Where is Australian Power headed in 2035?

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ABSTRACT

KEYWORDS: RESILIENCE, ELECTRICITY, RENEWABLE ENERGY, DISTRIBUTED GENERATION

Australia's plentiful supply of coal has defined the structure of its stationary energy power generation and consumption. Economies of scale derived from large coal-fired generation have enabled the supply of affordable electricity and encouraged investment in power intensive industries.

As we look to 2035, Australia's plentiful supply of coal seam gas could dominate the future structure of its power economy but it will be subject to the vagaries of international energy price volatility and environmental costs if carbon price is applied globally. Uncertain electricity prices as a result of global energy and carbon price volatility will discourage electricity and capital intensive investment in Australia.

We seek to understand the consequences of a gas-centric policy environment on Australian power in 2035.We conduct scenario analysis of the options facing the stationary energy industry by modelling the provision of electricity in 2035. In particular we seek to understand how the roll-out of large-scale solar thermal and solar photovoltaic power would alter the structure of the power economy and its ability to sustain energy-intensive industry. In order to facilitate the comparative analysis, we use a resilience index as a strategic, top down barometer of power economy performance because it allows a systematic and rational appraisal of the relative efficiency, diversity and security of power systems.

Our findings provide an indicator of how energy-intensive industries will view investment in Australia over the coming decades.

1. INTRODUCTION: RESILIENCE OF AUSTRALIAN POWER TODAY

After the energy crises of the 1970s and 1980s, Australia sought to promote development by investing heavily in power infrastructure. Large, coal-fired power stations from Queensland to New South Wales and Victoria were built to attract energy-intensive industries in search of abundant, affordable power. As a result Australia saw a growth in alumina, aluminium and copper refining infrastructure lured away from Japan after being severely affected by the energy crises because of their dependence on oil for power generation (Kellow, 1995).

A few decades later, and the Australian power sector finds itself with a generation fleet that is less efficient and more CO_2 emissions intensive than any of the OECD and many of the BRICS countries fleets with only South Africa and India showing worse statistics.

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We were able to draw this conclusion because we developed a metric, the Resilience Index. This index allows us to compare systematically the efficiency, diversity and security of national power systems providing a strategic, national (top down) analysis of power systems' vulnerability to, and ability to survive, shocks. A detailed description of the Resilience Index can be found in (Molyneaux et al., 2012).

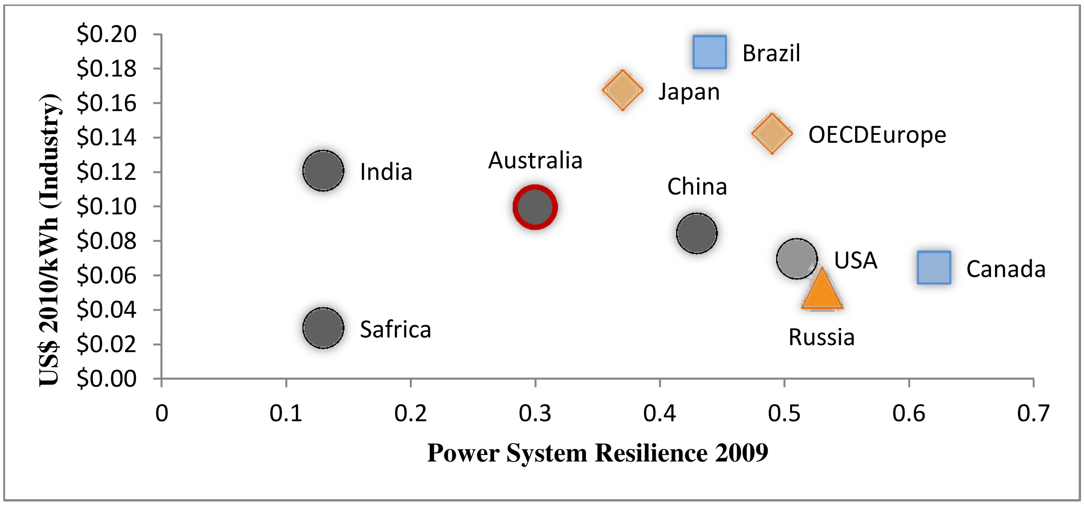

Figure 1: Power System Resilience in 2009

Sources: (IEA, 2011b, World Bank, 2011)

Figure 1 provides a graphical representation of the comparative countries' power system resilience mapped to the cost to industry for power. Countries with affordable, resilient power will be represented in the bottom right hand corner, by comparison to countries with cheap but vulnerable power systems which will be represented in the bottom left hand corner. Australian power is shown to be neither reasonably priced nor resilient. As evidence of this, some energy intensive companies have recently announced an intention to move to countries with more affordable, resilient power systems.

Recently introduced legislation to price carbon in Australia will increase the price of electricity as a result of a heavy reliance on emissions intensive power generation. With a sizable proportion of the generation fleet due for replacement in the next decade, Australia finds itself at the cross-roads of whether to invest in less emissions intensive gas-fired generation or embark on a path of renewable energy. The Draft Energy White Paper has indicated that investment in gas-fired generation will deliver affordable power whilst still meeting carbon dioxide (CO_2) emission reductions (Department of Resources Energy and Tourism, 2011).

In section 2 we conduct scenario analysis to anticipate the major shifts required to respond to the forces driving the industry over which the industry has little control. We submit that these forces are:

- Rising electricity prices driven by increasing global fuel prices and distribution investment;
- Emissions constraints;
- Infrastructure renewal;
- Public support for renewable energy; and
- A technology shift to renewable and distributed generation.

In the scenarios we outline the consequences of a major shift to gas or a major shift to renewable power generation by the industry.

2. Australian Power Scenarios for 2035

The dominant industry view is that renewable energy is too expensive and not able to meet base-load requirements. The Energy White Paper recently released in draft form supports substantial investment in the development of the unconventional gas resources and that the Carbon Price legislation and a Renewable Energy Target (RET) which expires in 2020, are sufficient to provide incentives to shift Australian power to sustainability and lower emissions.

We consider 2 different scenarios, Business as Usual which reflects the dominant industry view encompassed in the draft Energy White Paper, and a Consumer Action scenario which predicts a consumer response to rising prices, renewable energy being deployed as a result of public support, and the industry being overtaken by a wave of new technologies that are emerging as a result of developments in Europe, Japan and China.

To facilitate the scenario analysis we model the deployment required to meet demand in 2035 in the National Electricity Market (NEM). Modelling of the NEM is conducted using PLEXOS, an electricity market simulation package which uses deterministic linear programming techniques, and transmission and generating plant data, to optimise the power system and determine the least cost dispatch of generating resources to meet a given demand (Energy Exemplar, 2012). PLEXOS simulates generator behavior, such that generators participate in the market if they can cover costs and make a profit. Wholesale cost projections represent generator behavior and cost recovery, rather than just the latter.

2.1. The Business as Usual Scenario

2.1.1. BAU scenario assumptions

With its lower emissions intensity, gas is seen by the International Energy Agency (IEA) and the Australian Department of Resources, Energy and Tourism (DRET) as the transition fuel to reduce CO_2 emissions from power generation. This scenario reflects that view and the assumption that consumers will continue to react as they have over the last two decades, with consumption rising by around 2% per annum, a perception that consumption is not responsive to price rises, and that consumers are more concerned with cheap, reliable power than facilitating a shift to renewable forms of energy.

Gas-fired generation will be deployed in response to demand and carbon pricing, the development of Australia’s unconventional gas resources, and the retirement of aged coal-fired generators. As currently set out in legislation, although reductions are being sought by several industry participants, the RET will have delivered 41,000 GWh of renewable generation (mainly wind because of its lower cost) by 2020. After 2020 no further renewable generation will be deployed because of perceptions of its high levelised cost. With a loss of appetite for feed-in tariffs, described by the Draft Energy White Paper as expensive and contributing to electricity price rises, growth in energy from photovoltaic (PV) power is not considered a part of this scenario.

The assumptions that underpin this scenario are:

- Long-term historic trend in consumption growth
- No consumer reaction to rising prices
- Gas prices reflect global energy trends
- Climate change not a first order concern
- No recognition of technology shift toward renewable and distributed generation

2.1.2. The results of modelling BAU

Using Australian Energy Market Operator (AEMO) projections to 2035 for gas price, generation cost and demand, and Treasury projections for carbon price, the model predicts that generators in the National Electricity Market (NEM) will invest $61 billion to deploy 26GW of combined cycle gas turbines (CCGT), 2 GW of open cycle gas turbines (OCGT) and 12 GW of wind power to meet demand in 2035. The Key Performance Indicators (KPI) are outlined in Table 1.

Table 1: KPIs for Business as Usual scenario

	2000	2010	2035 Business as Usual
mtpaCO2 from electricity	161	183	167
Emission intensity	0.87	0.85	0.52
Generation (TWh)	185	215	324
Annual growth		1.5%	1.7%
Wholesale cost ($/MWh)	$60	$47	$154
Coal generation	87%	80%	42%
Gas generation	4%	11%	41%
Renew generation	9%	9%	17%
Fuel used (PJ)	1,789 [e]	2,059 [e]	2,372
Fuel cost ($mill)	n/a	n/a	$9,421
Generation investment (bn)			$61
Gas price ($2011)	$3.51	$5.19	$8.32
Carbon price ($2011)	$0	$0	$74

The investment in gas-fired and wind generation will result in a reduction in CO_2 emissions from 183 million tones of CO_2 emissions per annum (mtpaCO_2) in 2010 to 167 mtpaCO_2 in 2035. By comparison, if Australia were to meet its CO_2 emission reduction of 80% below 2000 levels by 2050, emissions from power generation in the NEM would have to decrease to 32 mtpaCO_2. This would require a further reduction of 135 mtpaCO_2 to reach the 80% target in only 15 years.

The wholesale cost of generation increases from approximately $40/MWh currently to $154/MWh in 2035. Much of this increase results from using higher cost gas as a fuel rather than low cost coal, and the cost associated with CO_2 emissions.

Coal-fired generation decreases from 79% currently to 42% with a corresponding rise in gas-fired generation increasing from 11% currently to 41% in 2035.With the benefits of the RET, renewable energy increases from 9% currently to 17% in 2035.

2.1.3. Sensitivity analysis for BAU

A number of uncertainties are inherent in the BAU scenario. The sensitivity of the system to significant shifts in gas price, the RET, and carbon price were tested and revealed that:

- a high carbon price of $159/tCO2 shifted more generation from coal to gas, decreasing emissions by 22% but increasing wholesale costs by 22% and an increase in fuel cost bill of $4 billion;

- extending the RET to 20% of generation in 2035, increases investment by $ 4 billion but decreases average wholesale cost by 5%;
- low gas prices of $4.89 (at the Moomba hub) improves abatement by 21%, decreases wholesale costs 41% and a corresponding reduction in the fuel bill of $2.2 billion. However, it should not be forgotten that the majority of the fleet would be relatively new making abatement post 2035 very difficult to achieve;
- high gas prices of $12 (at the Moomba hub) increase the fuel cost by $2.7 billion but with no evidence of a corresponding rise in average wholesale cost.

2.1.4. How the BAU scenario addresses the forces that are facing the Australian power industry

The internalization of gas prices on the east coast of Australia as a result of development of liquid natural gas (LNG) for export is forecast to increase domestic gas prices. Coupled with the shift from low fuel cost coal-fired generation to higher fuel cost gas-fired generation, this increases the cost of power generation. This fails to deal with the pressure on power prices.

Continued infrastructure investment to prepare for continually rising demand, especially residential peak demand, does not deal with concerns over rising retail electricity prices.

Although gas-fired generation is less energy-intensive than coal-fired generation, increasing consumption of power will negate the benefits associated with shifting to less-energy intensive power generation which does not deal effectively with a requirement for CO_2 emission reduction.

A relatively reasonable cost of investment makes the BAU scenario effective at meeting the requirement for infrastructure renewal.

The extraction of coal seam gas (CSG) has resulted in community concern over the impact on productive farming land and ground water resources. As CSG is renewable source of energy, shifting generation to CSG does not reflect public support for renewable forms of energy.

Substantial investment in production capacity and deployment of renewable and distributed generation is underway in Europe and Asia, which suggests that there is a global trend towards new forms of technology. The BAU scenario fails to address this global trend.

2.2. Consumer Action scenario

2.2.1. The Consumer Action scenario assumptions

In response to widespread support for renewable energy and a strong perceived need for action on climate change, the power industry would be encouraged to roll-out Concentrated Solar Thermal (CST) with storage and Geothermal power to replace coal-fired generation as it was retired. To enable the transmission of base-load power from remote locations to load centres, requires investment in transmission infrastructure. At the same time, high power prices would encourage consumers to seek insurance against rising electricity bills by investing in distributed generation (DG) technologies, including PV panels on rooftops (for domestic and commercial use to help reduce the impact of meeting summer peak demand) and the deployment of micro-gas turbines, landfill gas, co-and tri-generation using renewable sources for gas like Sydney is considering. (City of Sydney, 2012).

In summary, the assumptions that underpin this scenario are:

- Widespread public support for renewable energy;
- Consumer reaction to rising prices by pursuing domestic generation;

- Gas prices which reflect global energy trends;
- A strong requirement for abatement;
- Policy which encourages investment in large-scale renewable and distributed generation, and transmission from remote locations to load centres.

2.2.2. The results of modelling Consumer Action scenario

The scenario introduces complexity for our model in that rooftop PV generation needs to be accommodated. Being a distributed form of intermittent generation, PV is not schedulable nor does it operate through the market, making it difficult to include in modelling generator behavior. In the past, PV has been accounted for by reducing demand to reflect PV generation, but we have simulated PV generation through the market, projecting a change in focus for distributed generation. It is also notable that intermittent, renewable generation is always dispatched because of its low marginal costs.

As the model is designed to determine least cost dispatch of generation resources to meet demand, the deployment of renewable and distributed generation is facilitated by discouraging investment in: Gas and coal-fired power stations fitted with CCS; Nuclear; Supercritical pulverized coal; and CCGT.

Using Australian Energy Market Operator (AEMO) projections to 2035 for gas price, generation cost and demand, and Treasury projections for carbon price, the model predicts that generators in the National Electricity Market (NEM) will invest in 12GW of wind, 11GW of PV, 10 GW of CST with storage, 7GW of biogas, 5GW of distributed gas, 3 GW of geothermal, 2 GW of CCGT and OCGT at a total cost of $160 billion to meet demand.

Table 2: KPIs for Consumer Action scenario

	2000	**2010**	**2035 BAU**	**2035 CA**
mtpaCO2 from electricity	161	183	167	101
Emission intensity	0.87	0.85	0.52	0.31
Generation (TWh)	185	215	324	327
Annual growth		1.5%	1.7%	1.7%
Wholesale cost ($/MWh)	$60	$47	$154	$126
Coal generation	87%	80%	42%	31%
Gas generation	4%	11%	41%	15%
Renew generation	9%	9%	17%	54%
Fuel used (PJ)	1,789 [e]	2,059 [e]	2,372	1,734
Fuel cost ($mill)	n/a	n/a	$9,421	$7,329
Generation investment (bn)			$61	$160
Gas price ($2011)	$3.51	$5.19	$8.32	$8.32
Carbon price ($2011)	$0	$0	$74	$74

The investment in renewable forms of generation will result in a decrease in CO_2 emissions from 183 mtpaCO_2 in 2010, and 167 mtpaCO_2 in 2035 in the BAU scenario, to 101 mtpaCO_2 in 2035. Generation from coal-fired power stations will decrease to 31%, generation from gas-fired power stations will increase to 15%, and generation from renewable forms of energy will increase to 54% of total energy generated. The KPIs are outlined in Table 2.

Contrary to expectations, the average wholesale cost will be lower than the BAU scenario, at $126/MWh. A detailed analysis of the weighted average wholesale cost revealed that some coal and gas generators have to operate at very low capacity, close to their minimum requirement. This results in them earning very small margins on generation and is a consequence of failing to retire older power stations and in effect using them to balance intermittent load. It is unlikely that generators would operate older base-load plants on this basis, such that an implication of high levels of intermittent generation may be the requirement to make capacity payments to key generators to ensure load stability.

The risks associated with this scenario shift to the network, with investment needing to be made to facilitate transmission of energy from remote locations to load centres, and to ensure voltage stability in the face of rapid power changes or excess load from intermittent generation. Australian distributors are inclined to limit the installation of PV because of concerns about network stability but there are valuable insights to be gained from the European experience which has managed the integration of PV (25 GW in Germany, 12 GW in Italy and 5 GW in Spain) over a relatively short period of time. California too, is planning to accommodate 20 GW of PV by 2020.

If the industry facilitates the roll-out of DG over the next two decades then there will have to be substantial investment in the network. These costs could be offset against reduced requirements for peak demand if PV generation is used to address summer peaks and if consumers can be encouraged to shift demand from peak demand times.

2.2.3. How the Consumer Action scenario addresses the forces that are facing the Australian power industry

A shift to renewable and distributed generation implies reduced vulnerability to global fuel price volatility and therefore provides insurance against future increases in wholesale power costs;

Generating power from rooftop solar for use when summer demand peaks, will help reduce the impact of requiring generation for just a few hours' of peak demand in the summer, thus reducing the potential for sharply increasing retail electricity prices;

Shifting to renewable forms of generation significantly reduces emissions, such that it addresses the requirement for action on climate change;

The capital cost of this scenario is a barrier to renewing the generator fleet;

A visible shift to renewable forms of generation successfully addresses public expectations for more sustainable forms of power;

With European deployment of renewable and distributed generation and Asian development of affordable production of renewable and distributed generation, the Consumer Action scenario recognizes that there are technology changes underway globally that need to be deployed not protected against. Australia made a commitment to open participation in a global economy in the 1990s, the transformation of its power system should reflect that openness and willingness to embrace technological advancement.

3. How do the Scenarios Address the Forces Facing the Power Industry

3.1. Increasing Fuel Prices

Relying on fuels that are vulnerable to volatile global markets increases the risk of rising wholesale costs. The BAU scenario has a higher fuel cost component than the Consumer Action scenario, and a higher non-renewable fuel cost component which is likely to be more volatile than domestically available renewable fuels as can be seen in Figure 2.

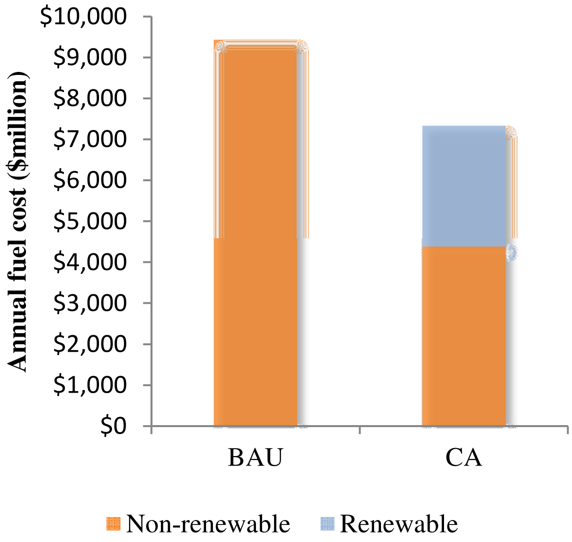

Figure 2: Annual fuel cost

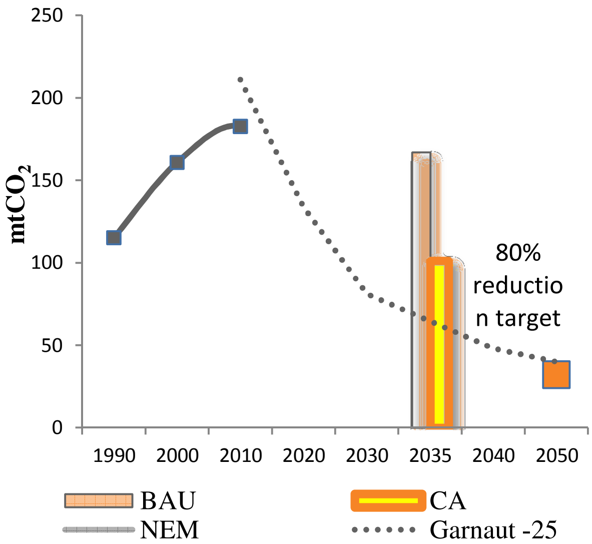

Figure 3 Scenarios proximity to 80% reduction

3.2. Emissions Constraints

Emissions reductions under the BAU scenario are very limited, whereas emissions reductions under the Consumer Action are much higher. Whilst the emissions under the Consumer Action are much better than the BAU scenario, emissions reductions to 32 mtpaCO_2 by 2050 would still pose a substantial challenge for the power industry to achieve. Figure 3 shows the difference between the 2 scenarios.

3.3. Infrastructure Renewal

The scenarios offer very different capital investment and fuel cost profiles. BAU offers relatively low cost capital renewal, versus the Consumer Action scenario which requires a high upfront capital spend coupled with lower annual fuel costs. Whilst the upfront capital cost for the Consumer Action scenario appears daunting, it should be noted that it offers the opportunity to spread the costs of generation investment across a wider base thereby reducing the risks associated with having to pick winners from amongst a complicated array of expensive technology options.

Figure 4 provides a comparison between the upfront capital cost of the 2 scenarios but also it does a simplistic comparison of the total fuel cost over 30 years. It is interesting to note, that the difference between the 2 scenarios narrows considerably when the fuel cost is capitalized (without discounting).

3.4. Public Support for Renewable generation

The BAU scenario essentially shifts generation from coal to gas whilst the Consumer Action scenario deploys generation with a considerably higher diversity of fuel source.

Having a higher diversity of generation, adds considerably to resilience, reducing vulnerability to technology and carbon lock-in. Figure 5 provides a breakdown of the proportion of generation from different renewable energy sources.

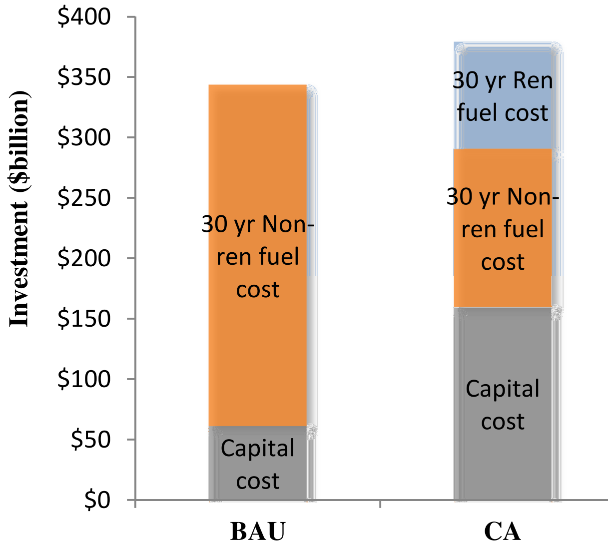

Figure 4: Investment required

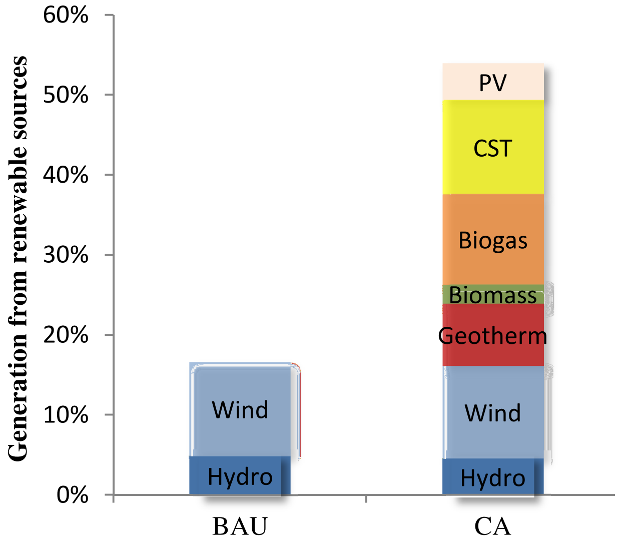

Figure 5: % of Generation from Renewable sources

4. Scenario Analysis of Power Resilience in 2035

Figure 6 provides an indication of the NEM's resilience in comparison to the IEA's projection for comparable countries. As can be seen, the resilience of the NEM will improve dramatically if the Consumer Action scenario was to eventuate. The BAU scenario shows a little improvement on current levels of resilience, but it doesn't improve dramatically compared to Australia's competitors.

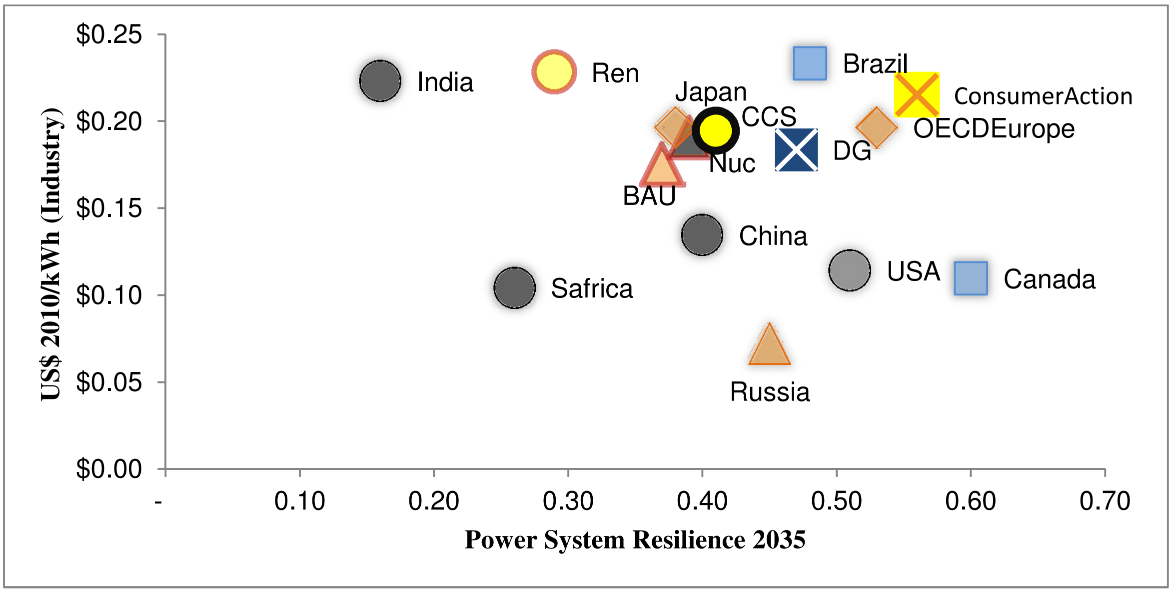

Figure 6: Power system resilience 2035

Sources: (IEA, 2011a)

5. CONCLUSION

The BAU scenario provides little evidence that it will adequately address the forces driving the power system. By contrast, the Consumer Action scenario provides considerably more evidence that it is preparing the industry to be able to respond to future uncertainties making it more attractive to energy intensive industries.

Table 3: Responses to forces driving the power system

Forces driving the power system	BAU	CA
Rising prices		
• **fuel**	**X**	√
• **distribution**	**X**	X
Carbon constraints	**X**	√
Infrastructure renewal	√	**X**
Public support for renewables	**X**	√
Technology shift to renewables and DG	**X**	√

The modelling undertaken shows no evidence that a shift from coal-fired generation to gas-fired generation will enable Australia to improve its emissions of CO_2. In addition, there is no justification for the claim that a high proportion of energy sourced from renewables will drive up wholesale costs. The modelling did not include the impact of high levels of distributed, intermittent generation on distribution networks, but it is suggested that if current levels of investment are refocused to provide a more robust distribution network able to accommodate DG rather than meeting peaky demand, then the money would have been well spent.

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