency deteriorations.

The competitiveness of the power economy, that is the combination of both resilience and price to reflect value, is driven by a multiplicity of factors, a subset of which is examined in more detail in the following sections.

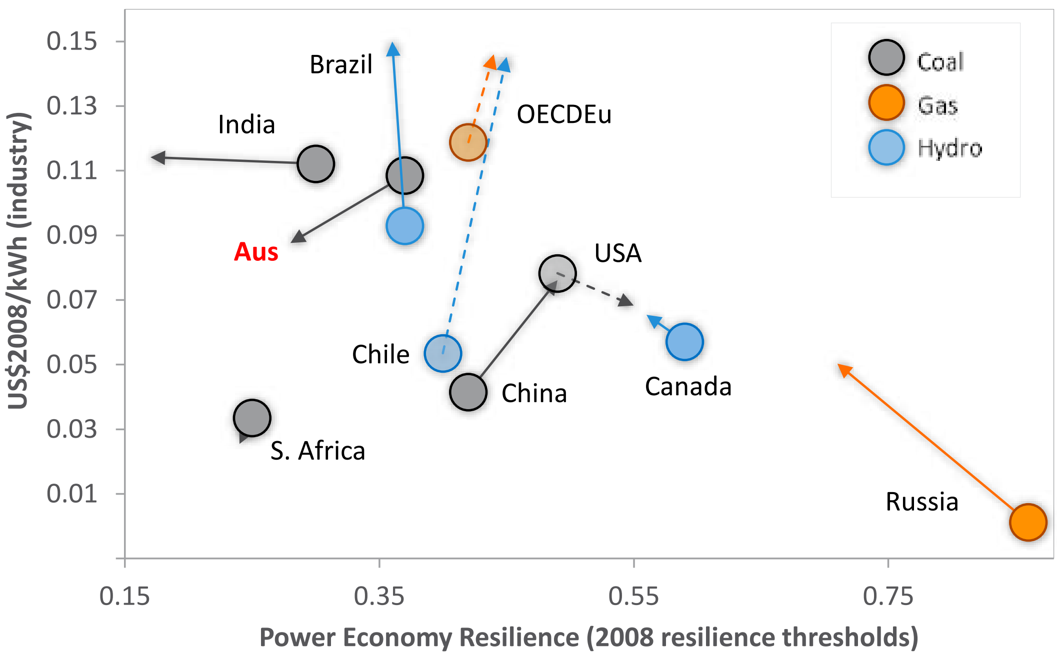
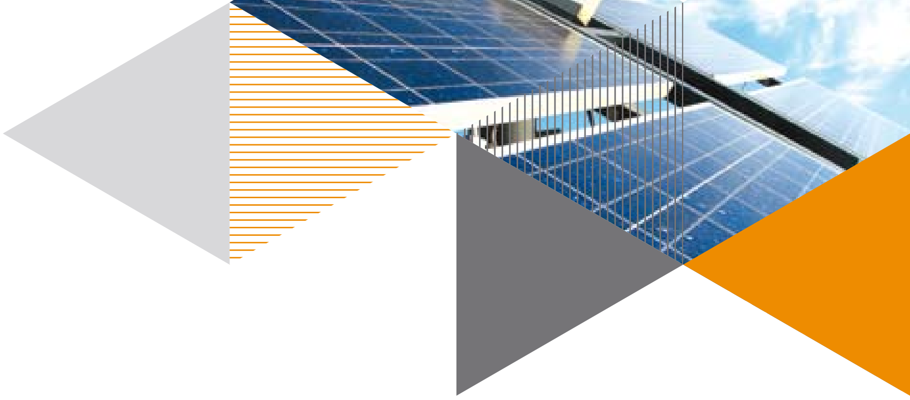


FIGURE 20: ELECTRICITY COMPETITIVENESS COMPARISON 1990 TO 2008

Sources: (IEA 2010), (IEA 2011), (IEA 1998), (ESAA 1994), (ABS 2011), (ABS 2011), (IMF 2011)



4.1 POLICY ENVIRONMENT

Energy policy in Australia is complex and dynamic, but it is important to highlight the first order issues that occupy the mainstream agenda and will affect the medium term implementation of market reform and the transition to a different power economy.

Carbon lock-in inhibits or delays the inevitable action needed to transition to less carbon intensive fuel sources (Unruh 2000; Unruh 2002; Unruh and Carrillo-Hermosilla 2006). Australian energy policy, like many developed countries, favours existing sources of generation with significant inertia to change as a result of multiple economic and social factors.

National ● State ▲

	REGULATORY POLICIES						FISCAL INCENTIVES				PUBLIC FINANCING	
	Feed-in tariff (incl. Premium payment)	Electric utility quota obligation / RPS	Net metering	Biofuels obligation / mandate	Heat obligation / mandata	Tradable REC	Capital subsidy, grant or rebate	Investment or production tax credits	Reducations in sales, energy, CO_2, VAR or other taxes	Energy production payment	Public investment, loans or grants	Public competitive bidding
Australia	▲			▲		●	●				●	
Brazil				●					●		●	●
Canada	▲	▲	●	●			●	●	●		●	●
Chile		●					●		●		●	
China	●	●		●	●		●			●	●	●
Germany	●			●	●		●	●	●		●	
India	●	●		●		●	●	●	●		●	●
Russia						●	●					
South Africa	●					●	●					●
Spain	●			●	●		▲	●	●		●	
UK	●	●		●		●			●	●	●	
United States	▲	▲	▲	●	▲	●	●	●	●	●	●	●

FIGURE 21: RENEWABLE ENERGY SUPPORT POLICIES

Source: (REN21 2011)

[9] This has subsequently been amended into two schemes to account for the high deployment of small-scale and domestic generation. The target for medium and large-scale generation has been reduced to 41,000GWh by 2020.

Australia's Renewable Energy Target (RET) requires that twenty percent of generation be met through renewable energy sources by 2020 (now quantified at 45,000GWh). This policy was part of a double policy measure which required an emissions trading scheme to increase the cost of existing high-emission generation relative to low-emission generation. The government of the day was unable to pass the emissions trading scheme, which came to be known as the Carbon Pollution Reduction Scheme, into law so the RET remains as the only source of incentive for investment in low-emission generation. The inability to introduce a carbon price into the Australian economy has increased uncertainty for strategic investment in generation.

The government commenced preparation of an Energy White Paper in 2008 to set a policy framework for "a secure, competitive, efficient and sustainable energy sector" (Department of Resources Energy and Tourism 2011). A draft of this paper is expected in 2011 with the paper to be finalised in 2012. Questions remain as to whether this will allow time for planning and construction of large-scale renewable generation to meet the ambitious renewable energy targets for 2020.

Future base-load renewable generation is a challenge for network connection and operation. Current policy requires that all costs relating to connection (and where required, grid upgrades) be met by the new generator. With potential base-load renewable generation (eg geothermal and concentrated solar thermal with storage) located considerable distances from existing grid infrastructure, the cost of connection is proving to be a barrier to entry. A recent Australian Energy Market Operator report, which considered transmission needs for the next twenty years, found it was not economically viable to include infrastructure requirements for remote renewable energy resources (AEMO 2010). Access to remote locations for renewable energy is not a new problem for network operators. Hydro-electricity has been driving investment in high volume transmission infrastructure around the world since 1965 (Lings 2005). The question for policy makers is what changes are required to existing policy to facilitate access to remote base-load renewable energy generation?

Distributed generation presents a significant opportunity to shave peak load, but it will not contribute significantly to the overall need for large-scale generation in the foreseeable future.

The central priority for Australian policy makers should be the identification of policies that will ensure the competitiveness of Australian large power users. Figure 21 provides a summary of the policies implemented by Australia and its competitors. Canada, China, India and the US would appear to have the most comprehensive range of policies implemented.

4.2 REGULATORY/INSTITUTIONAL FRAMEWORK

Australia has three distinct regulatory environments. The largest, the National Electricity Market, provides a deregulated electricity system, which can be broken down into four key sectors: generation; transmission; distribution; and retail sales. Most retail sales entities are privately owned but there is a significant mix in ownership structure controlling generation, transmission and distribution.

The current regulatory regime was put in place in 1998 and since 2006 has been controlled by the Australian Energy Regulator (AER), which is responsible for the wholesale electricity and gas markets as well as all transmission and distribution regulations. There have been significant increases in the price of electricity since that time, primarily due to the high cost of investment in distribution networks. There has been criticism of the current rules for distribution networks, which have been designed to encourage investment from the private sector but, in effect, have the potential to provide additional profits to Government owned corporations through over-investment in infrastructure (Garnaut 2011).

The electricity market is operated by the Australian Energy Market Operator (AEMO). Any changes to market rules are administered by the Australian Energy Market Commission (AEMC) with the Ministerial Council on Energy (MCE) having overall responsibility for policy oversight of the Australian energy market. It is intended that the rules will be reviewed in 2011 as part of the regulatory process.

There are 28 utilities in Australia with new emerging structures like Independent Power Producers (IPPs) which provide renewable energy and peaking power but also privately owned small scale PV facilities.

Western Australia and the Northern Territories are the two smaller regulatory environments. They both have an entirely

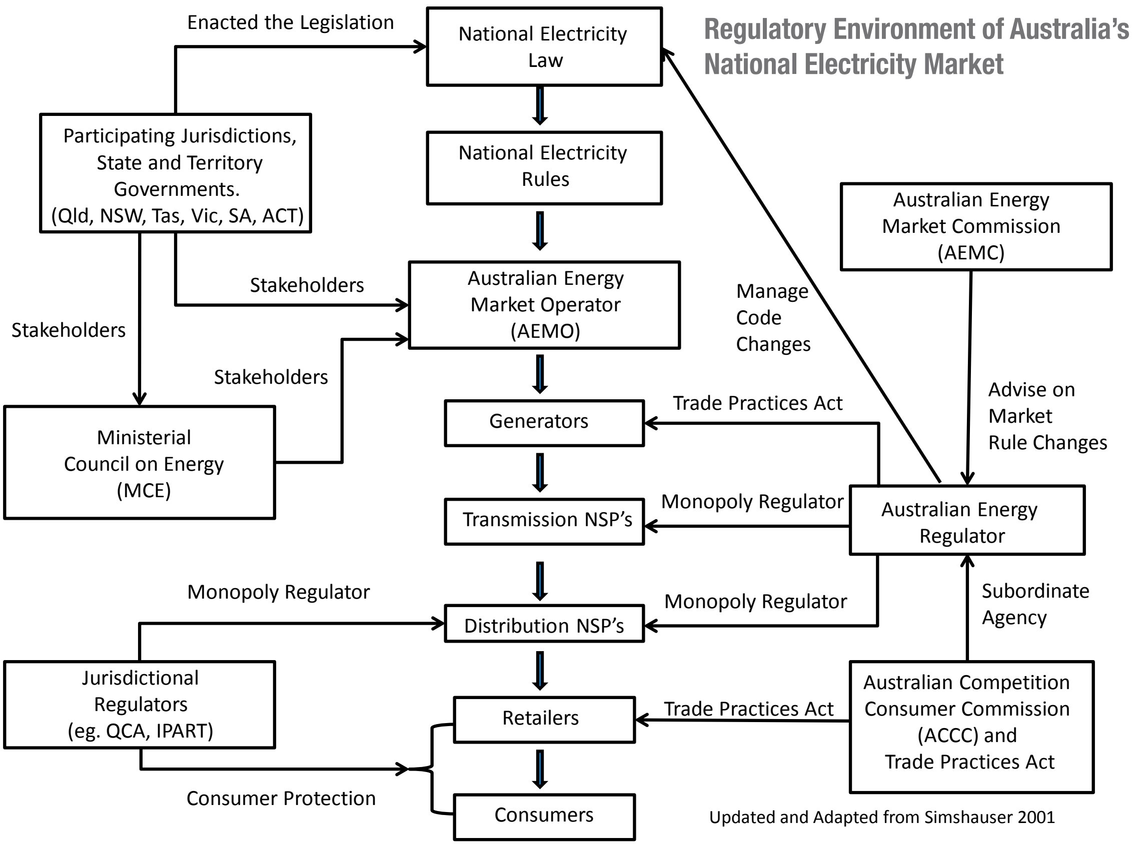


FIGURE 22: NEM REGULATORY ENVIRONMENT

separate and independent institutional framework, due to their geographic location. In the Northern Territories, electricity is supplied primarily by Power and Water, a state owned corporation, but private ownership of generation and distribution facilities is permitted. In Western Australia, a Wholesale Electricity Market was established in 2006 with generation separated from networks and retail, regulated by the Economic Regulation Authority (ERA).

The history of state-based power system development created a high number of generators, transmitters, distributors and retailers even though in recent times there have been efforts to increase the concentration through cross acquisition and mergers. This state-centric development has led to fragmented policy with little national oversight and planning. As an example Queensland was originally an isolated grid for a relatively small population. It had 1 transmitter, and a number of generation companies, retailers and distribution companies, suggesting that these utilities are small and experience limited benefits from economies of scale and critical mass. State based Feed-in-Tariffs (FiTs) are a good example of fragmented policy development for the Australian power economy. States have each offered different FiTs which have driven investment in renewable energy but not necessarily the optimum type or level of investment. If the Australian power economy continues to evolve through bottoms up regional target setting, rather than a more national, top-down, strategic planning process, it will not be able to reap the benefits from long-term strategic planning.

4.3 ELECTRICITY DEMAND AND LOAD PROFILE

Major demand drivers are:

- Rising living standards and increased GDP
- Population change
- Change of electricity use (electrification of energy-intensive industries, consumer behaviour, electrification of transportation, electrification of fuel production)

Major Load Profile drivers are:

- Behaviour of residential consumers (technology, particularly home entertainment systems, are a major factor currently)
- Climatic conditions (air conditioning, heating)
- Presence of capital and energy intensive industries

Australian electricity consumption has grown by 2.7% per annum since 1990. Population growth of 1.3% per annum has driven a portion of that 2.7% increase, but other major contributors have been: metals processing industry consumption which has grown by 3.6% per annum since 1990, adding 0.7% per annum growth to electricity consumption; commercial and public service consumption has grown by 3.9% per annum, which increased overall consumption growth by 0.8%; and residential consumption, has grown by 2.3% contributing 0.4% to overall consumption growth.

The growth in metals processing consumption is confirmation that Australian power remains competitive globally, but an international mining company's recent decision to close its refining operations (ABC 2011) could foreshadow an exodus of metals processing operations, if Australia does not get the efficiency/resilience mix right. An increase in commercial consumption is to be expected since the Financial Intermediation sector, a major contributor to the commercial sector, has increased employment by 3.1% per annum and made a GDP contribution of 4.6% per annum since 1990. Residential sector electricity consumption has been driven by increasing house sizes, decreasing electric appliance costs and affordable electricity tariffs which have created not only a "Boomerang Paradox" where low income earners become trapped by increasing electricity prices (Simshauser, Nelson et al. 2010) but also resistance to any carbon mitigation policy that might impact on electricity prices (Hanson 2011).

Figure 24 provides further detail of state energy projections to 2020 showing an inexorable march upwards. Figure 25 provides the state projections for peak load through to 2020 showing a steeper increase than the energy projections.

Figure 26 provides a comparison of the growth in consumption and the growth in generation plant installed. Generation capacity has increased by 1.9% per annum since 1990, which is significantly less than the 2.6% annual increase in electricity generated. The projected increase in generation capacity of 2.6% per annum to 2020 reflects the increased proportion of wind in the mix with a capacity factor of less than 35% and an increase in peak demand over-and-above average load between 2008 and 2020 will contribute substantially to an increased requirement for peaking generation capacity.

The management of demand is still in very early stages in Australia. As a result, the growth in peak demand must be serviced by increasing levels of generation and transmission infrastructure. This will continue to weigh heavily on electricity tariffs and affect the competitiveness of Australian electricity for the large industrial users unless measures are taken to address energy efficiency, energy conservation and demand management more aggressively.

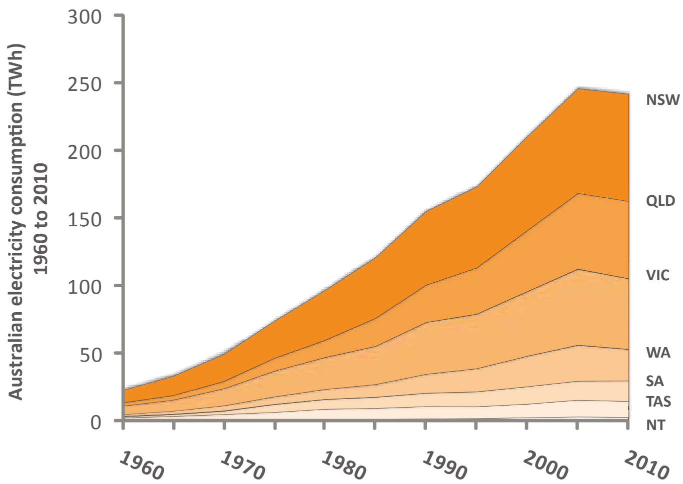


FIGURE 23: AUSTRALIAN ELECTRICITY CONSUMPTION 1960 TO 2010

Source: (ABARES 2011)

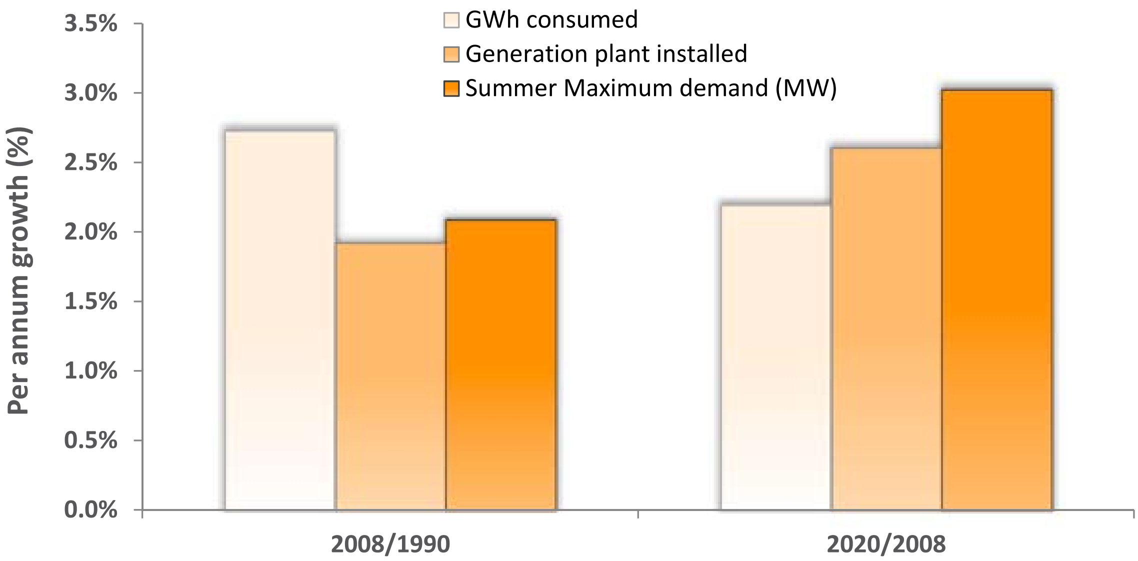


FIGURE 26: AUSTRALIAN ELECTRICITY SYSTEM GROWTH

Source: (ESAA 1994), (ESAA 2010), (AEMO 2010), (WesternPower 2009), (IES 2011)

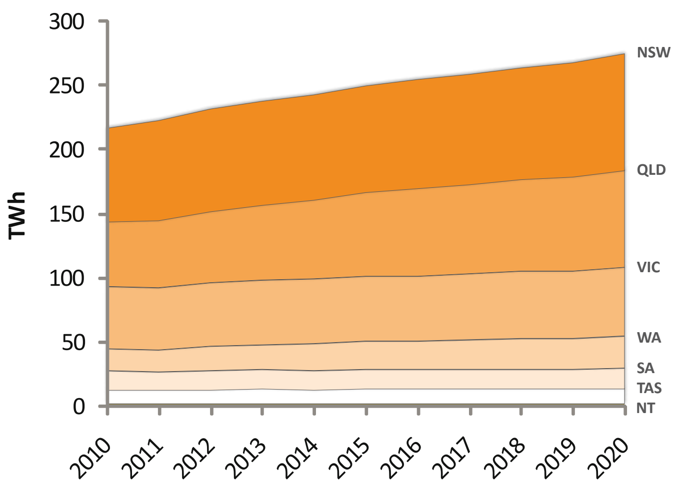


FIGURE 24: AUSTRALIAN ENERGY PROJECTIONS

Source: (ESAA 2011)

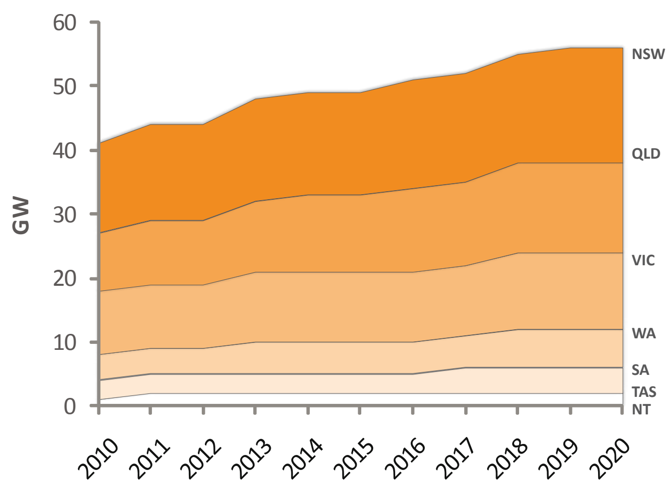


FIGURE 25: AUSTRALIAN PEAK LOAD PROJECTIONS

Source: (ESAA 2010)

4.4 CAPACITY UTILISATION OF GENERATION

As Australia has increased generation capacity by only 1.9% per annum since 1990, it is pertinent to understand how effectively the generation fleet is being utilised. For this purpose, it is assumed that renewable technologies are always at their intrinsic full capacity, so the analysis includes only coal, oil, gas and nuclear generation.

Figure 27 shows that in 1990 Australian generation provided 53% capacity utilisation, but that by 2008 that had increased to 62%. The US and OECD Europe had capacity utilisation factors of 49% and 55% respectively in 2008. The only countries that had greater efficiency of generation than Australia were South Africa and India, but South Africa's reserve margin slipped below 5% in 2008 resulting in mandatory load shedding and by 2010 Indian supply shortages were estimated at 10% (IEA 2011), so there would appear to be certain risks associated with aggressive utilisation of capacity.

South Africa's lack of investment in generation is a stark warning of the consequences of failing to carry out market reforms effectively and as a result invest adequately. In an attempt to decrease South Africa's public utility, ESKOM's, monopoly of the market, the government required that 30% of generation come from independent power producers (IPPs). However, due to the low price of electricity in South Africa, no IPPs stepped forward and there was no investment in generation. Whilst consumption kept growing, only in 2004 did the government policy on IPPs change and ESKOM was instructed to increase capacity. Due to the time constraints in delivering generating units, the reserve margin decreased to 6% and in 2006 mandatory load shedding started and was to continue until 2008 when a national electricity crisis was declared. By 2008 the reserve margin was below 5% which created peripheral problems like deteriorating plant performance due to rushed maintenance and higher than normal capacity levels. South Africa plans to have new capacity commissioned between 2012 and 2017 and hopes to see its electricity system challenges recede after 2012 (ESKOM 2008). With South Africa's generation capacity woes since 2006, it is interesting to note that it has still managed GDP growth of 5.6% in 2007 and 3.6% in 2008. What might its growth have been, had it not been constrained by rolling blackouts?

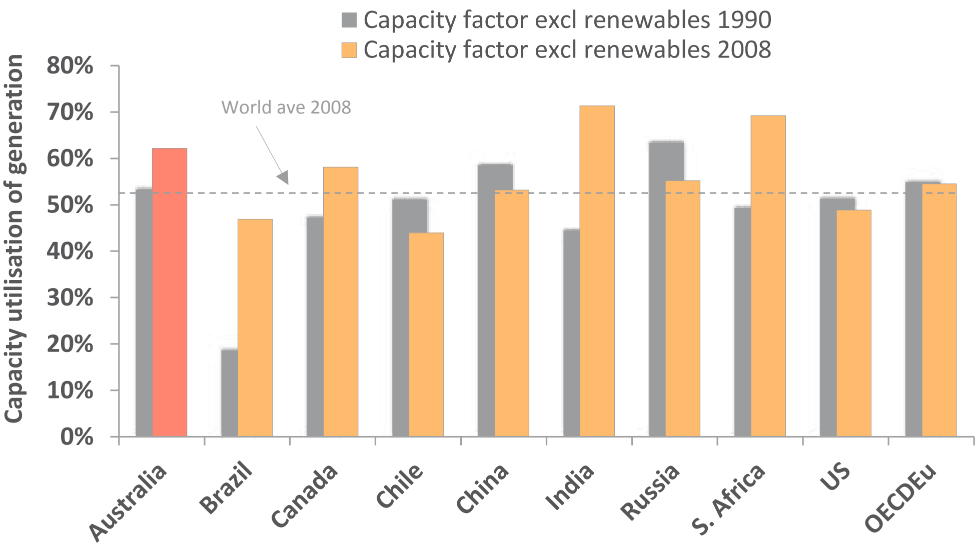


FIGURE 27: CAPACITY UTILISATION OF GENERATION

Source: (IEA 2010), (IEA 2010), (EIA 2011)

4.5 POWER AT CALL

The provision of flexible power in Australia is:-

- Provided through state based peaking plants;
- Mostly gas fired, but costly and offers no storage capability;
- Or fast reacting coal-fired power stations;
- Little power storage in the form of hydro pump storage facilities;
- Largely confined to individual states, for instance Queensland has only been interconnected with New South Wales since 2006;
- Therefore flexible power in Queensland could be vulnerable to international gas price increases.

Future requirements for flexible power in Australia

- More flexible power will be required to service
  - o More intermittent power generation
  - o Peak load growth over and above average load
  - o Electrification of transport (Electric vehicles and public transport)

4.6 INVESTMENT IN POWER INFRASTRUCTURE

To service electricity consumption growth of 64% since 1990, Australia has increased its generation capacity by 47%, its transmission lines by 14% and its distribution lines by 19%. By comparison, the US has met its 45% growth in consumption by increasing its generation capacity by 45%, transmission lines by 22% and distribution lines by 32% since 1990. Canada has increased its transmission and distribution capacity by 26% and 25% respectively, reflecting its use of the grid for electricity inter-regional trading. As an example, Canada buys up cheap power (often coal fuelled) at off-peak and sells hydro power at peak, within the country and across the border to the US. Chile's three-fold increase in generation and massive investment in transmission and distribution is all the more remarkable for having been financed and built almost entirely by the private sector.

China's investment is nothing short of astonishing. To service consumption growth of 477% it has increased its generation capacity by 464% and more than doubled its transmission and distribution lines; and yet it might have been even better. Because of perceived excess capacity in 1999, the government declared a moratorium on new capacity which was only lifted in 2002. This translated into power shortages from 2002 through to 2005, including planned power outages to industry, and enforced change of operating hours (in some cases firms were restricted to working three to four days a week, or only at night). The power shortages led to significant economic losses from supply disruptions.

In summary, investment in the power economy is essential to increasing or maintaining efficiency and resilience. China has invested massively in its power economy since 1990 to support its burgeoning industrial base. At the other extreme, an attempt at market reform in South Africa resulted in a lack of investment and a national electricity crisis. It is important to get investment levels right.

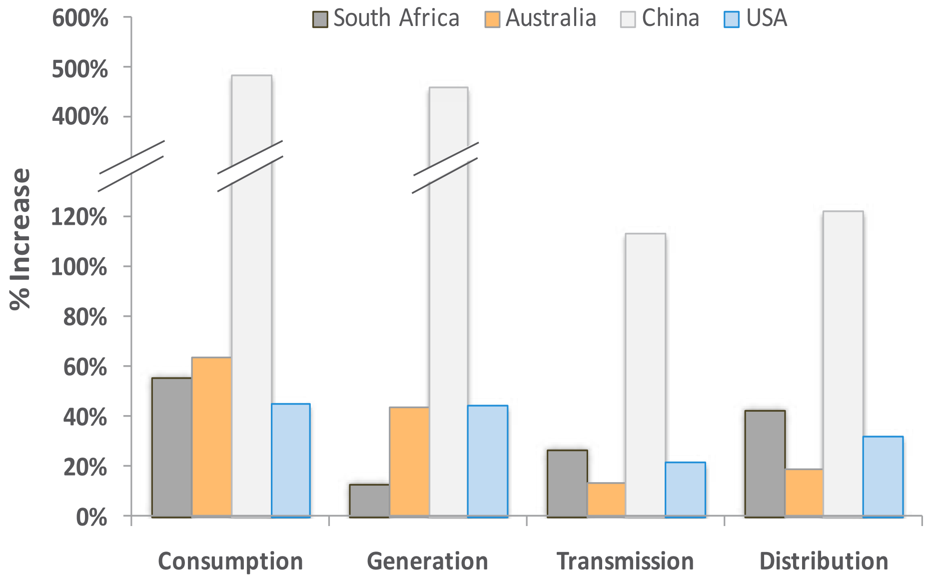


FIGURE 28: POWER SYSTEM INVESTMENT

Source: (IEA 2010), (ABS Energy Research 2010)

4.7 TRANSMISSION

Australia's National Electricity Market (NEM) transmission network has the longest alternating current (AC) transmission system in the world, supplying 200,000 GWh p.a. over the 40,000 kilometres of transmission line with its network extending 5000km from Far North Queensland to South Australia and Tasmania. In comparison to European, Asian and North American transmission networks, the NEM is considered predominantly a radial type of system than meshed (AEMO 2010).

The NEM transmission network has originally evolved from the joining of state based transmission networks, originally designed and constructed independently in the past to meet the supply needs within each state. As a result, the primary transmission voltage for each state is varied and inconsistent from state to state. For example, as of 30th June 2009, the Queensland network, being one the longest networks and the largest land mass in comparison to other states, has a 275kV primary backbone with limited 330kV and long 132kV transmission lines; while Victoria, having the smallest land mass and the most meshed network within the NEM, has a 500kV primary backbone with some 330kV and long 220kV

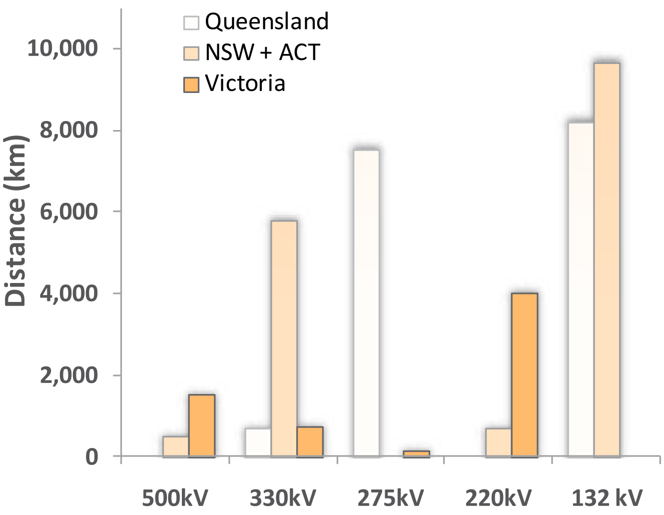


FIGURE 29: TRANSMISSION NETWORKS IN THE EASTERN STATES OF THE NEM

Source: (ESAA 2010)

networks. In between Victoria and Queensland, NSW and ACT has 330kV as the primary backbone with limited 500kV systems and long 132kV networks. The transmission distance of each voltage level in Victoria, Queensland, NSW and ACT is depicted in Figure 29 (ESAA 2010).

Australia's long distance transmission networks are primarily overhead and the NEM has very limited high voltage DC network systems. The longest high voltage DC network in the NEM is Basslink, which connects Victoria to Tasmania to transmit 600 MW of power through a 300km, 400 kV undersea / underground/overhead link.

In comparison to China, USA and Canada's, transmission networks :-

All three countries have an AC primary backbone at voltage greater than 400kV.

China has a primary backbone transmission system of 500kV with almost 22,400 km lines to connect most inter-provincial grids (Zhou). USA has 55,480 circuit km of transmission systems for 400-599 kV AC systems and 15,000 circuit km of transmissions systems at 600-800 kV AC systems (NERC 2009). Hydro-Québec in Canada maintains over 32,000 kilometres of transmission lines, with its AC 735/765 kV power lines as the main backbone of the entire transmission system.

All three countries have long extensive high voltage DC (HVDC) networks for system security. China has recently installed 660kV HVDC transmission system to transmit 4000 MW of electricity over a distance of 1,333 km (Xinhua Economic News 2011). Large scale power transmission through HVDC has been operational in the US and Canada for many years at 500 kV level, e.g. Pacific DC Intertie between Oregon to California to transmit 3000 MW of power for 1350 km, Nelson river HVDC Bipole 1 in Canada links 895 km at ±450 kilovolts from Radisson to Dorsey to transmit maximum power of 1620MW, and Bipole 2 connects through 937 km of ±500 kV line from Henday to Dorsey transferring a maximum power of 1800 MW.

From a global scale there is concern with the transmission investment per annum growths. In most countries around the world transmission investment is much lower compared to the generation investment growths. As shown in Figure 30 from 1990 to 2008, there is significantly lower growth in the transmission network in Australia compared to its competitor countries.

In conjunction with global low transmission investment growth, ageing transmission infrastructure is another concern. Many countries around the world developed their transmission infrastructures during 60's, 70's and 80's. According to the U.S. Department of Energy, 70% of the transmission lines and transformers in the US in 2006 were 25 years or older (Fitch Ratings 2006). A similar situation is evident globally and in Australia, where in 2000, 50% of substation transformers were older than 25 years (Allan 2004).

In 2010 Australian Energy Market Operator (AEMO) conducted comprehensive scenario based transmission expansion studies (optimised generation and transmission modelling) to fulfil the growth of electricity by 2030. These scenarios include carbon price volatility, inclusion of base load gas-powered and coal fired generation (with and without carbon capture and sequestration (CCS) technology), new wind and geothermal generations, new conventional CCGT generation with and without significant retirement of brown coal and (to a lesser extent) black coal generation. Based on different scenarios, different levels of reinforcement of the existing network is required to deliver gas-powered and coal-fired conventional generation in existing locations, and remotely located new renewable generation, to the major load centres (AEMO 2010).

AEMO has also introduced and studied a conceptual project called NEMLink, to significantly increase power transfer capabilities in the NEM from South Australia and Tasmania to Queensland. The NEMLink proposal considered high capacity 500 kV double circuit, AC transmission backbone connecting

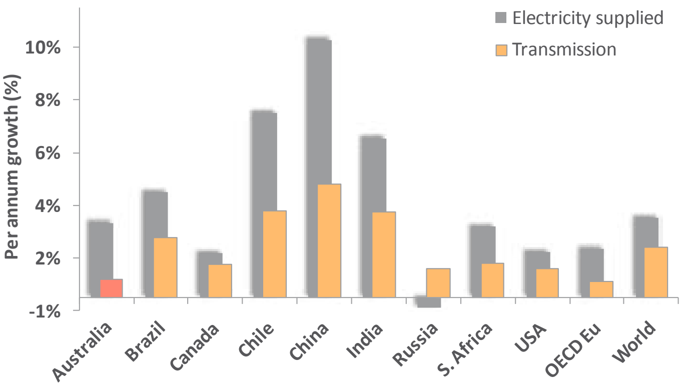


FIGURE 30: PER ANNUM GROWTH IN TRANSMISSION NETWORKS VERSUS GROWTH IN ELECTRICITY SUPPLY 1990 TO 2008

Source: (ABS Energy Research 2010)

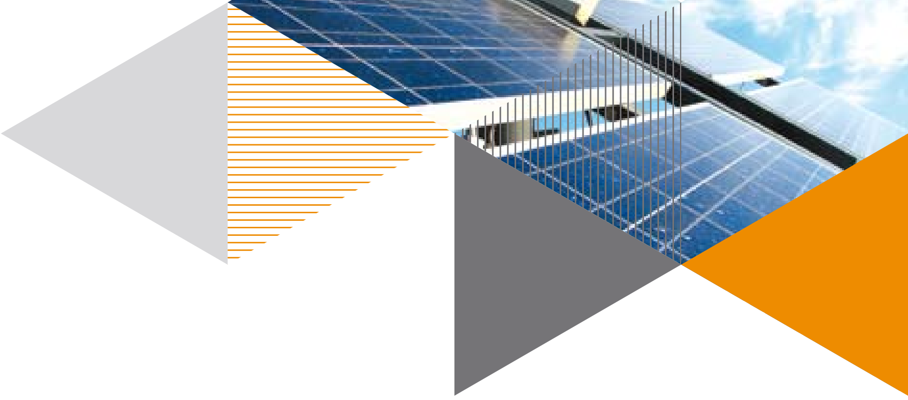
the mainland regions, and 400 kV high-voltage direct current (HVDC) connections between Tasmania and the mainland. The NEMLink project represents AEMO's study of potential extension of existing and planned regional transmission networks (AEMO 2010). The shortcoming of this viewpoint is that there is no planned expansion HVDC into transmission system and that there is still some degree of uncertainty to their model. However despite the uncertainty in the proposed NEMLink model, it demonstrates the importance of comprehensive research required towards future transmission expansion in the NEM to meet the future demand growth.

Overall it is imperative that the future expansion of the AC transmission system should be at a higher voltage level than it is currently throughout the NEM. For long distance transmission system optimised voltage level plays an important role to significantly reduce system loss and making the NEM more efficient and reliable. More long distance HVDC lines should also be considered as part of the overall expansion strategy as it can provide significant improvements in power system security to meet the future growth in electricity, in particular to transmit electricity from remotely located, renewable energy based power plants such as wind, solar-thermal and geothermal. In the next 20 years significant capital investment is required not only to deal with expansion, but also maintain the status quo of the current energy demands in the transmission system.

4.8 CONSUMPTION EFFICIENCY

"Investing in energy efficiency is often cleaner, cheaper, safer, faster and more reliable than investing in new supply" (IEA 2006). Others see energy efficiency as a "transition fuel" bridging the gap to new technologies. But companies in competitive generation markets strive for an increase in profit and revenue and therefore are focussed on maximising output. Government incentives to increase efficiency despite low cost primary energy and low cost electricity remain a requirement. Demand-Side Management provides a managed approach to support balanced load profiles and efficiency. However, low primary energy cost will continue to limit any action on efficiency measures.

Currently the Energy Efficiency Industry in Australia is immature and not well supported, although Low Carbon Australia and other publicly driven initiatives are an early start in this direction. According to Low Carbon Australia there is an efficiency improvement potential on the consumption side (residential, commercial and industrial) of 30% or more.



4.9 COST DRIVERS

There are three major factors that have influenced the cost of electricity between 1990 and 2008. Firstly, Australia has a plentiful supply of thermal coal for electricity generation. Whilst consumption of fuels by generators in the National Electricity Market (NEM) has increased by an annual average of 3%, the weighted average cost of those fuels has increased from $11.91/MWh to an estimated $12.75/MWh in 2008/09. If adjusted for inflation, the weighted average cost of fuel has decreased by an average of 2.2% per annum. During the same period, the thermal coal export values increased from $49 to $109.75 per ton (ABARES 1999; ABARES 2009) which translates to a real price increase of 1.9% per annum. Figure 31 provides a summary of the use and cost of fuel in the NEM from 1990 to 2008.

Keeping fuel costs low for local electricity generation has been possible because of a combination of coal mine ownership by generators, long term contracts with mines that reflect lower thermal coal prices and 'stranded' resources, that is resources unable to be exported because of lack of infrastructure or demand for low quality coal. Figure 32 provides an overview of coal and gas export values compared to the calculated weighted average national electricity fuel cost.

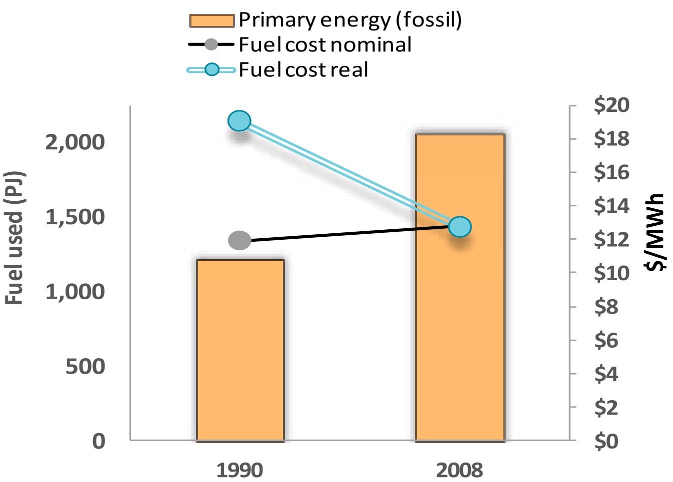


FIGURE 31: USE AND COST OF FUEL IN THE NEM 1990 TO 2008

Source: (ESAA 1994), (ACIL Tasman 2009), (AEMO 2010)

New South Wales is already starting to experience the impact of increasing global energy prices, with overnight prices for coal-fired generation now clearing at $25/MWh instead of $15/MWh in previous years. Queensland on the other hand, remains inured to increasing global energy prices due to low quality coal used in generation.

The general consensus is that generators will seek to fend off international price impacts. Whilst gas generators will be affected once existing contracts expire and infrastructure facilitates gas exports, it is considered unlikely that coal generators will be affected by a steep increase in international coal prices. Examples like the formation of an unincorporated joint venture to develop new mines in NSW to hedge against export parity prices are cited as evidence that generators will be able to continue to secure fuel at cheap domestic rates (IES 2011). Figure 33 provides an example of the generation costs as modelled by Intelligent Energy Systems (IES) for the Energy White Paper for three power plants, namely: Callide a coal fired plant; Tallawarra, a combined cycle gas fired plant; and Braemar, an open cycle gas fired plant. Callide's coal input costs are assumed to stay at domestic prices ensuring that generation cost remains at current levels into the foreseeable future. Braemar and Tallawarra's gas input costs are assumed to increase initially as long-term contracts expire and then to match international prices. The increased cost of gas-fired electricity will put pressure on end-user prices and substantially advantage coal generators over gas generators. If these projections are correct, the higher cost of gas-fired generation and the design of the electricity market will encourage generation from coal-fired generation over gas-fired generation, continuing the trend experienced from 1990 to 2008 of favouring lower cost, less efficient, higher emission generation over high cost, more efficient, lower emission generation.

The second major influence on the Australian power system has been deregulation. As a consequence the National Electricity Market has focused on low-cost generation, rather than diversification to, and investment in, more capital-intensive renewable energy technologies or efficiency measures. Australian generators were able to continue with a base-load generation infrastructure that is vulnerable to internationally driven energy prices and environmental policy. For these reasons, alternative base-load technology options like concentrated solar thermal power and geothermal power for Australia today remain in their infancy.

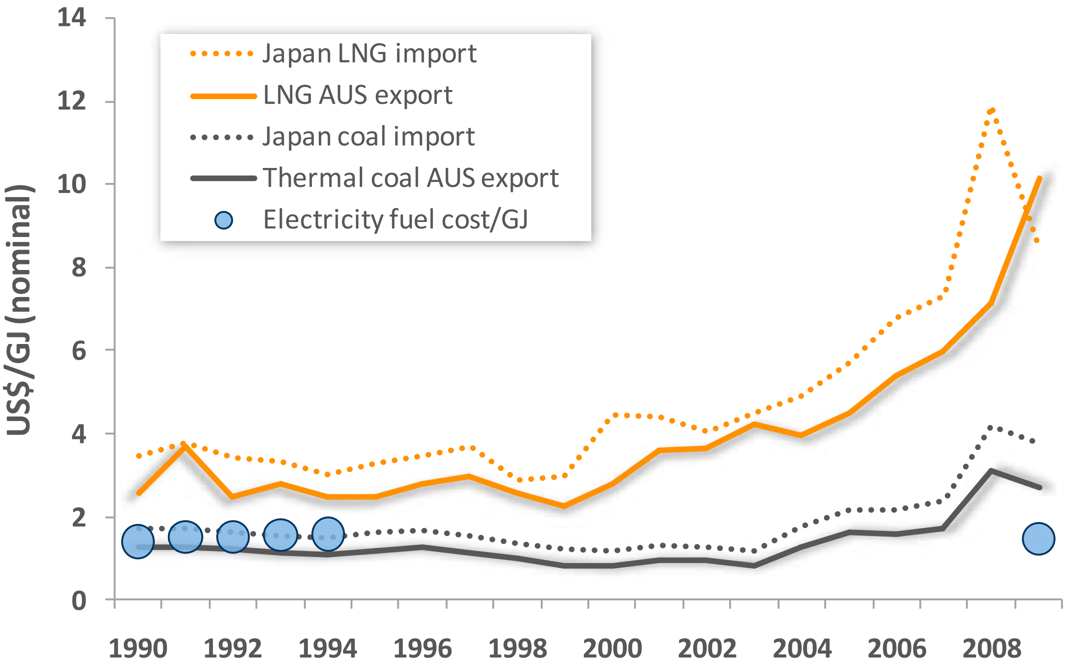


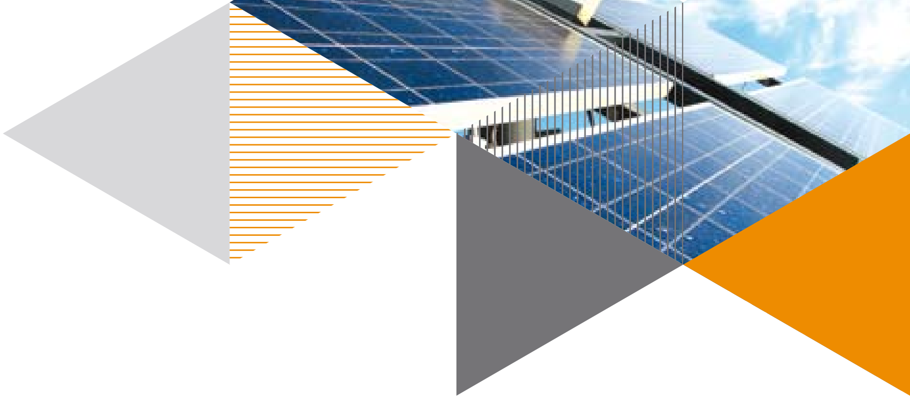
FIGURE 32: COMPARISON GLOBAL VERSUS DOMESTIC FUEL COSTS

Sources: (ABARES 1999), (ABARES 2011), (ESAA 1994), (ACIL Tasman 2009), (AEMO 2010), (BP 2010)

Deregulation has also established generation, transmission and distribution as separate entities or a combination thereof in the provision of power. Whilst generation is supplied according to price and availability, transmission and distribution tend to have monopoly power although pricing is heavily regulated. Has the Australian Energy Regulator provided a strategy for the optimisation of the entire power economy, or has it focused on cost-effective service-provision from each of the separate entities?

State governments played a substantial role in attracting energy - intensive aluminium manufacturing to Australia, including the provision of long-term preferential electricity tariffs and a variety of subsidies which made investment in Australia attractive (Simshauser 2001). With electricity tariffs negotiated as incentives by government rather than through the market, has deregulation had any effect on the attractiveness of the Australian power economy to energy-intensive industry, though? A related question would be how much incentive, or subsidisation, is offered by competitor countries to secure energy-intensive industry? Answering these questions is not within the scope of this paper, however Australia continues to extract its metal ores at increasing revenue contributions, perhaps there is a case to use this resources boom to fund electricity infrastructure and secure the metals processing and fabrication sector for the future.

The third major influence on the power system, federal and state regulation, has delivered the Renewable Energy Target (RET) to encourage investment in wind generation, and Feed-in-Tariffs (FITs) to drive investment in distributed photovoltaic (PV) power. These only occurred in any magnitude after 2008 and are continually being reset by state governments subject to budgetary constraints, providing few guarantees for long-term investment decisions. There are claims that the



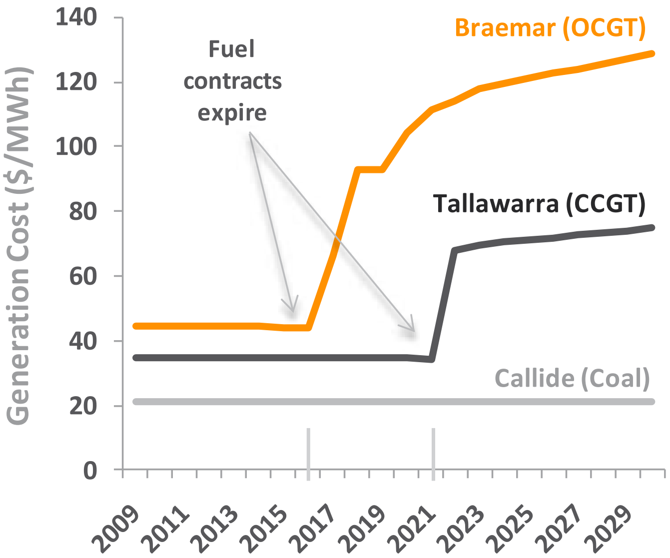


FIGURE 33: PROJECTED GENERATION COSTS (FUEL COSTS PLUS FIXED AND VARIABLE OPERATING COSTS) AS CONTRACTS EXPIRE

Source: (IES 2011)

carbon reduction benefit of the investment in PV has come at a high cost (Productivity Commission 2011) but, due to the low investment by 2008, the costs of PV are not reflected in 2008 electricity prices.

In summary, a lack of cost drivers in the provision of electricity to large consumers has negated any rationale for investment in efficiency by consumers, generators and transmitters. (This inefficiency has also made the Australian power economy more susceptible to future shocks like carbon mitigation.) Referring back to figures 10 and 11, evidence for a lack of supply efficiency improvement can be found in the increased losses between generation and consumption. With respect to consumers, the Australian Industry Group conducted an online survey in November/December 2010 and found that 67% of firms had made no efficiency adjustments over the last 5 years (AIG 2011).

4.10 ENERGY SECURITY

With a large supply of local fuels, Australia is considered to have energy security. To date international pricing has not been passed through to the Australian cost of electricity. If the black coal and gas used in the generation of electricity had been priced at global prices, the cost of fuel for the NEM in the 2008/09 year would have been considerably more. A simple extrapolation of global fuel prices ($8/GJ for gas[10] and $4/GJ for thermal coal) applied to NEM generation in 2008/09, represented in Figure 34 suggests that the bulk cost of electricity in the NEM would have jumped from $53/MWh to $74/MWh; an increase of 40%. It is not implied here that this level of cost increase could be experienced overnight, but it does provide an indication of the potential threat to Australia's power system if global market forces are brought to bear on fuel costs.

Energy security is also an issue within Australia. Interconnection weaknesses between states remain a thorny issue and are contributing to the need for increased generation capacity and thus higher investment requirements. This will need to be resolved to boost energy security.

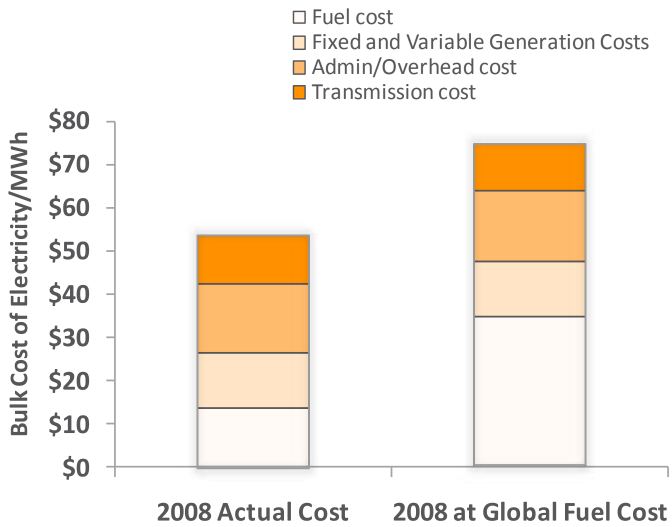


FIGURE 34: COST OF ELECTRICITY IN THE NEM IF GLOBAL FUEL COSTS ARE PAID

Source: (ACIL Tasman 2009), (ESAA 2010), (Abare 2010),(AER 2011)

[10] Gas price of $8/GJ represents the $12/GJ Japan LNG import price in 2008 adjusted to NETBACK.

4.11 TECHNOLOGY PERSPECTIVES

Thermal power generation in Australia is not efficient. Figure 35 shows the amount of energy used to produce electricity from the combustion process compared to the amount of energy supplied to consumers. As can be seen, 76% of the energy in brown coal is lost from generation to consumption, with the other fossil fuels supplying slightly higher percentages of energy from the energy used. State of the art technology could improve coal-fired thermal efficiency to in excess of 45% from the fleet average of 31%, and gas fired technology could deliver 58% thermal efficiency.

However, the use of non-renewable fuels perpetuates vulnerability to non-renwable fuel shortages and global price increases, and as shown in the coal-fired generation of electricity, fuel costs will establish a floor on the costs of electricity generation irrespective of technology improvements (McNerney, Farmer et al. 2011). For this reason, there is no simple path to follow to achieve competitive resilience. Generation reliant on non-renewable fuels will always come with potential cost increases in years to come. The provision of carbon capture and sequestration adds additional cost and only offsets the carbon emission cost associated with fossil fuels.

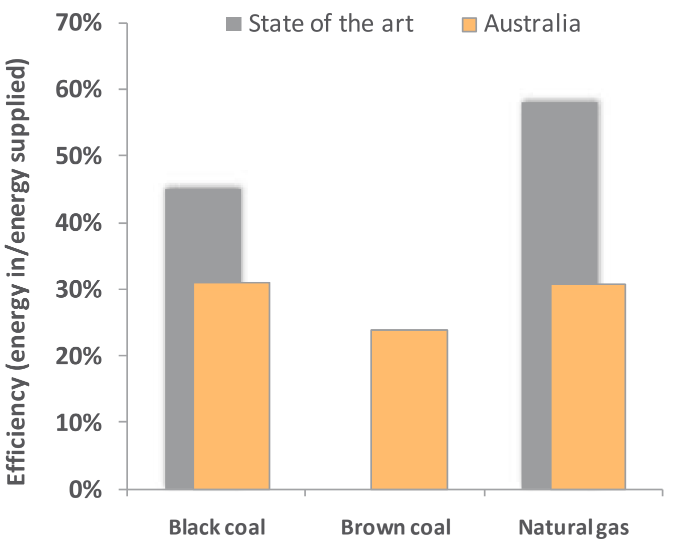


FIGURE 35: AUSTRALIAN POWER ENERGY INPUT/ENERGY SUPPLIED

Source: (IEA 2010), (IEA 2010), (ESAA 2010)

Solar and wind generated power have the potential to assume significant roles in the power systems of the future. However, they are reliant on strategies to enable the power system to integrate and manage intermittent power generation at large scale. These strategies might consist of a combination of energy storage, demand side management, bulk power trading across the NEM and dispatchable large consumers. Geothermal power could provide substantial base-load generation but it continues to struggle with technological challenges. Transmission and distribution infrastructure will influence the type and quantity of the generation fleet. Competitive resilience may only result from the pursuit of a combination of options subject to a clear vision of a target position. In the following sections we summarise the strengths, weaknesses and key features of the technology options available to diversify the supply base.

4.11.1 Power Generation: Solar Photovoltaic

There are two basic types of solar energy generation technology: solar photovoltaics where solar photon energy is directly converted into electricity in a semiconductor material; solar thermal in which the sun's energy is converted into heat, steam and ultimately into electricity. Solar PV is a modular technology and is applicable from small, distributed domestic scale up to utility. Electricity generation based on solar thermal technologies requires a high temperature delta in order to achieve reasonable energy and capital efficiency. Scale effects through utility size are critical for viability.

Solar PV technology status

A small number of relatively mature solar PV technologies dominate the market, namely: crystalline silicon (c-Si); amorphous thick film silicon (α-Si); and thin film cadmium telluride (CdTe). Emerging technologies such as thin film copper indium gallium diselenide (CIGS), thin film copper indium diselenide (CIS), and concentrating high efficiency triple junction (CPV) are predicted to gradually erode market share of the generation 1 silicon technologies over the next 5 years (currently ~ 80% c-Si). Costs for PV modules have dropped considerably in recent times and have more than halved in the past 2 years. Current module prices for c-Si and CdTe are now < $2/W with manufacturing costs < $1/W. Correspondingly the utility-scale "system" prices (including all balance of systems) have now dropped to < $4/W meaning an estimated LCoE over plant lifetime of $200-$300 / MW h dependent upon location, financing costs, etc. World production capacity for

PV exceeded 16GW in 2010 with estimated cumulative installed capacity of 40GW. The firm-prediction of production capacity in 2011 is 22GW with an associated ~$7B of capital investment in manufacturing capability. Looking forward, this exponential growth is set to continue with sub $150 / MW h being plausible by 2015. The European PV Industry Association predicts a total global installed capacity of between 130 and 190 GW in 2015. The IEA predicts a global installed capacity in excess of 400 GW by 2035.

The SWOT analyses below provide a synopsis of the PV potential to assume a significant role in future power economies.

SWOT - Photovoltaics - utility size

Strengths
- Renewable, operation CO_2 free
- Technology mature, 40GW in operation (2010)Grid parity expected in 7-10 yrs.
- Scale versatility 10 W – 1000 MW
- Direct energy conversion
- Excellent resources in Australia

Weaknesses
- Intermittent and partly dispatchable without storage or backup
- Energy intensive production but energy payback now <2 years and falling
- Capital intensive for installation

Opportunities
- PV hubs > 500 MW
- Natural hedge against fossil fuel prices
- Potential to defer or replace grid augmentation

Threats
- Dedicated Transmission infrastructure, generation capacity often distant to load centers
- Integration of larger intermittent PV capacity requires increased costly flexible control energy (peaking capacity)
- Technical challenges of power systems need to be explored for large scale PV

SWOT - Photovoltaics - decentralised

Strengths
- Renewable, operation CO_2 free
- Technology mature
- Grid parity expected in < 5 yrs For domestic and commercial/industrial
- Scale versatility
- Reduction of Distribution grid load
- Excellent resources in Australia
- Low loss - proximity generation consumer

Weaknesses
- Intermittent and non-dispatchable without storage or backup
- Institutional change - PG with consumer
- Capital intensive - low scale

Opportunities
- Deferred Distribution grid investments
- PV decentralized power generation
- Natural hedge against fossil fuel prices
- Commercial/industrial scale PV well suited for scale and load profile reasons

Threats
- If large capacity is installed - back-up through full capacity network or energy storage required
- Technical challenges of power systems need to be explored for dispersed uncontrolled PVs

Technology Deployment: Solar PV

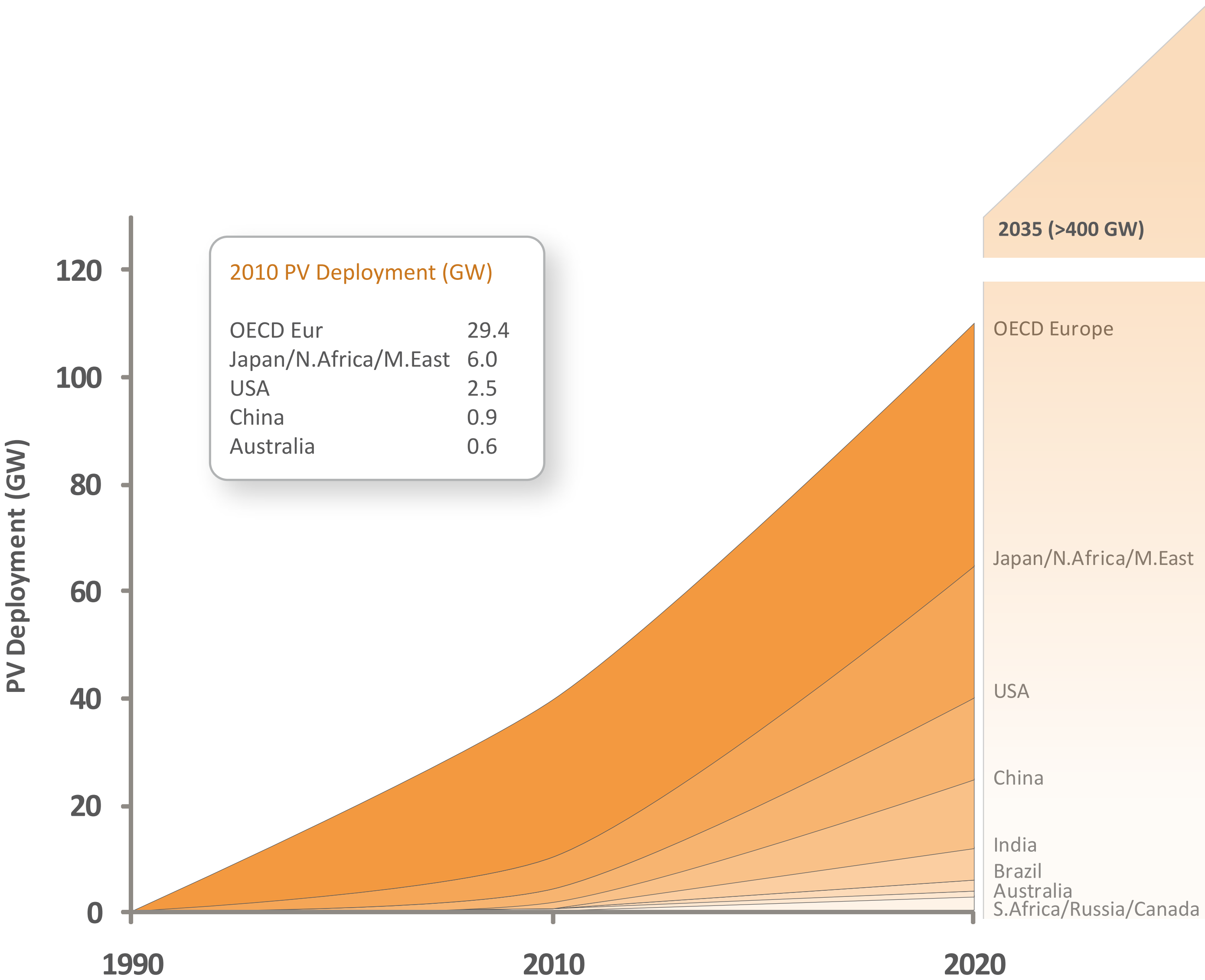


FIGURE 36: GLOBAL PHOTOVOLTAIC DEPLOYMENT

Source: (IEA 2010)

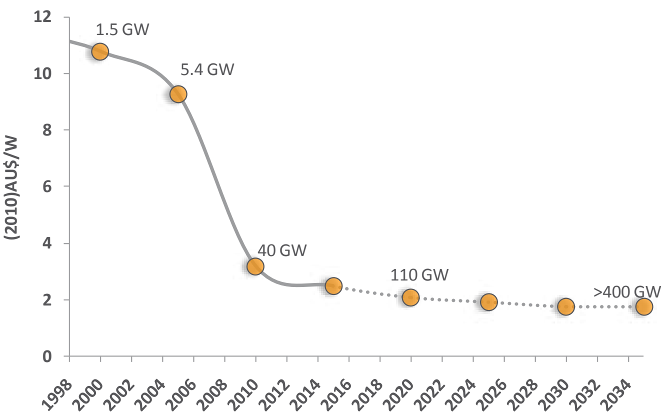


FIGURE 37: PHOTOVOLTAIC MODULE COST TREND 1993 TO 2035

Source: (Australian PV Association 2011), (IEA 2010), (NREL 2010), (Brown 2011), (European PV Industry Association 2011)

4.11.2 Power Generation - Solar Thermal

Concentrating Solar Thermal technology status

Concentrating Solar Thermal (CST) technology is also relatively mature with the first utility-scale plants built in the 80s (Solar Energy Generating System in the Mojave Desert) in response to the oil crisis. Irrespective of the exact “flavour” of the technology, CST relies upon using tracking mirrors to concentrate the sun’s energy in a line or point focus onto an absorbing heating element. Variants of CST concentrating elements include linear parabolic trough, compact linear Fresnel reflectors, heliostatic tower and solar concentrating dish (the latter two being higher temperature point focus systems and the former two being line concentration systems). The concentrated solar energy can be used to heat a working fluid, create steam and drive a turbine (or equivalent engine), or, in the high temperature case a more efficient thermodynamic process or chemical reaction. CST technology has the stated advantage of being able to provide base load power using relatively low cost and simple thermal storage approaches with high specific heat capacity materials such as molten salt or graphite block. Furthermore, the thermal steam process has direct synergies with standard coal and gas generation with strong potential for low carbon augmentation (as per the Kogan Creek Solar Boost Project which will improve the efficiency of the power plant by using solar technology to heat feedwater for the boiler). Current global installed capacity of CST is - 1.2GW (2011) with the largest plants in the 50-100MW range. The Solar Dawn consortium will soon commence building Australia’s largest CST plant in 2012 (250MW also at Kogan Creek in Queensland) and the Ivanpah Solar Electric Generating System in California’s Mojave Desert (BrightSource) is currently the largest plant under construction (392MW). Due to the relatively low levels of installed capacity, the CST LCoE is relatively high ($200 - $300MW h) but like PV, this is due to drop as the estimated 17.5GW of current projects globally are built and commissioned over the next 5 years. The IEA predicts a global installed capacity of 91 GW by 2035.

The SWOT analysis below provides a synopsis of the solar thermal potential to assume a significant role in future power economies.

SWOT – Solar Thermal

Strengths
- Renewable, operation CO_2 free
- Technology advanced, 1.2 GW in operation
- Grid parity expected in 5-10 yrs.
- Heat storage simple technology
- Excellent resources in Australia
- Very suited to thermal plant augmentation
- Very suited to gas/coal hybrid and synergistic with geothermal

Weaknesses
- Intermittent and partly dispatchable unless hybridised or used with storage
- Large scale essential for cost advantages

Opportunities
- CSP hubs > 1 GW
- Natural hedge against fossil fuel prices
- Efficiency booster for CFPP (coal)
- Synergies with CCGT

Threats
- Dedicated Transmission infrastructure
- Larger capacity – requires Integrated Transmission Network, back-up generation or storage

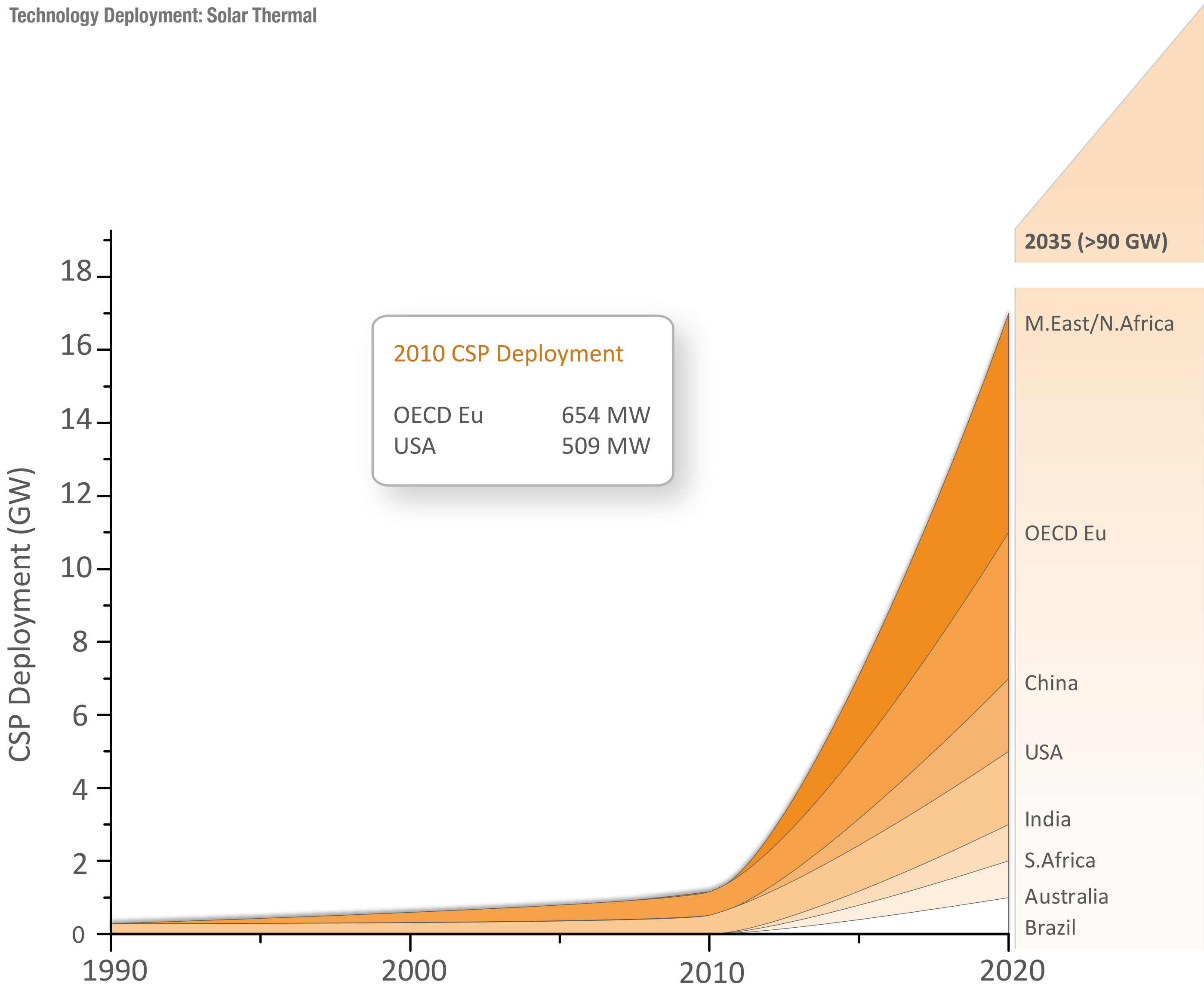


FIGURE 38: GLOBAL DEPLOYMENT OF CONCENTRATED SOLAR THERMAL

Source: (SEIA 2011), (IEA 2010)

4.11.3 Power Generation - Wind

Wind generation technology status

- Global installed wind generation capacity was 197GW in 2010
- On-shore and off-shore wind-farms have reached utility scale (London array, offshore 1000MW)
- Intermittent generation requires system integration, transmission capacity and energy storage
- Significant deployment has led to cost reductions and efficiency improvements reaching grid parity in many regions with strong wind resources
- In the Australian context, South Australia has good to excellent resources but grid strength and the grid interconnection with other states constrain greater levels of deployment at this point in time.

The SWOT analysis below provides a synopsis of the wind generation potential to assume a significant role in future power economies.

SWOT – Wind

Strengths
- Renewable, operation CO_2 free
- Technology mature, 200 GW in operation
- Grid parity reached or close
- Good wind resources in Southern Australia

Weaknesses
- Intermittent and non-dispatchable
- Large scale required
- Visual
- Noise

Opportunities
- Wind farms on-/off-shore > 1 GW
- Natural hedge against fossil fuel prices

Threats
- Dedicated Transmission infrastructure, as generation capacity often distant to load centers
- Integration of larger wind generation capacity requires increased flexible control energy (peaking capacity)

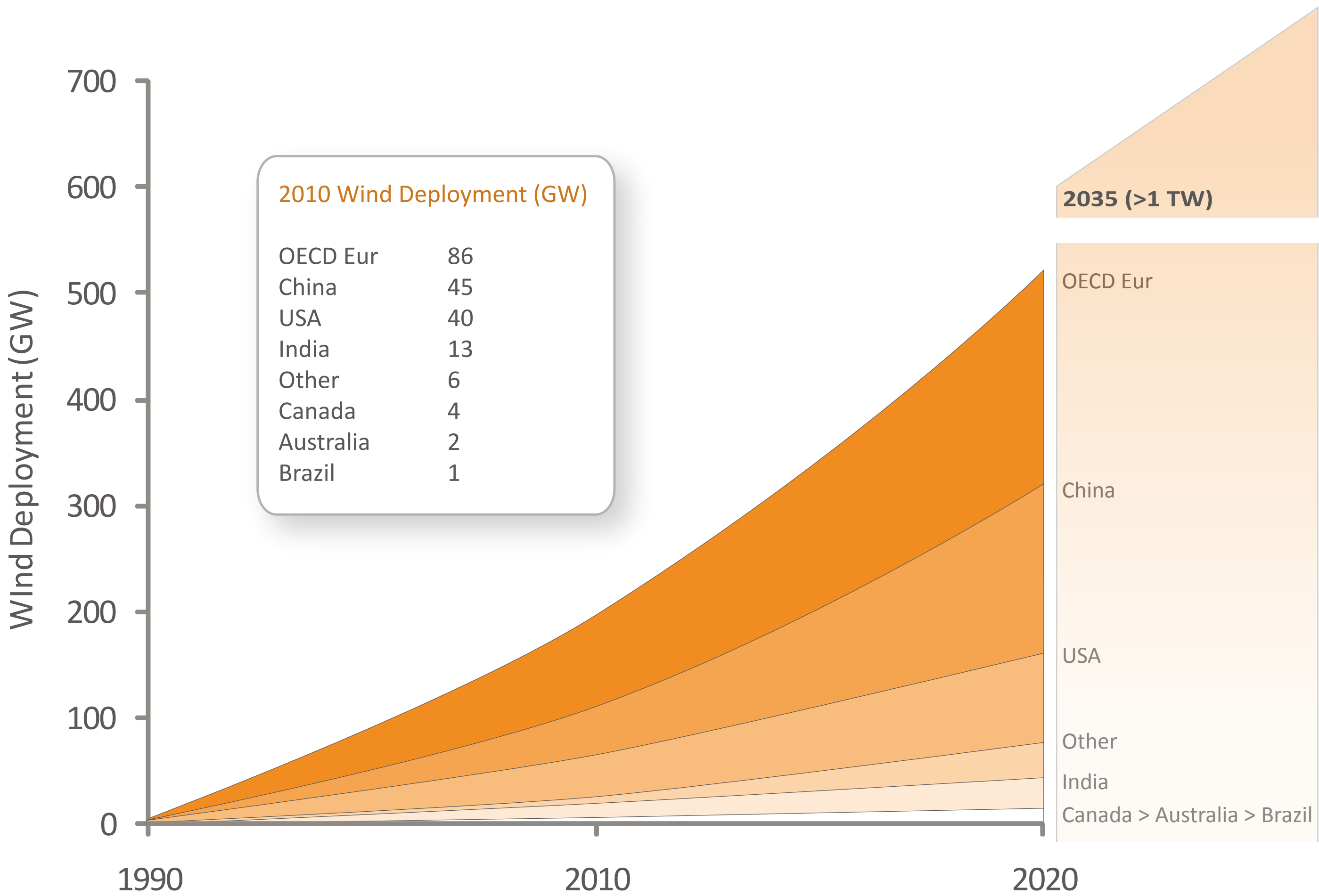


FIGURE 39: GLOBAL WIND DEPLOYMENT

Source: (IEA 2010), (UNData 2011)

4.11.4 Energy/Electricity Storage - Utility Scale

Electricity storage technology status

- A key functionality of energy storage facilities is to provide and absorb flexible energy (power). That means the storage reacts similarly to a rapid response power plant in peak-load situations and like a dispatchable large consumer in times of power oversupply.
- Large scale storage technologies are of key importance as they can provide flexible control energy to backup intermittent generation technologies; increase grid reliability; reduce peak demand and most importantly improve asset utilisation. There are currently many research and development programs, however current capacity is insufficient to make any impact on networks.
- Globally, hydro pump storage facilities amount to 127 GW and pump storage is the only reliable storage technology of utility scale today. Of this amount, Australia has 1.5 GW of hydro pump storage with little opportunity for any additional large scale projects.
    - Other potential storage technologies include: Physical: air pressure storage; heat storage (molten salt, basalt, water);
    - Electro-chemical: batteries (lithium);
    - Chemical storage: production of hydrogen, methane, methanol
    - Electrical: super conducting coils.
- Air pressure and heat storage have lower efficiency, battery storage is capital intensive, and the remaining technologies are at an early stage of development although US stimulus funding may catalyse new storage demonstrations by 2012.
- An IEA working paper predicts 100-150GW of additional global storage capacity will be needed by 2035 to balance power systems- if renewable intermittent sources contribute around 20% of power. However, based on the data shown in Figure 40, Australia will not contribute to the additional amount required until after 2020.

The SWOT analysis below provides a synopsis of the electricity storage potential to assume a significant role in future power economies.

SWOT – Electricity / Energy Storage - Utility Scale

Strengths	Weaknesses
• Large scale, fast, flexible controlled energy • Power provision and absorption • CO_2 free, emission free • Modular, so can be scaled up if required	• Limited hydro resources, being the most mature technology, available in Australia • Capital intensive, long project horizons • Large land footprint required close to the source of generation
Opportunities	**Threats**
• Ensures supply meets demand • Facilitates system integration of intermittent power generation • Other physical and chemical storage technologies are emerging	• Insufficient hydro storage capacity in Australia • Alternative storage technologies are immature • Size of Australian market is a deterrent to some suppliers

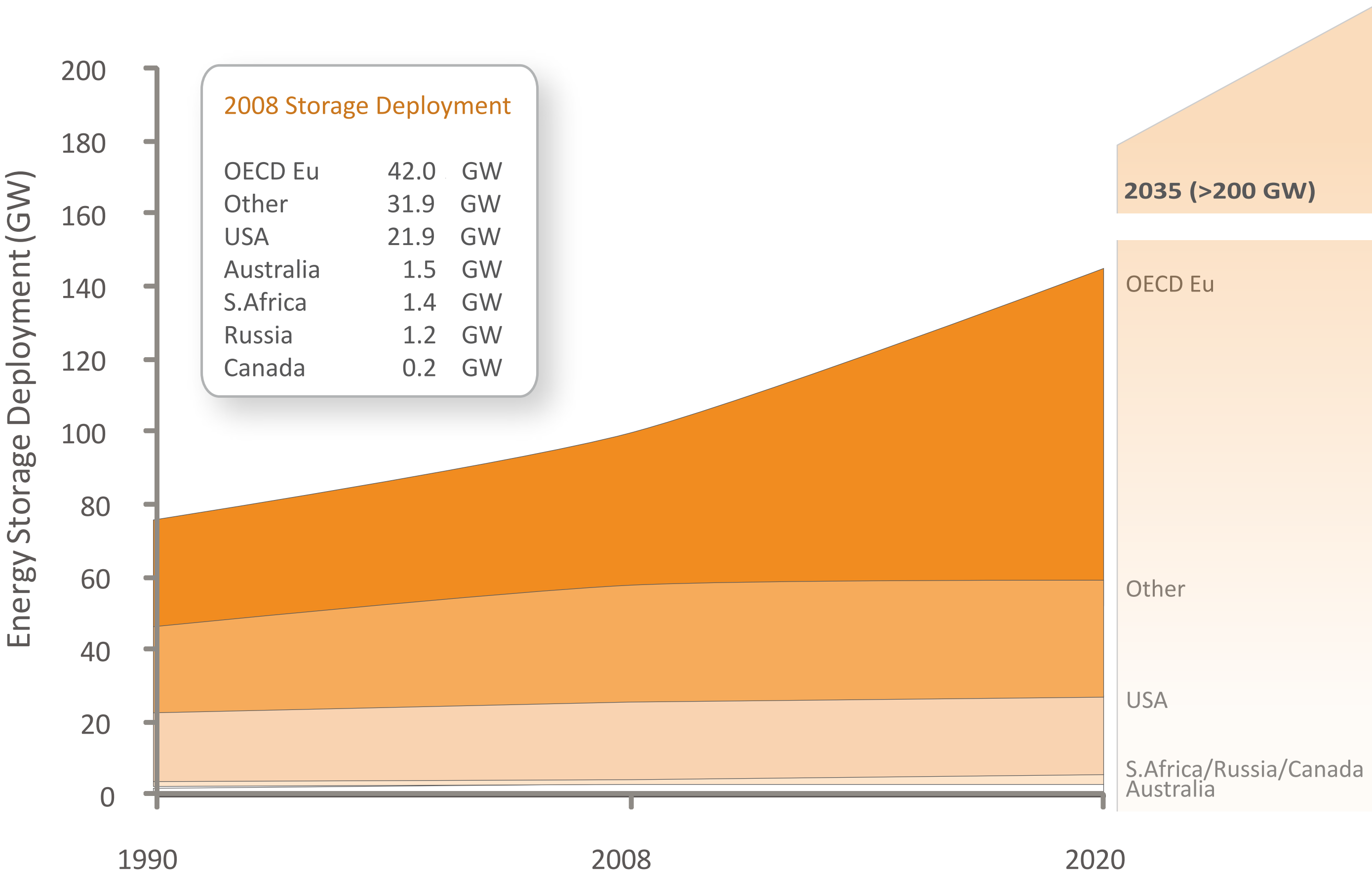


FIGURE 40: ELECTRICITY ENERGY STORAGE DEPLOYMENT

Source: (IEA 2010), (EIA 2011), (Inage 2009)

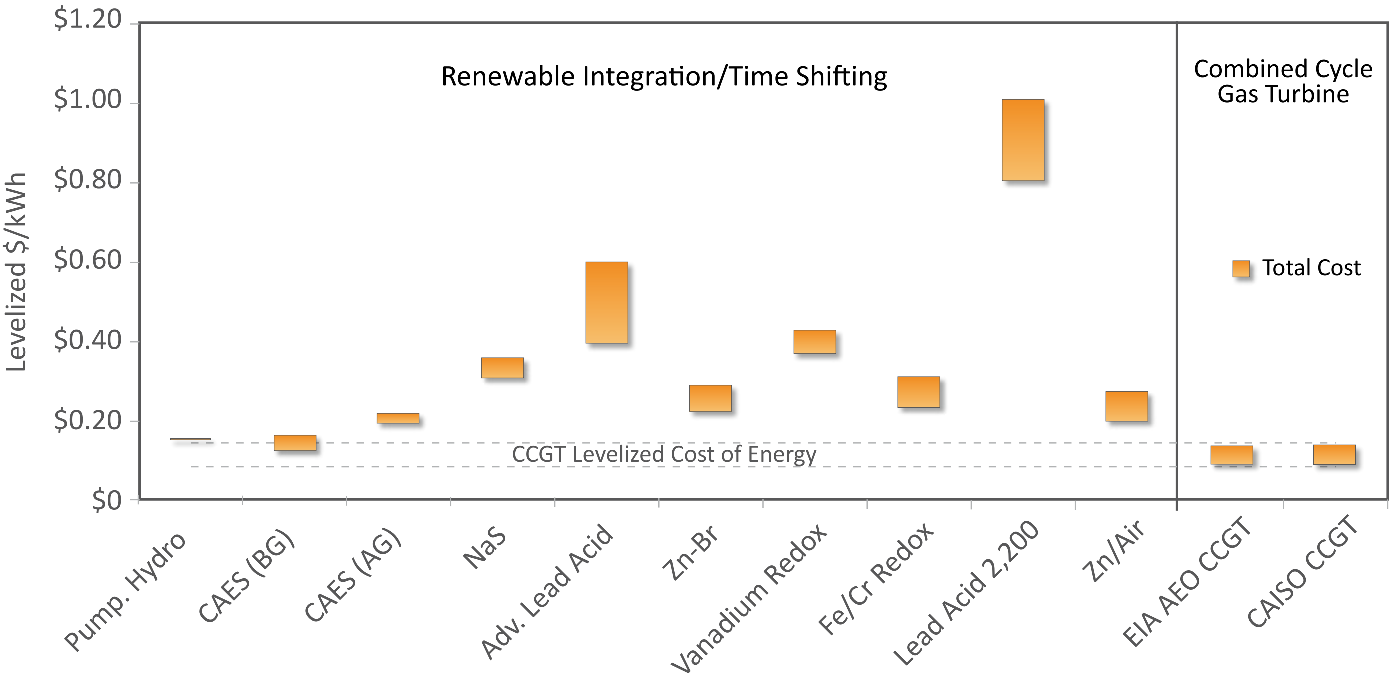


FIGURE 41: LEVELISED COST OF DELIVERED ENERGY FOR ELECTRICITY STORAGE

Source: (EPRI 2010)

One of the main barriers to deployment of storage is the levelised cost of delivered energy using storage as shown in Figure 41. This indicates that currently only hydro pumped storage and compressed air are in a position to compete with CCGT as an option for integration and power quality issues associated with the introduction of higher levels of renewables.

4.11.5 Power Generation - Geothermal (Hot Dry Rock (HDR) or Enchanced Geothermal Systems)

Geothermal technology status

- Geothermal energy is capable of contributing large-scale, low-emission base load power. At present there are technical and cost barriers to large scale implementation. These are expected to be able to be overcome in the medium term.
- HSD - Hot sedimentary aquifers are only viable in regions with district heating markets.
- HDR – Hot Dry Rock or EGS – Enhanced geological systems provides potential for higher temperatures and therefore higher efficiencies however there are only a handful of small power plants operating today.
- To improve efficiency rates, staged steam cycles such as binary cycles or kalina cycles are required which increases technological complexity and investment costs.
- The IEA predicts relatively small global deployment due to the location of the resource. However there is significant available resource within Australia to make a significant contribution but it will be constrained by network infrastructure requirements.

The SWOT analysis below provides a synopsis of the geothermal potential to assume a significant role in future power economies.

SWOT - Geothermal

Strengths
- Baseload, renewable, CO_2 free
- Technology proven, 11 GW in operation
- Synergies with heat based generation technologies, i.e. solar thermal, CCGT
- Excellent, large geothermal resources in Australia's uninhabited areas
- Primary energy inherent

Weaknesses
- Limited hydro resources, being the most mature technology, available in Australia
- Capital intensive, long project horizons
- Large land footprint required close to the source of generation

Opportunities
- Geothermal hubs > 5 GW
- Natural hedge against fossil fuel prices
- Synergies with solar-thermal technologies
- Could facilitate an Integrated Transmission Network in Australia

Threats
- Insufficient hydro storage capacity in Australia
- Alternative storage technologies are immature
- Size of Australian market is a deterrent to some suppliers

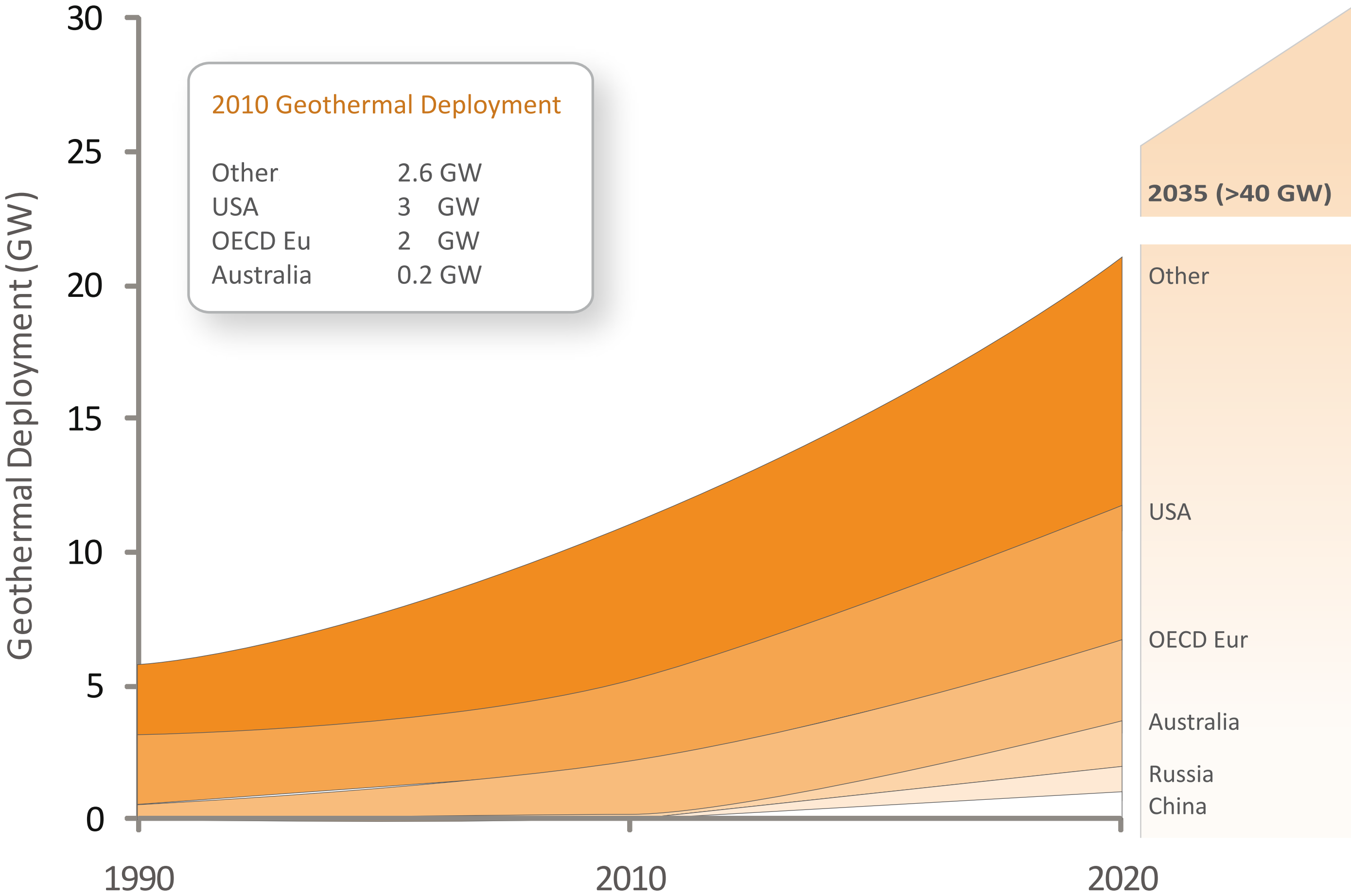


FIGURE 42: GLOBAL DEPLOYMENT OF GEOTHERMAL

Source: (IEA 2010), (UNData 2011)

The Australian Government believes that geothermal energy will make a significant contribution to Australia's Renewable Energy Target by 2020. However, as shown in Figure 42, due to the long lead periods required to establish geothermal generation facilities and the current lack of network infrastructure from the areas where the greatest resources are located, the majority of the growth to 2035 will occur post-2020.

4.11.6 Power Generation – Nuclear

Nuclear technology status:

- The lifecycle cost has been shown to be very high, and disposal of spent fuel and decommissioned power plants remains problematic.
- Renaissance of Nuclear Power is limited to countries, where state owned utilities or governments shoulder the risk.
- Substantial risks associated with fuel supply, operational costs and decommissioning
- Decommissioning costs are not part of cost calculations today.
- Australia has substantial viably extractable Uranium resources (i.e. Olympic dam)
- Technology competence centres: US, Germany, France, UK, Russia, Japan
- 2010: Reactors in operation 443, under construction 62, planned 140
- Number of reactors expected to decline by 20% in 2020
- Fuel price impact on generation cost is as low as 10%
- In Germany the development and decommissioning of nuclear power technology is heavily subsidised.

The SWOT analysis below provides a synopsis of the nuclear potential to assume a significant role in future power economies.

The SWOT analysis below provides a synopsis of the nuclear potential to assume a significant role in future power economies.

SWOT - Nuclear

Strengths
- Baseload Power
- CO_2 free, emission free
- Technology mature
- Long-term availability of fuel

Weaknesses
- Capital intensive
- Technology intensive
- Financial risks beyond private enterprises capabilities
- Unsolved waste storage technology
- Generation cost (~100$/MWh), excluding decommissioning
- Decommissioning 15 yrs, $5 billion
- Large scale required

Opportunities
- Reliable Baseload Power
- Potential hedge against fossil fuel prices
- Possible bridging technology

Threats
- Small risk of failure, but with potentially catastrophic consequences
- Absorption of financial and technical resources

Technology deployment: Nuclear

- 57GW under construction: 25GW in China, 8GW in Russia, 6GW in Korea, 4GW in India,
- 59GW planned: 15GW in China, 13GW in Japan, 10GW in Korea, 8GW in Europe, 6GW in UAE

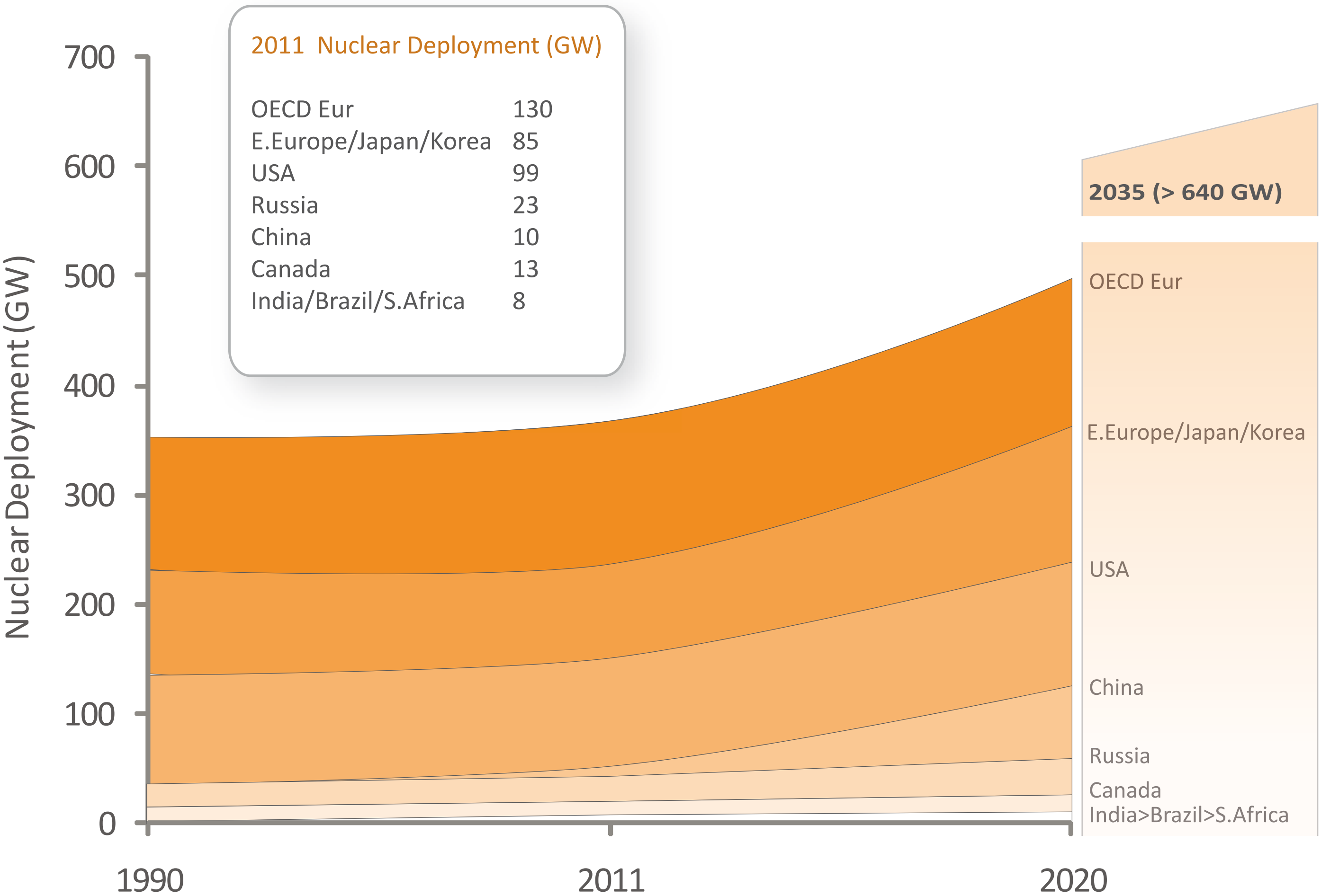


FIGURE 43: GLOBAL DEPLOYMENT OF NUCLEAR

Source: (UNData 2011), (IEA 2010)

4.11.7 Carbon Dioxide Capture and Storage

Carbon capture and storage technology status

- Carbon Capture and Storage is an Energy Intensive Process:
  - o Sequestration – Carbon Capture (pre- and post-combustion) 0.2 MWh/t CO_2
  - o CO_2 Transportation 0.1MWh/t CO_2/400km
  - o Treatment and storage 0.15 MWh/t/CO_2
- Molecular dimension of Hydrocarbons (small) and CO_2 (large) differ substantially
- With CO_2 storage, oxygen is also stored under ground
- Significant infrastructure requirements
- There are a few small pilot programs in early stages of testing

The SWOT analysis below provides a synopsis of Carbon capture and storage potential to assume a significant role in future power economies.

SWOT - Carbon Capture and Storage - CCS

Strengths	Weaknesses
• Enables low carbon fossil fuel based power generation • Pre- and post-combustion carbon sequestration technologies are proven	• CO_2 sequestration, transportation and storage is energy intensive • Electrical efficiency of fossil power station reduced by 30-50 % • Capital intensive infrastructure - comparable to reversed natural gas infrastructure • Storage technology - experimental
Opportunities	**Threats**
• Possible bridging technology • CO_2 recycling	• Consumption of financial and technical resources

Technology Deployment: Carbon capture and storage

- Related use of the carbon capture technology has been deployed to improve gas and oil extraction in eight Carbon Capture plants currently in operation, capturing carbon from gas fields and fuel processing plants with 2.7 million tonnes of carbon per annum reinjected into reservoirs and 21.5 million tonnes of carbon per annum used for enhanced oil recovery
- A 450 MW Integrated Gasification Combined Cycle Power Plant (gas turbine) with pre-combustion carbon capture is in planning (RWE, Muehlheim, Germany)
- According to the Global Carbon Capture and Storage Institute, current projects planned could result in total capture and storage of carbon from 29GW of power plants before 2020

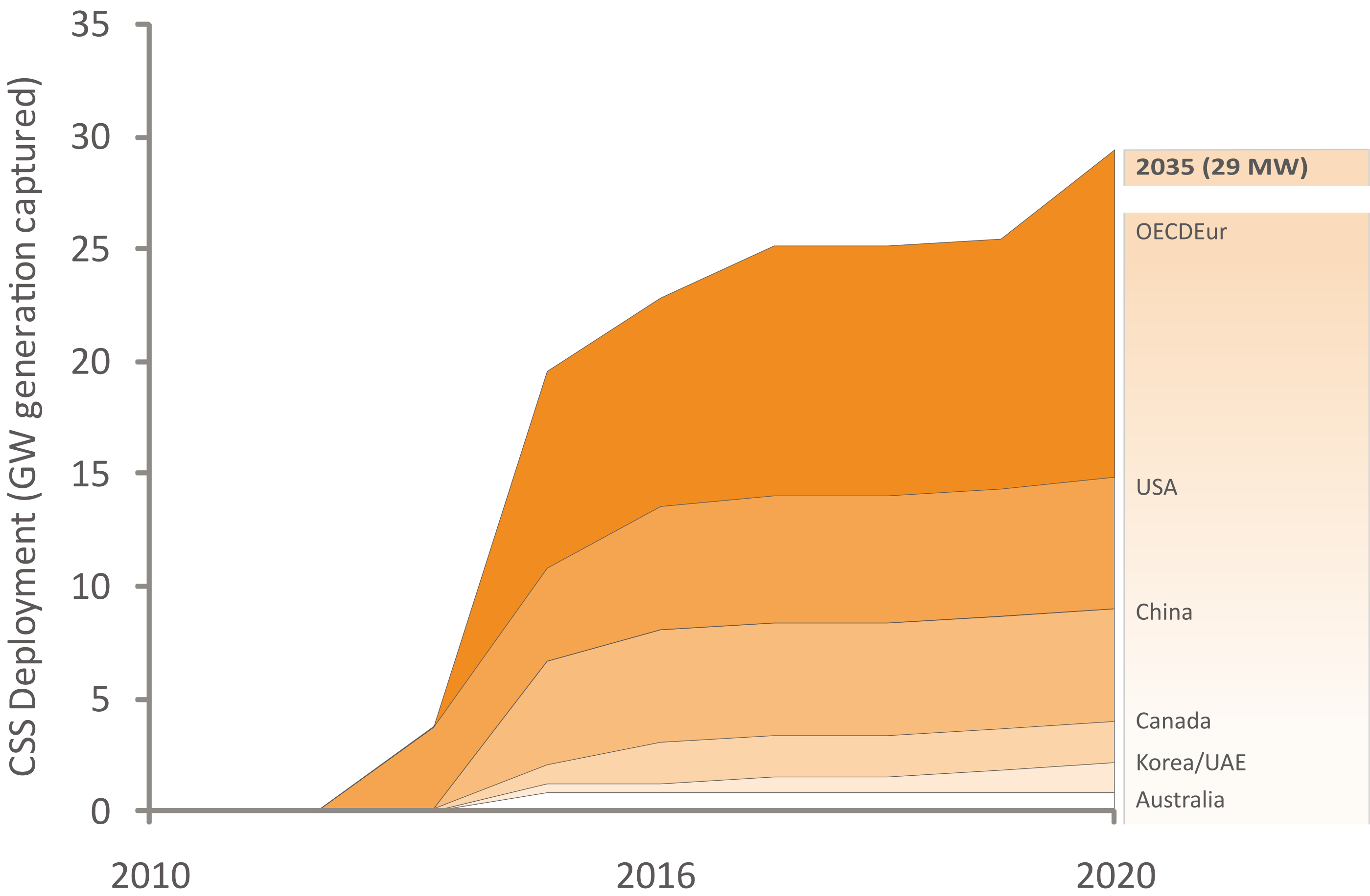


FIGURE 44: GLOBAL DEPLOYMENT OF CCS

Source: (GCCSI 2011), (IEA 2010)

4.11.8 Comparative Costs of Technology Options

It is a complex task to compare the absolute costs of electricity from various technologies. One of the more common, accepted methodologies is the Levelised Cost of Energy (LCoE) which seeks to provide a single cost price for every KWh of electricity for the plant's useful life.

We have performed an LCoE analysis on the technologies discussed in this section based on a range of overnight and operating costs provided by ESAA, Worley Parsons, AEMO, ACIL Tasman, Georgia Power and EPRI. Figure 45 provides a comparison of the levelised costs for the technologies today based on a gas price of $4/GJ, a coal price of $1.50/GJ, a uranium price of $0.83/GJ, a $23 /t$CO_2$e carbon price and a $40 REC price until 2020.

The bar in the middle of each option provides the average of those projections. Evidenced by the escalation of wind power deployment around the world, wind power generation is now within reach of the coal and gas fired generation cost.

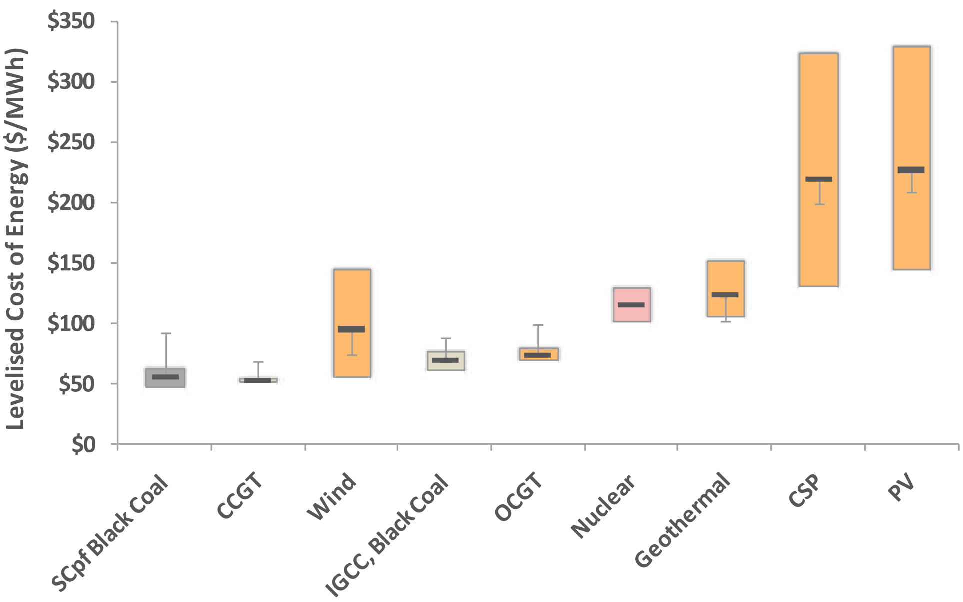
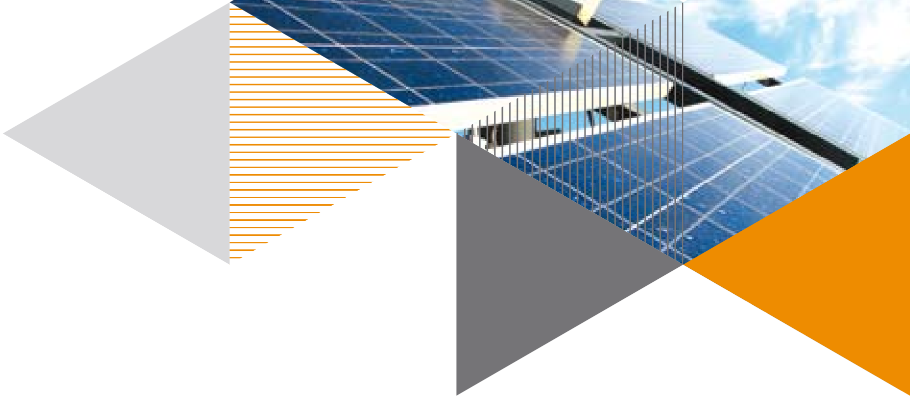


FIGURE 45: LEVELISED COST OF ELECTRICITY: TECHNOLOGY COMPARISON (GAS $4/GJ, COAL $1.50/GJ, URANIUM, $0.83/GJ, $23 CARBON PRICE, $40 REC)

Source: (Wagner and Foster 2011)



Geothermal offers cost effective potential but needs to overcome its implementation challenges. Nuclear too provides cost effective potential but needs to overcome its uninsurable risk and storage challenges. The solar technologies still present a cost challenge but with the projected deployments around the world, prices should reduce substantially.

Figure 46 provides a comparison of the levelised cost of electricity for the major technology types relative to their emissions intensity. As with figure 45, it can be seen that the levelised cost of (emission free) wind power is now almost on a par with the levelised cost of (interim emissions intensive) open cycle gas turbine power generation. Wind power, however, doesn't generate base-load power. Nuclear and geothermal offer emission free base-load power, but are plagued with insurance and waste risks for nuclear and technological risk for geothermal. Solar thermal with storage is, at this stage expensive but, the only risk-free technology available for emission free base-load power generation.

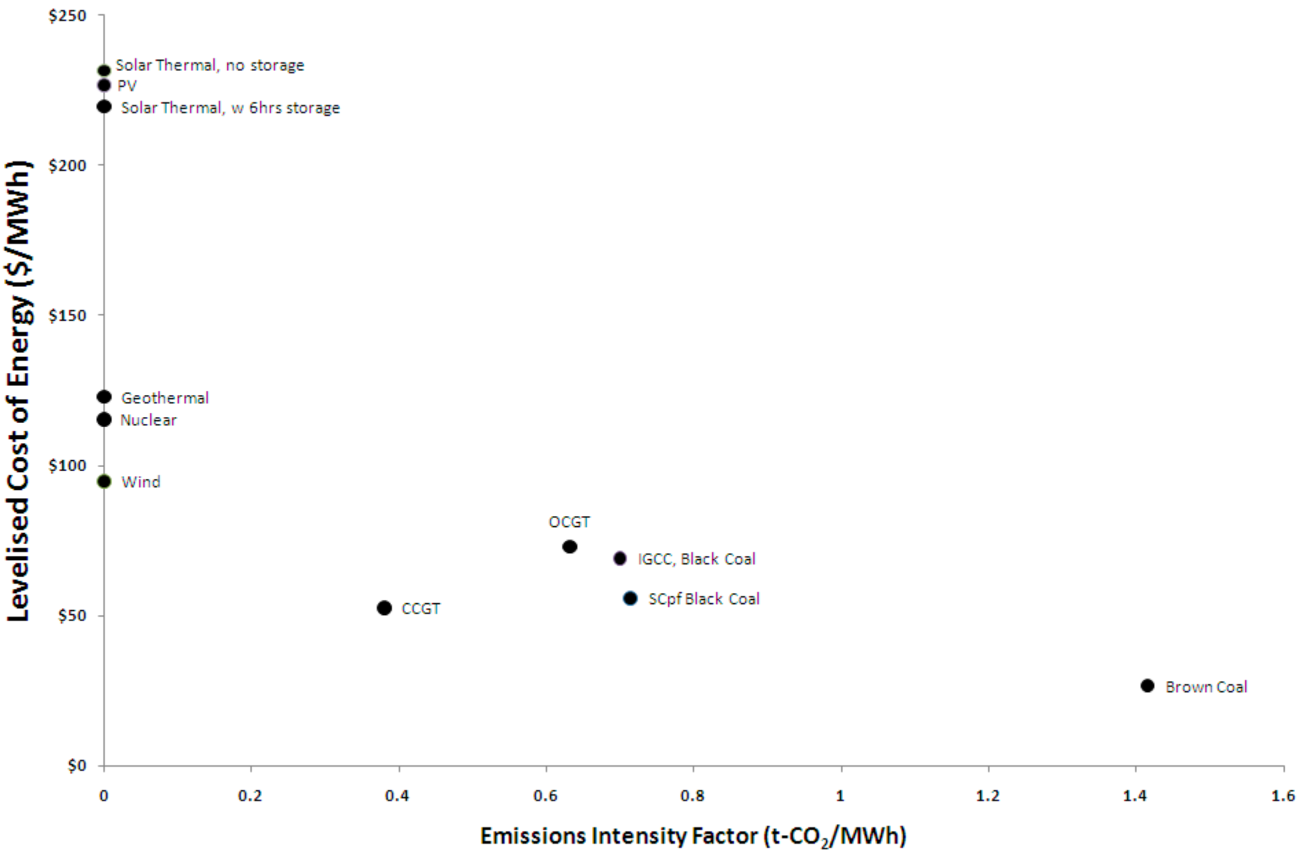


FIGURE 46: LEVELISED COST VERSUS EMISSIONS INTENSITY

Source: (Wagner et.al 2009)

5 POWER ECONOMY RISK PROFILE - A LOOK TO THE FUTURE

Australia needs to offer a competitive power economy to attract energy-intensive industry. Historically, offering a competitive power economy enabled Australia to attract investment after the oil shocks of the 1970, and as a result build an electricity backbone for capital intensive industry. How prepared Australia, and its competitors, are for the shocks of the future, is represented in Figure 47 based on the IEA's modelling.

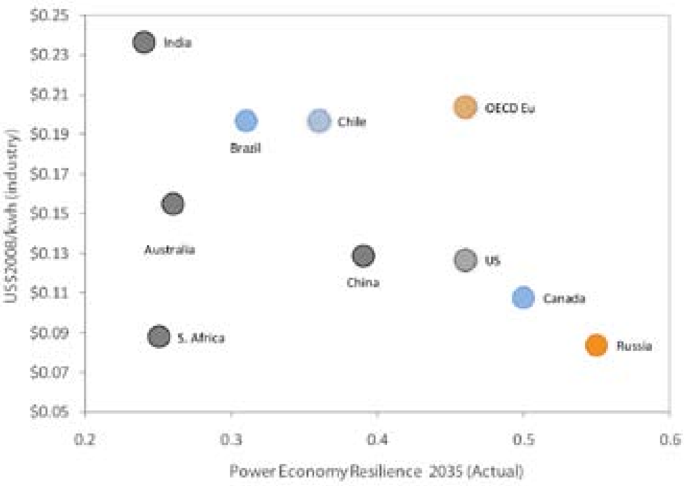


FIGURE 47: POWER ECONOMY RESILIENCE 2035

Source: (IEA 2010), (ESKOM 2008), (ESAA 1994), (ABS 2011), (IEA 2011)

How the look to the future shows Australia's risk profile.

- Australia's relative position will have deteriorated. Whilst it will still be more resilient than South Africa and India, its improvement on India will have decreased from 39% in 2008 to 8% in 2035
- 23% of Australia's electricity will come from renewable energy compared to 29% worldwide. Only South Africa and Russia will have a smaller proportion of electricity from renewable energy. Australia will be relatively more vulnerable to fossil fuel price shocks.
- Australia is projected to shift one quarter of its generation from coal to gas and renewables, but that will still leave generation from coal at 53%. Only China and South Africa will generate proportionately more electricity from coal.

Australia will be relatively more vulnerable to shocks from reduced diversity.

- Australia will have increased its industry consumption of electricity by 35% compared to China's increase of 165% and India's increase of 290%.

Australia will continue to lose market share of metals processing to China and India.

- The McKinsey Global Institute warns that interest rates may be on a long term rise as a result of the investment demands of very populous developing countries. Delayed investment decisions as a result of uncertainty will increase investment costs

Australian electricity will be impacted by higher financing costs

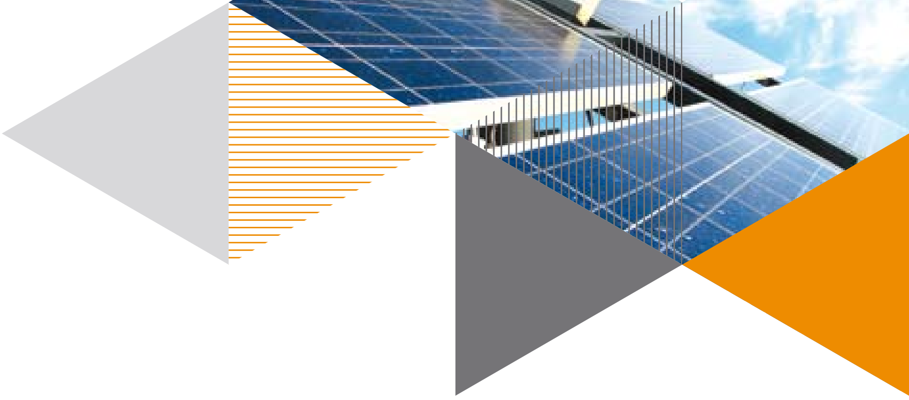


Figure 48 shows Australia's relative resilience to the competitor countries in 2008 and in 2035. To be on an equal footing with its competitors, Australia's relative resilience should rotate on the 0% grid line. In general, Australia is less resilient than its competitors. In 2008 Australia was 39% more resilient than India and 14% more resilient than South Africa, but by 2035 the IEA modelling predicts that Australia will be 8% more resilient than India and 4% more resilient than South Africa.

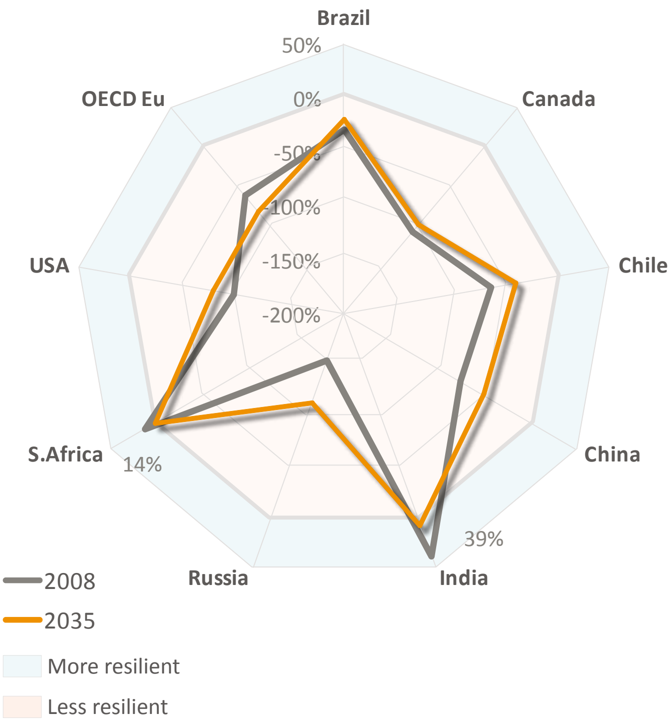


FIGURE 48: AUSTRALIA'S COMPARATIVE RESILIENCE 2008 AND 2035

Source: (IEA 2010)

Australia's options to improve power economy resilience

- Greater investment in renewable energy will improve Australia's non-renewable fuel use, its carbon emissions and its diversity of generation
- Offering incentives for more efficient coal fired generation, in particular encouraging a shift away from brown coal fired generation, will improve Australia's generation efficiency
- Investing in high voltage transmission infrastructure will improve Australia's transmission efficiency and reduce its requirement for new generation capacity to service peak load
- Offering incentives to replace aged power plants with Concentrated Solar Thermal plants (with storage) rather than gas fired power plants will encourage a shift away from base-load generation vulnerable to global price pressures
- Focusing on the whole power system rather than on the component parts is required. A national policy framework taking into account the whole power economy will ensure that the optimum level of investment is made for the targeted outcome
- With an ageing fleet of base-load generators, Australia has a golden opportunity NOW to make the leap to a resilient power economy instead of shuffling forward based on business as usual, but it will require planning and commitment by the key stakeholders to identify and shift to this new paradigm
- Government, large power users and residential end-users each have roles in this transformation process. China and India have already formulated the strategic vision of their power economies and are moving forward not because they have to, but because they are preparing for the future. Australia too needs to prepare NOW for a power economy fit for the future

6 CONCLUSION

This paper has analysed Australia's current position with respect to the competitiveness of our power economy. We have compared our past and present position and potential future trajectories versus mineral rich competitor countries. The Resilience Index gives us a quantitative measure by which to reduce this multi-variant comparison and business as usual for Australia shows increased risk from a continued lack of resilience. Based upon this analysis one can extract a number of key drivers and associated questions that require solutions and answers. These are:

6.1 WHAT IS THE OPTIMAL MIX OF GENERATION TECHNOLOGIES TO MAXIMISE RESILIENCE?

Australia's current mix of largely fossil-fuel based technologies makes it vulnerable to non-renewable fuel shocks and carbon emission constraints. This paper does not suggest that all fossil-fuel based generation be replaced immediately but it would appear that power economies with substantial generation from renewables like Canada are far-better placed than Australia to meet the energy challenges of the next few decades. Consideration needs to be given to the optimum generation mix for Australian competitive resilience.

6.2 WHAT IS THE BEST TRANSMISSION INFRASTRUCTURE TO OPTIMISE INVESTMENT?

How might Australia design its network infrastructure to meet its peak load demand through the use of renewable sources, demand shifting and energy storage thereby optimising the amount of investment required? Consideration needs to be given to a strategy for the whole power economy rather than on meeting the requirements of each of the institutional entities.

6.3 WHICH POLICIES WILL BE MOST EFFECTIVE IN FACILITATING THE TRANSFORMATION TO IMPROVED RESILIENCE AND COMPETITIVENESS?

The renewable energy target and a carbon price are the only measures currently under consideration to transition the power economy to greater resilience. These policies will not influence the quality and efficiency of the transmission and distribution systems nor do they take into account the optimal mix required to balance loads and manage demand. A full range of policies should be introduced that lead to optimal infrastructure investments rather than just deploy single measures like a carbon price or a renewable energy target.

6.4 WHAT WILL ENERGY AND CAPITAL INTENSIVE INDUSTRIES BE EXPECTING FROM POWER ECONOMIES IN THE NEXT 2 DECADES?

In 1990, Australian electricity was relatively more expensive than it is today and yet it still attracted energy intensive industry investment. Was it preferential tariffs negotiated by State Governments to boost employment, or was it the prospect of a secure power supply that brought them to Australia? Possibly a combination of both but nearly two decades of carefully managed electricity pricing have resulted in relatively less expensive electricity, and yet Australia has lost market share in metals processing to China and India. It is generally accepted that price should never be the unique selling feature of a sale and, in this context, consideration needs to be given to balancing cost concerns with resilience requirements, to attract energy intensive firms that adopt a long view in making investment decisions especially since Australia can offer many other benefits like stable Government and protection of rights.

6.5 HOW MIGHT AUSTRALIA FUND SUBSTANTIAL INVESTMENT TO SHIFT TO A RESILIENT POWER ECONOMY?

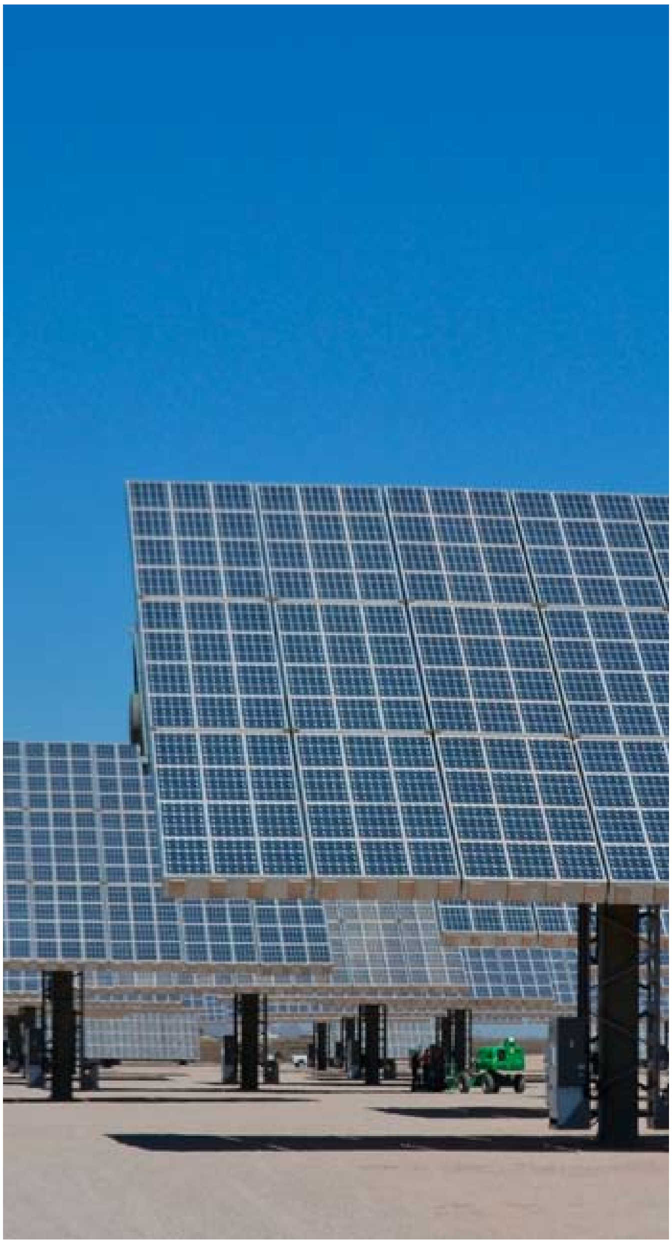
In an environment where global investment is focussed on the developing world, funding the shift to resilient power could become a real challenge for Australia. Consideration needs to be given to funding options available for investing in a shift to greater competitive resilience. In particular, many of the competitor countries rely on Government led initiates to facilitate investment in the power economy. The Australian Government should also consider taking the lead in initiating investment in the power economy.

6.6 ARE THERE LIMITS TO EFFICIENCY IMPROVEMENTS?

In the main, efficiency improvements have positive pay backs, but is there a floor and/or a ceiling to the electricity intensity of an economy, beyond which gains become losses? The key attribute of resilience is the ability to absorb variation, but to do that the system requires diversity and redundancy. A focus on efficiency only may remove the essential diversity and redundancy required for resilience. Conversely, a lack of focus on efficiency may lose the benefits to be gained from prudent resource use. A much better understanding of this trade off is required in formulating policies that target a preferred ratio between electricity and GDP.

6.7 OTHER QUESTIONS

There are other questions that have surfaced in this discussion. Is Australia utilising its metal ores to build a robust economy? Is Australia's energy consumption impacting negatively on its growth? A further question that is not expressly posed but is implicit in the discussion is how countries have kept prices down? It is not sufficient to assume that current prices are an accurate reflection of consistent policies. For instance, how much historic subsidisation is reflected in South African, Russian and Canadian pricing? These questions are important but outside the scope of the reflections on the Australian power economy discussed in this paper.



7 FUTURE DISCUSSION PAPERS

The research conducted for this discussion paper has produced some interesting findings and led to a number of pertinent questions for stakeholders in the power economy to consider. As a result future discussion papers on delivering a competitive Australian power system are planned. Part 2 of the series will look at Australia's target position (where we need to be) and will seek input from stakeholders to achieve a consensus of the targeted position. Part 3 of the series will look at Australia's transition to a competitive power system (how we get there) and once again will seek input from stakeholders to achieve consensus of the possible roadmap(s) to reach the target. It is envisaged that the series of discussion papers on "Delivering a competitive Australian power system" will provide valuable input for stakeholders and the general public.

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APPENDIX B: BUILDING A RESILIENCE INDEX FOR THE POWER ECONOMY

Resilience is the ability of a system to absorb external shocks. Key attributes of resilience are:

- The ability of a system to absorb variation
- That keystone processes of the system interact, and even overlap, in an apparently redundant way
- That the system is able to generate major changes and renewal at small scales
- That the system is composed of functional group variety

Enabling resilience requires:

- Monitoring
- Capacity to respond
- Political will

So, how does this relate to a power economy?

The provision of power is an integrated network of keystone processes that interact with each other to provide a service to consumers. Upon this network is built a further integrated network of economic transactions with its own set of keystone processes that interact with each other to meet the fundamental needs of society. Because the economy is reliant on the power network to complete its transactions, its success or otherwise is dependent on, amongst other things, the performance of the power network.

Why resilience, why not just efficiency?

Efficiency is important for sustainability. If non-renewable resources aren't conserved they may become scarce and hence more expensive. To ensure that gross domestic product is produced at least cost, and thus welfare maximized, care needs to be taken to use the optimum quantities of resources. But efficiency does not address the need for adaptation in that it is focused on improving current processes rather than preparing for completely different, unplanned, requirements that might eventuate in the future. Creative destruction is a good example of how economist Joseph Schumpeter views the adaptation process to address different, unplanned activities. Resilience on the other hand, is concerned with something more akin to creative restructure. Instead of focusing all resources on efficiency, resilience requires that if resources are also focused on diversity and redundancy, the process of adaptation is much more comfortable. This is why resilience is essential for the orderly management of change.

Why do we need a composite index to measure resilience?

Our society is comfortable with the provision of information in a single metric. Price is the most important composite metric in that it embodies many different variables within a single transfer of information that facilitates decision making. Economics has delivered to society a plethora of composite indices that provide us with data from how our economy is tracking, to the health of our financial systems, and the human development index which enables us to rank how well disparate societies' are addressing the needs of their people. Within the same context, to understand the resilience of an integrated power network, it is important to measure many different metrics which will indicate how the integrated network is performing today and how it might react to substantial change.

How were the resilience measures selected?

As mentioned previously, efficiency is important, but not the only metric required to assess resilience. Within the power economy resilience index there are four efficiency measures:

- Non-renewable fuel use per KWh consumed, provides evidence of the use of fuels that may have a limited life span. Where fuel use is high, the system is vulnerable to price increases that may result from the market anticipating fuel use scarcity.

  mtoe non-renewable fuel used /Total GWh consumed

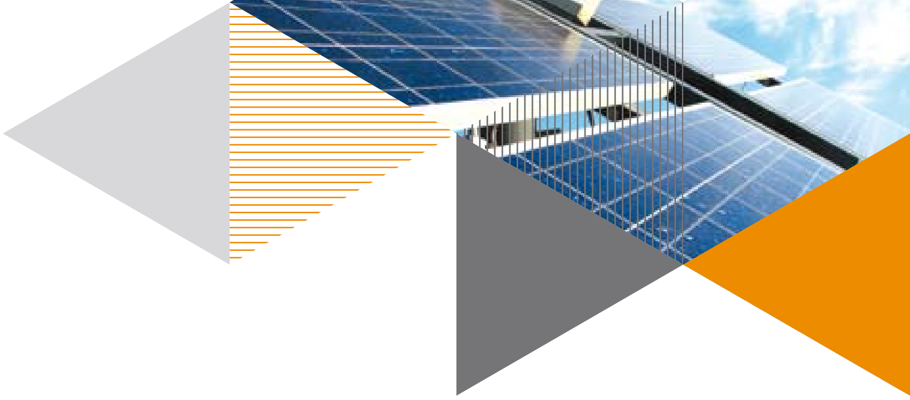
- Carbon emissions per KWh generated provides evidence of the waste from the production process, which makes the system vulnerable to increased costs if society imposes a cost on pollution for polluters.

  tCO_2e emitted / Total GWh generated

- Generation efficiency is the amount of energy used in the generation of KWh. Inefficient processes ensure that above optimal consumption of resources will in the long-run cost society more.

  mtoe fossil fuel used/ GWh fossil fuel power generated

- Distribution efficiency is the amount of energy lost between generation and consumption. This includes the amount of



energy used by the energy industry in generation (auxiliary use), mining energy, transmission and distribution losses
KWh generated plus imported / Total KWh consumed

Security too is important to realize resilience. For this reason, there is one security measure:

- Security of supply which measures the amount of fuel that is imported for electricity plus the amount of actual electricity that is imported/exported measures how dependent the system is on other countries for the provision of their electricity
  Proportion of GWh from imported fuel plus GWh imported / Total GWh supplied

There are two resilience measures which seek to establish diversity and redundancy:

- Diversity of fuel type which measures diversity by calculating the probability that the next watt will be generated from a different fuel type. This measure is based on a generic diversity calculation and is used in a variety of measurements from biodiversity (Simpson's diversity index) to market competition (Herfindahl Index). The probability that the next watt will be from the same fuel type is defined here as the sum of the squares of the percentage of generation from each fuel type within the power system. To establish the probability that the next watt will be from a different fuel type is:

  P(different fuel type)=$1-\Sigma^{N}_{i=1}s^2$

  where

  N = number of different fuel types

  S = proportion of generation from each fuel type

- Redundant electricity which measures the amount of spare energy available for use in the economy and seeks to assess the redundancy within the power system. It is calculated as
  (Total KWh possible at capacity less KWh generated) / Total GDP
  and notably a high proportion of KWh is deemed to be good and a low proportion of KWh is deemed to be detrimental. There are a number of assumptions that have to be made to be able to calculate this metric, namely:

- Coal, gas, nuclear and geothermal generators have a potential 90% capacity
- Oil generators have a potential 50% capacity reflecting their remote, off-grid installation characteristic
- Wind, solar, marine, and biomass always operate at capacity
- Hydro generation is subject to too many variables to assess potential capacity, so is assumed to have 20% in reserve.
- Heat generation. Too little data is available for this calculation, so it is assumed to have 20% in reserve.

The **composite index** methodology follows the same methodology as the Human Development Index as calculated until 2010.

1. Transform the raw variable of each measure into a unit-free index between 0 and 1 as follows:

$$x\ index = \frac{x - \min(x)}{\max(x) - \min(x)}$$

   Where min(x) and max(x) are the best of the group less 10%, and the worst of the group plus 10%, respectively.

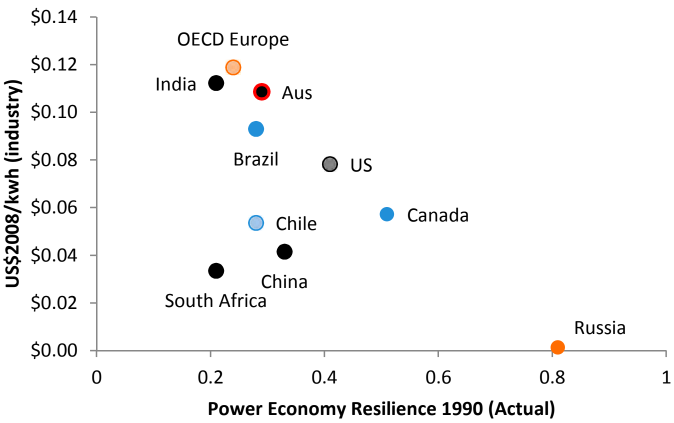
2. Calculates the geometric mean of the 7 normalised indices to show the power economy resilience indicators:

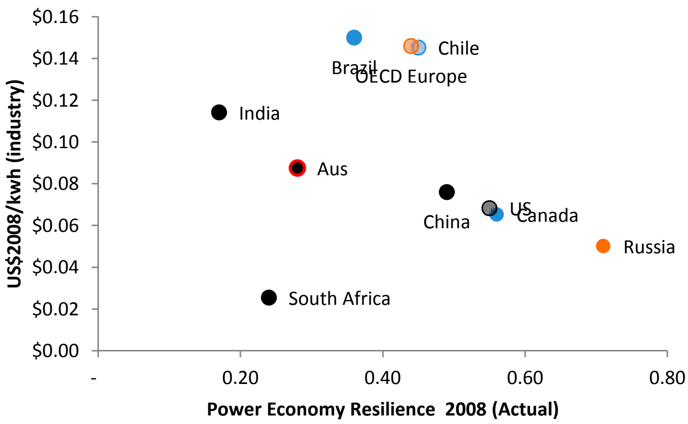
Power economy resilience = $\sqrt[7]{a.b.c.d.e.f.g}$

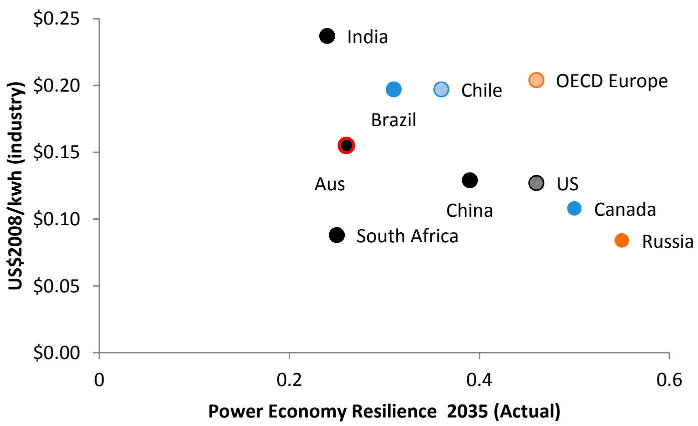
Where:
a = mtoe non-renewable fuel used/Total KWh consumed
b = tons of carbon emissions /Total KWh generated
c = probability that next watt will be from a different fuel type
d = percentage of energy generated from non-renewable fuel used (Generation efficiency)
e = percentage of energy lost between generation and consumption (Distribution efficiency)
f = percentage of Total KWh from external source (Security of supply)
g = unused kWk/$GPD (redundant generation for use in GDP)


10020
10010
30%
20%
10%

COMPETITIVE POSITIONS AT 1990, 2008 AND 2035



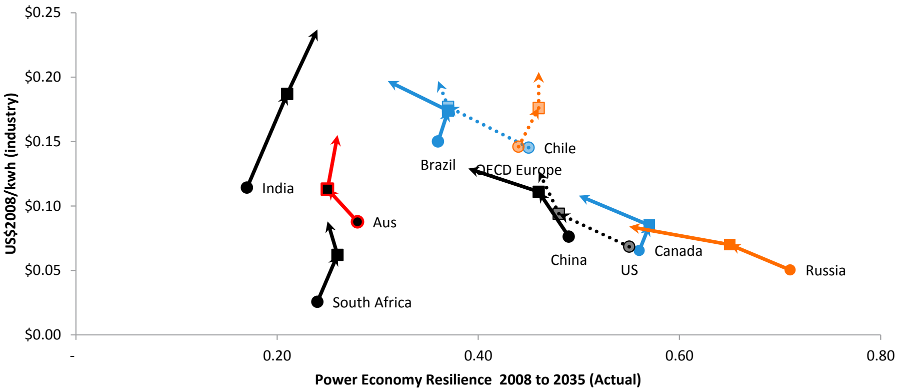


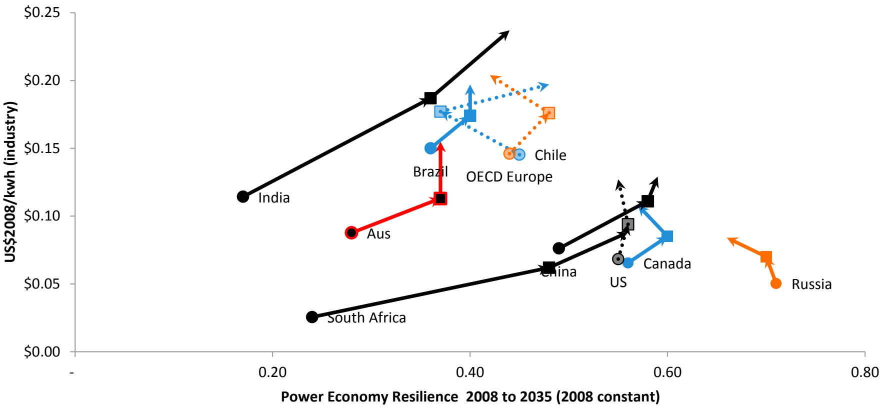


COMPARING THE COMPOSITE INDEX FROM 2008 TO 2020 AND 2035

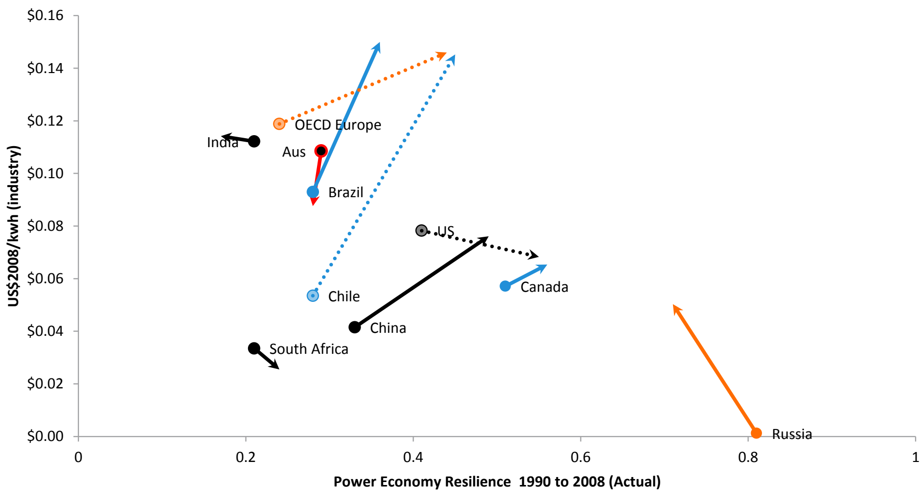
The power economy resilience index as calculated for each year has no absolute minimum and maximum values for each of the measures because the countries selected are a subset of the global group and thus it is not possible to establish absolute measures against which to compare. As countries improve or reduce their performance, especially countries with the highest and lowest measures, the relative calculation changes substantially making comparison between different periods complicated and not necessarily informative. As an example consider comparing the GDP in 2010 to the GDP in 1990 both at current prices. GDP at 2010 will include inflationary measures which obscure the base information sought to establish the real growth of the economy since 1990.It is for this reason, that constant dollar measures are used for year on year comparisons when measuring GDP growth.

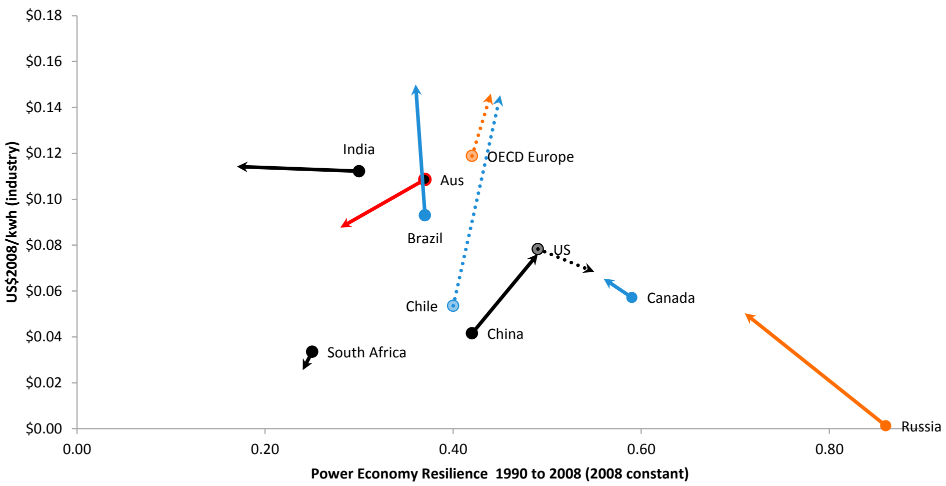
To eliminate the underlying relative position shifting associated with the change in minimum and maximum values for each measure, comparison of Power Economy Resilience in 2008 to 1990, and to 2020 and 2035, is based on 2008 minimum and maximum values.





COMPARING THE COMPOSITE INDEX FROM 1990 TO 2008





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