The impact of climate change on electricity demand in the Australian national electricity market

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The Impact of Climate Change on Electricity Demand in the Australian National Electricity Market

William Paul Bell
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Abstract

This paper aims to identify climate change adaptation issues in the Australian National Electricity Market (NEM) by assessing the robustness of the institutional arrangements that support effective adaptation from the demand side. This paper finds that three major factors are hindering or are required for adaptation to climate change: institutional fragmentation both economically and politically; distorted transmission and distribution investment deferment mechanisms; and failure to model and to treat the NEM as a node based entity rather than state based. Proposed solutions to the three factors are discussed. These proposed solutions are tested and examined in forthcoming reports.

Keywords

Climate change adaptation, electricity demand, Australian National Electricity Market

1 Introduction

The objectives of this paper are to examine the adaptive capacity of existing institutional arrangements in the Australian National Electricity Market (NEM) to existing and predicted climate change conditions. Specifically the paper aims to:

- identify climate change adaptation issues in the NEM;
- analyse climate change impacts on reliability in the NEM under alternative climate change scenarios to 2030; and
- assess the robustness of the institutional arrangements that support effective adaptation.

The main motivation stems from the development of existing institutional arrangements under the premise of stable climate conditions. Environmental issues, such as drought and increased climate variability have been largely overlooked and the recent past has demonstrated that this premise is no longer appropriate. The Government's policy response has been varied and somewhat uncoordinated, which has the potential to compromise the reliability of the NEM. In support of this observation, Ford et al. (2011) make a systematic review of the observed climate change adaption in developed countries using a meta search of the literature and find comparatively limited reporting from Australia. There is a need to redress this situation with the final conclusion from this paper highlighting possible ways forward.

This paper assumes a need to adapt to climate change based on the arguments in Garnaut (2008) and Yates and Mendis (2009) that accurate prediction of climate change is fraught with uncertainty but there is scientific consensus that climate change is highly probable and the cost of not proactively adapting to climate change is high.

Institutional arrangements in the context of this paper refer to structure, ownership and regulations where structure includes market operations, market design, spot pool and market trading. Ownership includes public versus private and regulations include pricing.

This paper informs the development of four research reports within a project titled '*Analysis of institutional adaptability to redress electricity infrastructure vulnerability due to climate change*'. The titles of the forthcoming research reports are:

1. analysing the impacts of climate change on electricity demand;
2. analysing the impacts of climate change on electricity generation capacity and transmission networks;
3. analysing the effects of changes in water availability on electricity demand-supply; and

4. assessing the current institutional arrangements for the development of electricity infrastructure to inform more flexible arrangements for effective adaptation.

2 Literature Review

An extensive literature review has been undertaken in order to identify those areas where key research overlaps. Some studies have been performed to understand the risks associated with climate change, for instance Yates and Mendis (2009), however, the literature relating to Australia's electricity supply interests are significantly under-developed. Specifically, this review will consider three key points:

1. the potential impacts of more variable climate conditions on the electricity industry;
2. the effectiveness of adaptation actions being carried out in the NEM and the potential for maladaptation (Barnett & O'Neill 2010); and
3. the flow-on effects of climate change impacts and maladaptation (Barnett & O'Neill 2010) actions in other linked infrastructure industries such as water.

This review provides focus for the research in this project by exposing gaps and informing our methodologies for investigation.

Yates and Mendis (2009, p. x) note that climate change affects multiple units and functions of the electricity infrastructure, so a systematic approach is required to identify vulnerabilities and maladaption in the infrastructure to formulate a climate change adaption strategic plan. Furthermore, they recommend that any plan must be embedded into the various units and functions rather than overlayed.

This paper finds that three factors are hindering or are required for adaption to climate change:

1. fragmentation of the NEM both politically and economically;

2. accelerated deterioration of the transmission and distribution infrastructure due to climate change requiring the deployment of technology to defer investment in transmission and distribution; and
3. failure to model and to treat the NEM as a node based entity rather than state based.

These first three factors are interrelated, for instance, the fragmentation of the NEM has hindered the deployment of technologies to allow deferment of investment in transmission and distribution. The investment in transmission and distribution is primarily driven by peak demand, which could be mitigated with smart meters, flexible retail tariffs and consumer engagement. On the supply side, the renewable energy targets (RET) scheme has primarily driven onshore wind and solar PV uptake to the detriment of a broader portfolio. The onshore wind and solar PV each have their intermittent supply cycles that present a challenge to matching supply and demand. A broader portfolio of generation technology, storage and energy sources could both mitigate the intermittent supply cycles and aid deferment in transmission and distribution investment. However, promoting a broader portfolio of renewable energy would require modifications to the existing policy to incorporate targets for specific technologies and energy resources.

The fragmentation of the NEM has been acknowledged through the formation of a number of bodies to address coordination issues including, the Ministerial Council on Energy (MCE), Australian Energy Market Commission (AEMC), Australian Energy Market Operator (AEMO) and the Australian Energy Regulator (AER). However the underlying fragmentation and induced coordination problem still remains. Politically the NEM covers six states or territories and their legislative requirements. Economically the NEM has thirteen distribution companies and seven transmission companies. In contrast, South Korea, with two and half times the population of Australia, has a single company running both transmission and distribution within a single legislative entity. But it must be acknowledged that South Korea covers an area smaller than the NEM region. However, a single company, Telstra, manages the entire copper based telecommunications network for the whole of Australia, which covers a much larger area than the NEM. Hence the NEM's region covering a larger area than South Korea is a poor justification for fragmentation. South Korea's adaption to climate change is more advanced than the NEM because South Korea lacks the political and economic coordination overhead of the NEM. Forthcoming reports will include an international comparison to test this fragmentation observation.

The linking of the once separate state transmission and distribution networks to form the NEM's network has transformed the once natural monopoly within each state into a single NEM wide natural monopoly. So, the legacy fragmentation of the NEM's network causes coordination problems, which are a source of maladaption to climate change. In contrast, retail and generation are more amenable to numerous companies competing, so the fragmentation brings these markets closer to perfect competition to derive benefits for consumers. However the state ownership of transmission, distribution, generation and retail provides a conflict of interest for companies installing new generation to attach to the state owned networks to compete with the state owned generators. This conflict of interest is an impediment to the development of a broad portfolio of generation technology and energy sources. Both the NEM's transmission and distribution network fragmentation and the conflict of interest cause maladaption to climate change.

There has been an increase in demand for electricity for over two decades. However there are many countervailing trends in the demand for electricity. For instance there is uneven population growth across Australia, which will increase demand unevenly. The growth in the uptake of air conditioners is nearing a plateau, which will reduce the rate of increase in electricity demand. The price for electricity has increased rapidly over the last 10 years, which may see people become sensitive to price, so a price elasticity of demand starts to slow the rate of increase in demand. There are education campaigns to make people aware of their electricity use, which will reduce the rate of increase. Finally, there is climate change affecting both temperature and humidity, which could provide a countervailing effect on demand for electricity where an increase in temperature increases the use of air conditioners and a decrease in humidity decreases demand for air conditioners. The aforementioned countervailing trends make temporal and geographic modelling of demand essential to make predictions.

This section discusses the aforementioned trends in demand to expose any maladaptive policy and to inform the development of a model of demand to produce demand profiles.

2.1 Demand profiles

For this project, the demand profile is the electricity demanded in MWh for each hour of the day for 20 years from 2010 to 2030. There is a demand profile for each of the nodes on the NEM grid. Figure 1 shows the 11 nodes in Queensland's transmission line topology. These nodes serve three functions:-

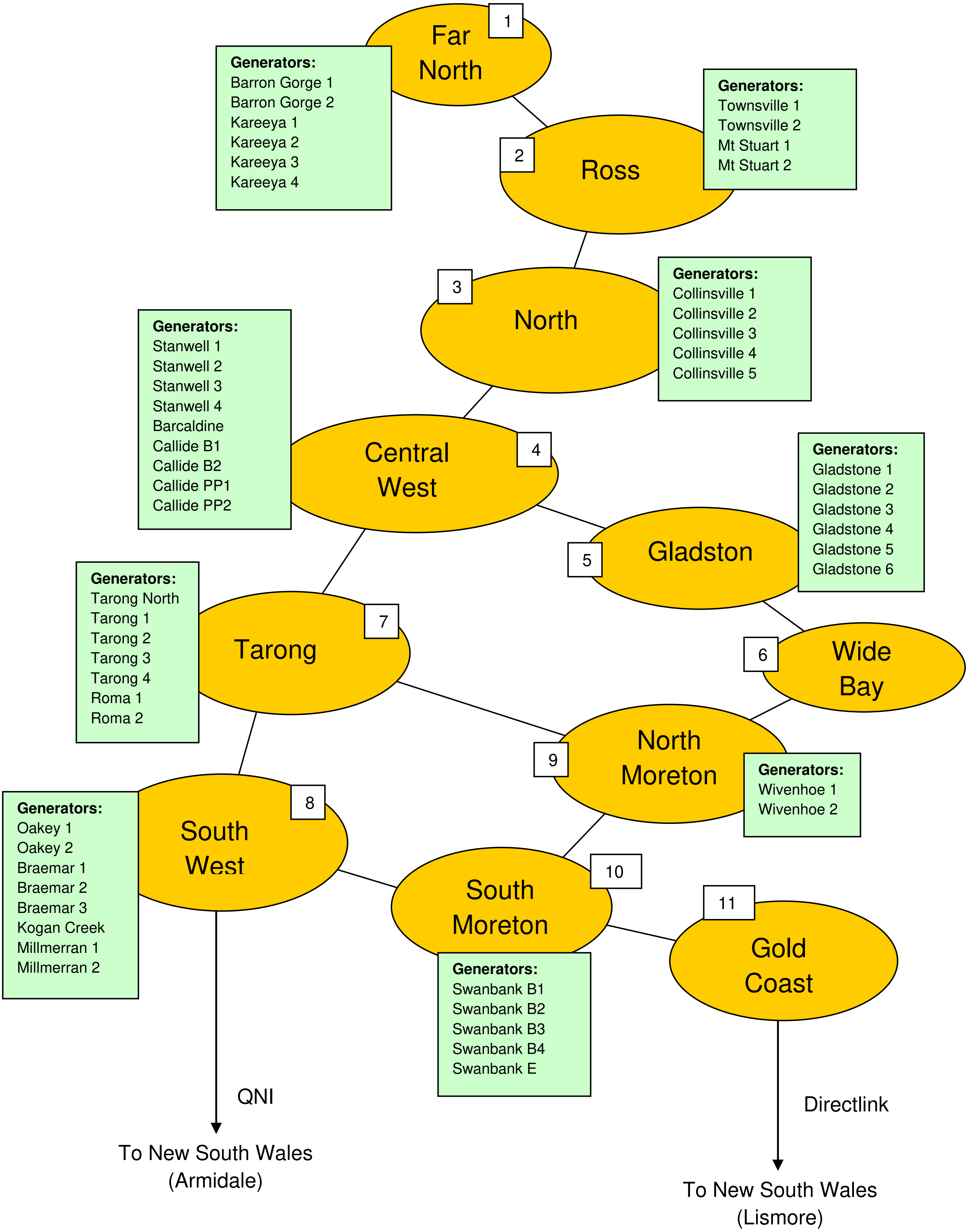
- Demand - the node represents an area or region of demand.
- Supply - the node represents the connection point for generators.
- Transmission - two nodes represent the connection points.

Geographically the demand is an area, the generators are points and the transmission lines are lines. These three topologies have bearing on the use of the climate change projections discussed in Foster et al. (2012 sec. 2.1). In addition, for demand, there is a requirement to relate population projections to these nodes. The population and climate change projections are used to create a demand profile for each of the 53 nodes on the NEM. The 53 nodes of the NEM are shown in Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5 for QLD, NSW, VIC, SA and TAS, respectively. Note that the nodes for ACT are incorporated within the node structure of NSW shown in Figure 2. These figures represent the topology of the network rather than geographic distance.

Notably, the nodes Bayswater, Murray and Hazelwood are supply only nodes without any demand. Additionally, there are three pseudo demand nodes at Moreton North, Wollongong and Tumut, which are required for modelling the demand from the pumped hydro storage at

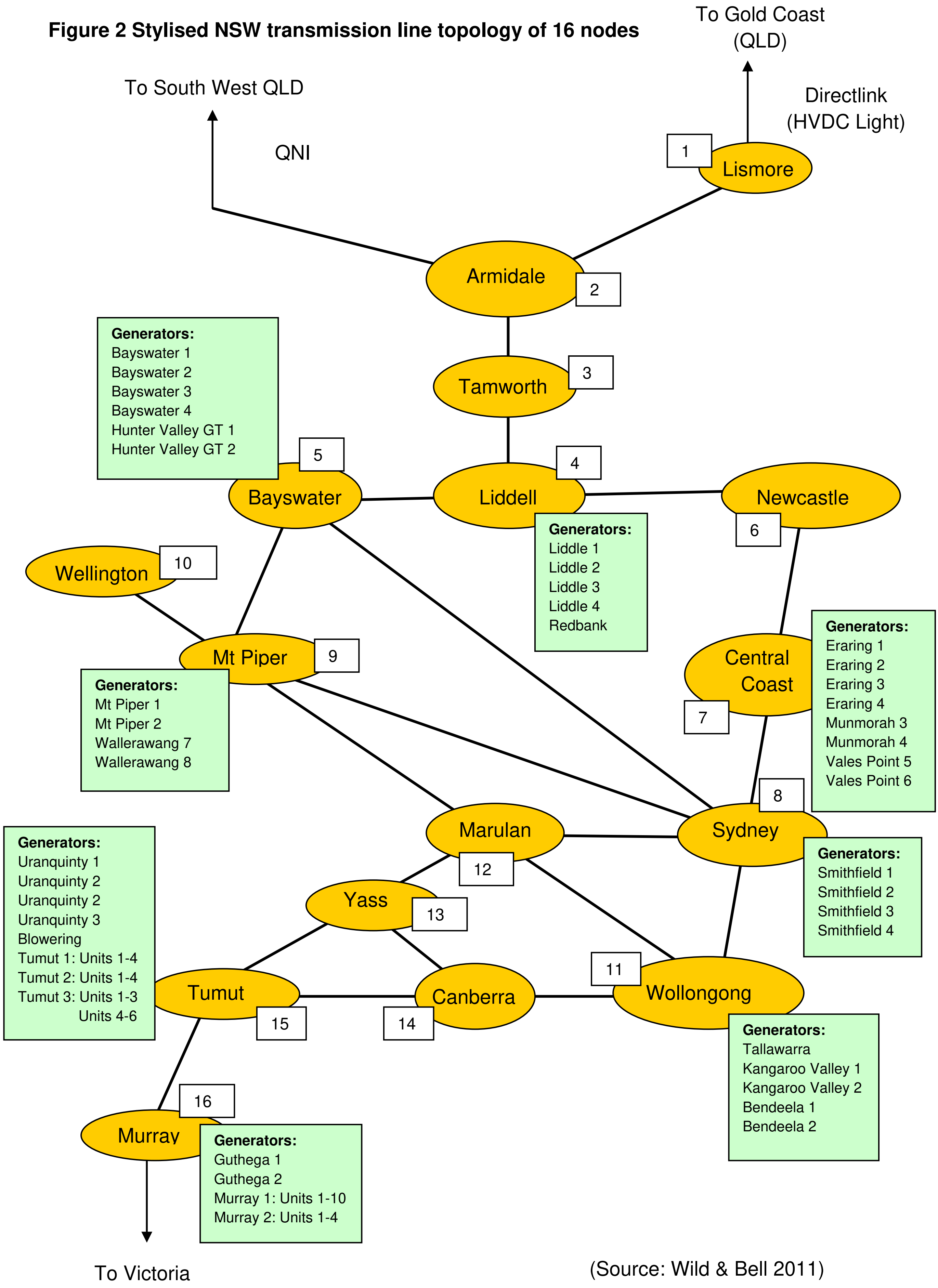
Wivenhoe, Shoalhaven and Tumut respectively. Furthermore, in Figure 1, the node number 8 called 'South West' is to be re-designated by Powerlink (2011 App. C) as two nodes being Bulli and South West. However this project will continue to use the topology in Figure 1 that is with the single node 'South West' without Bulli, for two reasons, being there lacks historical data on the two nodes to calibrate the models in the forthcoming reports and the project has a tight deadline.

Figure 1 Stylised QLD transmission line topology of 11 nodes



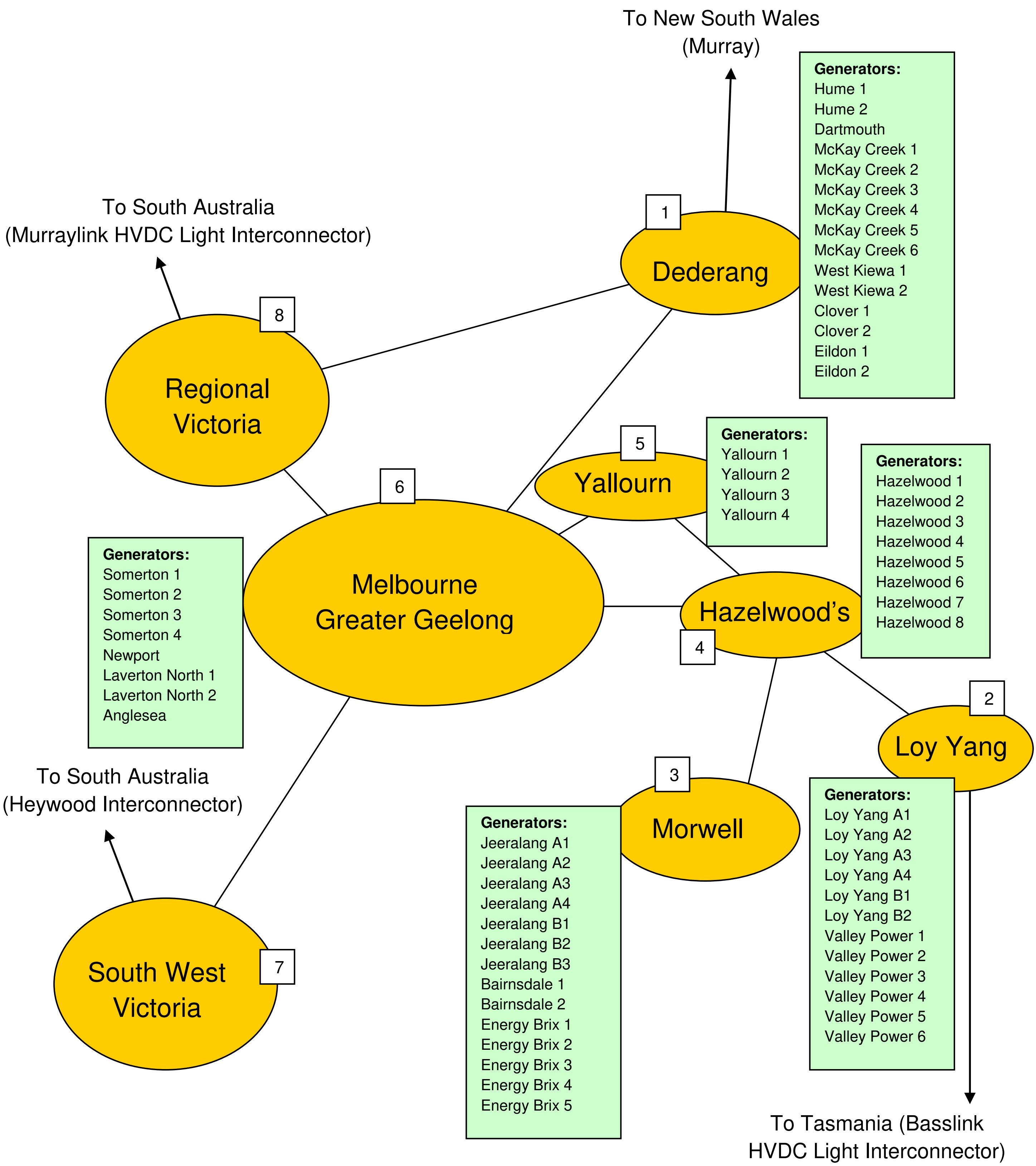
(Source: Wild & Bell 2011)

Figure 2 Stylised NSW transmission line topology of 16 nodes



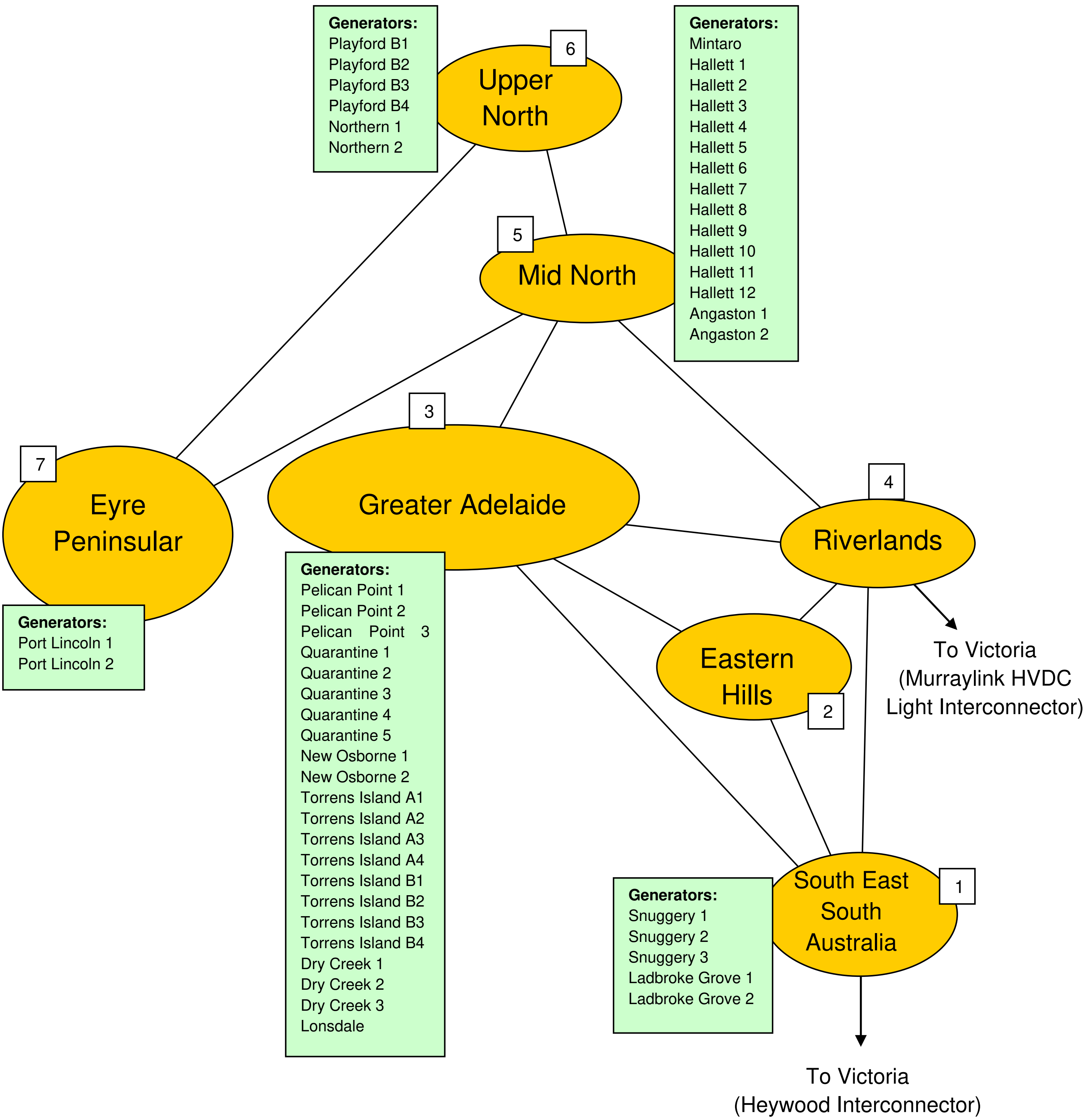
(Source: Wild & Bell 2011)

Figure 3 Stylised VIC transmission line topology of 8 nodes



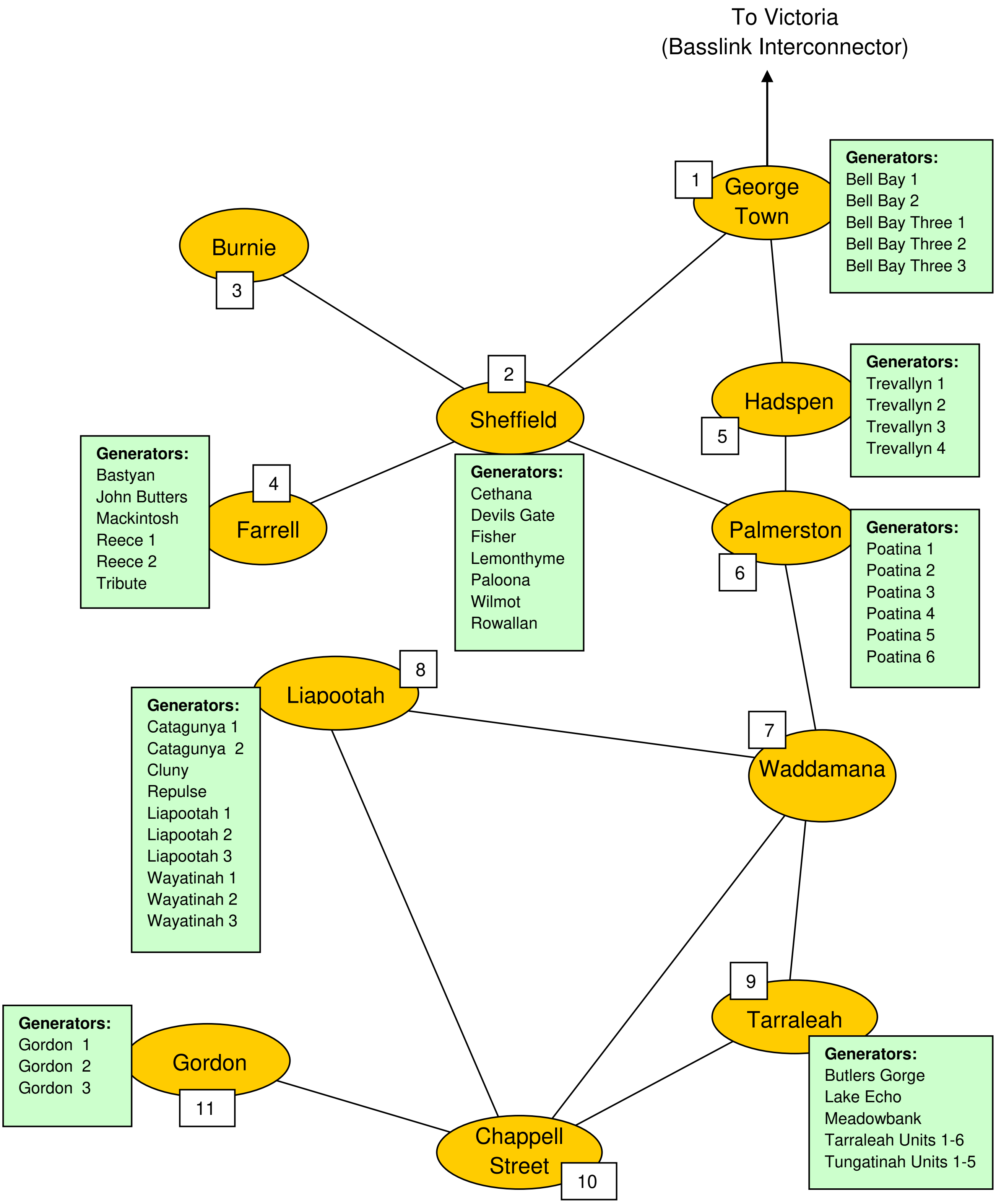
(Source: Wild & Bell 2011)

Figure 4 Stylised SA transmission line topology of 7 nodes



(Source: Wild & Bell 2011)

Figure 5 Stylised Tasmanian transmission line topology of 11 nodes



(Source: Wild & Bell 2011)

2.2 Short-run and long-run drivers for electricity demand

Yates and Mendis (2009, p. 111) consider short-run drivers for demand due to weather and long-run driver due to climate change. For instance in the short-run people can turn on fans or air conditions to meet changes in weather conditions and in the long-run people can buy air conditioners or install insulation to meet climate change.

Yates and Mendis (2009, p. 111) consider the following short-run electricity demand drivers.

- Weather – air temperature, wind speed, air humidity and radiation
- Indoor environmental factors – indoor air temperature, wind speed and humidity
- Time of the day
- Day of the week
- Holidays
- Seasons
- Durations of extreme heat days
- Urban heat island effects
- Utilisation of appliances
- Person's financial position
- Personal factors – clothing, physical activity and acclimatisation

Yates and Mendis (2009, p. 112) consider the following long-run drivers.

- Climate change
- Population growth composition and geographic distribution
- Real price of electricity
- The price of electricity relative to the price of gas
- Economic growth
- Real income and employment status
- Interest rates

- Renewal of building stock
- Households and floor space per capita
- Previous years consumption
- Commercial and industrial electricity use

There is an extensive literature in short-run electricity demand forecasting. However, Taylor and Buizza (2003) state that there is no consensus as to the best approach to electricity demand forecasting citing three different approaches. Harvey and Koopman (1993) forecast hourly demand using time-varying splines, Ramanathan et al. (1997) use multiple regression models and Hippert, Pedreira & Souza (2001) use artificial neural networks for short-run forecasting. For this project regression is chosen because it is the most commonly understood method.

There is a much less extensive literature on long-run electricity demand projections. In addition, Yates and Mendis (2009, p. 113) consider that there are the following difficulties in producing long-run projections.

- Limitations in climate change projections
- Limitations in demand modelling
- Limitations in data
- Lack of industry sector studies.

However this paper must extend the literature on short-run electricity demand forecasting to form long-run electricity demand projections. The method essentially involves using the existing literature to form a short-run forecasting model of electricity demand, then using the short-run forecasting model on simulated weather profiles of the years from 2010 to 2030. The simulated weather profiles are generated using the project's baseline weather year incremented by climate change projections. These resulting demand projections are factored for long-run derivers of electricity demand, such as population growth.

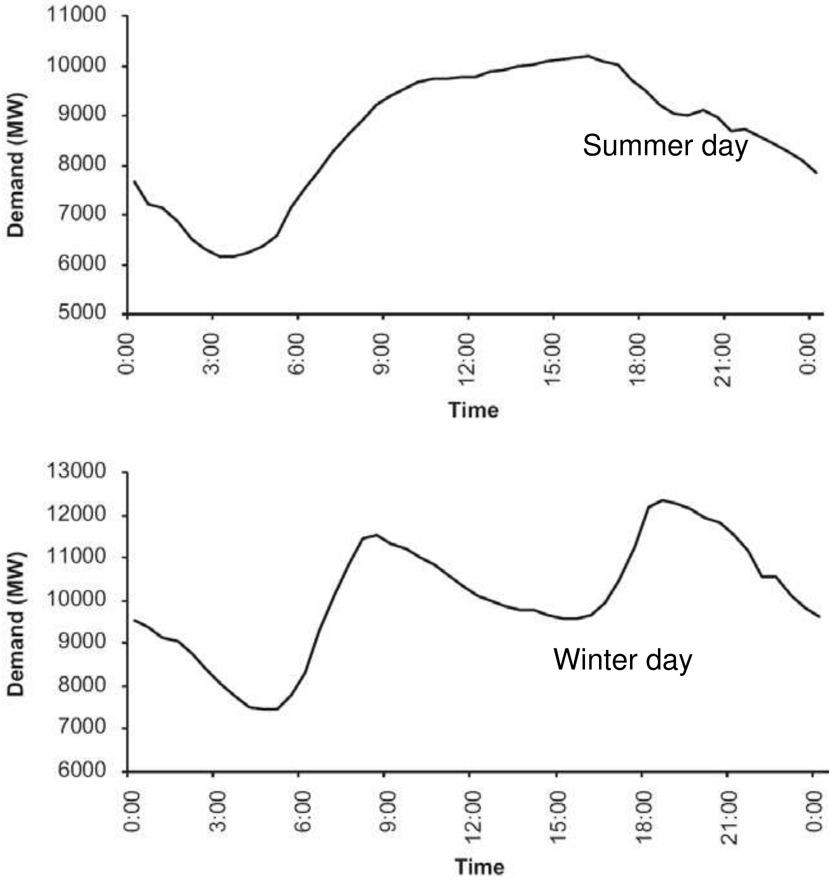
2.3 Weather and other short-run drivers for electricity demand

Equation (1) shows the short-run factors or weather variables driving demand that are readily modelled from the previous section and based on Ramanathan et al. (1997, p. 163).

$$\text{demand}_{(\text{season, day of week, hour, holiday, node})} = f(\text{temperature, humidity, wind speed, radiation})_{(\text{season, day of week, hour, holiday, node})} + \text{Auto regressive term} \qquad (1)$$

The subscripts in Equation (1) mean that there is a separate equation, for each season either summer or winter, for each day of the week, for each hour of the day, for whether the day is a holiday or not and for each node. Figure 6 shows the typical demand profiles for summer and winter days. In summer, people start to use the air conditioners about mid morning and continue using air conditioners until late afternoon. In winter people use the heating early in the morning and later evening but tent to switch off the heating during the middle of the day. This difference in profile illustrates the importance of capturing the typical summer and winter day in Equation (1).

Figure 6 Examples of the NSW intraday demand for a typical summer and winter day



(Source: Thatcher 2007, p. 1649)

Equation (1) ignores a *person's financial position* and *personal factors* as the equation models an aggregation of all the consumers on a node. Equation (1) captures the *utilisation of appliances*, in particular air conditioners, by using the variables for time of day and temperature. Equation (1) partially captures the *urban heat island effects* using the node variable. The *durations of extreme heat days* affect the use of air conditioners as buildings retain heat from the previous day. The auto regressive term in Equation (1) captures this residual heat effect. The auto regressive term simply means that today's demand for electricity is related to yesterday's demand for electricity, which is related to the demand for electricity of the day before yesterday, and so on but the relationship dissipates over time.

There is a possibility that the environment variables are highly correlated or synchronised, so a subset of the variables, that are the most uncorrelated, are selected to form the regression to model the demand for electricity. The process is known as *principle component analysis* of historical demand. For instance the effect of the following four variables on demand for electricity may be adequately modelled with just three of the variables: population, number of air conditioners owned, number of households and climate change.

Table 2 cites results from Howden and Crimp (2001) who forecast the increase in peak demand under given temperature increases for Adelaide, Brisbane, Melbourne and Sydney. The response to an increase in temperature varies greatly between the metropolitan centres, which stresses the importance of modelling demand for each node.

Table 1 Effect of temperature change on peak demand for electricity in 4 capital cities

ΔT (°C)	Projected impact on peak electricity demand
<1	Melbourne and Sydney decreases up to 1% Adelaide and Brisbane increases 2–5%
1-2	Melbourne and Sydney decreases 1% Adelaide and Brisbane increases 4–10%
2-3	Adelaide, Brisbane and Melbourne increases 3–15% Sydney decreases 1%
3-4	Adelaide, Brisbane and Melbourne increases 5–20% Sydney decreases 1%
4-5	Adelaide, Brisbane and Melbourne increases 9–25% Sydney decreases 0.5%
>5	Sydney decreases 0% Adelaide, Brisbane and Melbourne increases 10–25%

(Source: Preston & Jones 2006, p. 29)

Table 3 show the increase in peak demand for a one degree increase in temperature in the states NSW, Vic, Qld and SA.

Table 2 Projected increase in peak demand for a one degree increase in temperature

Region	Change in peak regional electricity demand
NSW	–2.1% ±1.0%
Vic	–0.1% ±0.7%
Qld	+1.1% ±1.4%
SA	+4.6% ±2.7%

(Source: Thatcher 2007, p. 1655)

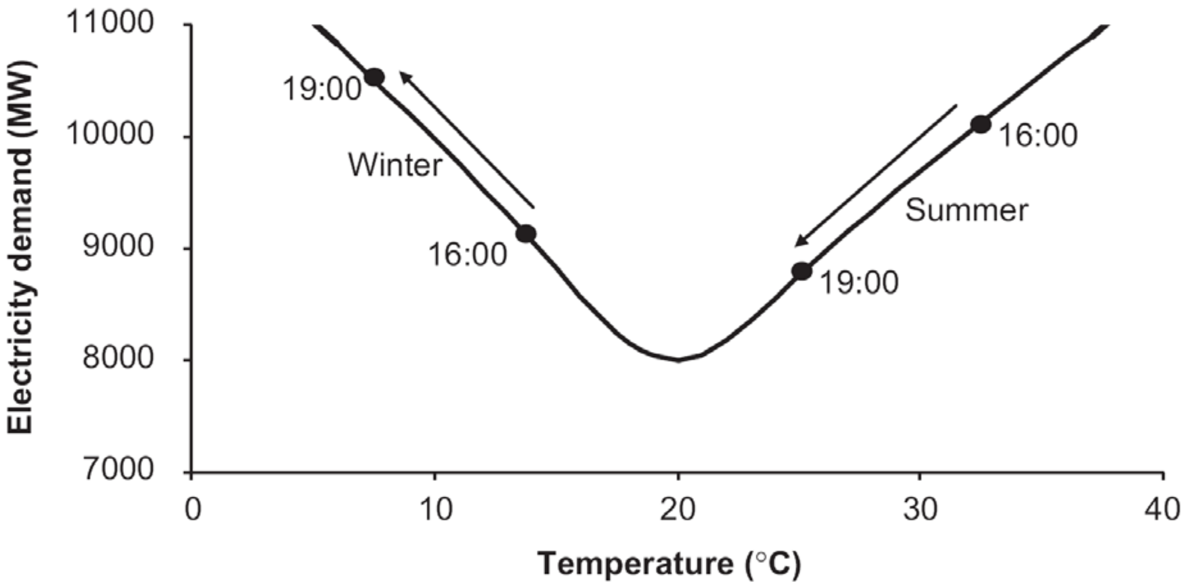
When comparing Table 2 and Table 3 it indicates a discrepancy between the change in peak demand between the capital city and the state. The *urban heat island effect* can partially explain why demand in a capital city would differ to the state. This discrepancy adds weight to the need to model demand for each node rather than aggregate by state. Unfortunately, the demand profiles of the years 2006 to 2011 from AEMO (2011) are aggregated by state. However, the demand profiles for each node are available via company websites and annual reports.

Furthermore, these large increases in peak demand have traditionally been met by increased investment in generation, transmission and distribution even though the peaks are for relative short periods. The consequence is a considerable increase to electricity bills to meet peak demand, which lasts for a relatively short duration. Sections 2.6 and 3 discuss methods to defer investment in generation, transmission and distribution.

Howden and Crimp (2001) and Thatcher (2007) use Heating Degree Days (HDD) and Cooling Degree Days (CDD) to model the effect of temperature on peak demand. This degree day technique provides a better modelling technique than the season variable in Equation (1), as the degree day technique accommodates unseasonal days. For instance, with regards to the profile in Figure 6 there are very cold summer's days that could have the winter's day demand profile and very hot winter's days that could have the summer's day demand profile.

Figure 7 shows a schematic that illustrates the degree day concept where in summer at high temperatures the demand at 16:00 is greater than at 19:00 and in winter at low temperatures the situation is reversed. This technique can be applied to any hot or cold day but a base temperature (T_b) is required to determine whether a day is a HDD or a CCD. In Figure 7, the base temperature appears about 20 degrees Celsius.

Figure 7 Relationship between electricity demand and temperature at different time



(Source: Thatcher 2007, p. 1650)

Table 4 shows that the base temperature varies amongst the capital cities and state and between capital city and home state, which adds further weight to developing demand profiles for each node. As expected, the base temperatures forms some indication of acclimatisation, for instance the base temperature for Brisbane is higher than Melbourne, which indicates that somebody in Melbourne is more likely to switch on an air conditioner at lower temperature than somebody in Brisbane and that somebody in Brisbane is more likely to switch on heating at a higher temperature than somebody in Melbourne.

Table 3 Comparing base temperature in degrees Celsius for cities and states

City	T_b	T_b	State
Brisbane	18.6	19.70	QLD
Sydney	17.5	19.16	NSW
Melbourne	16.9	16.94	VIC
Adelaide	16.8	18.08	SA
(Source: Howden & Crimp 2001, p. 656)		(Source: Thatcher 2007, p. 1653)	

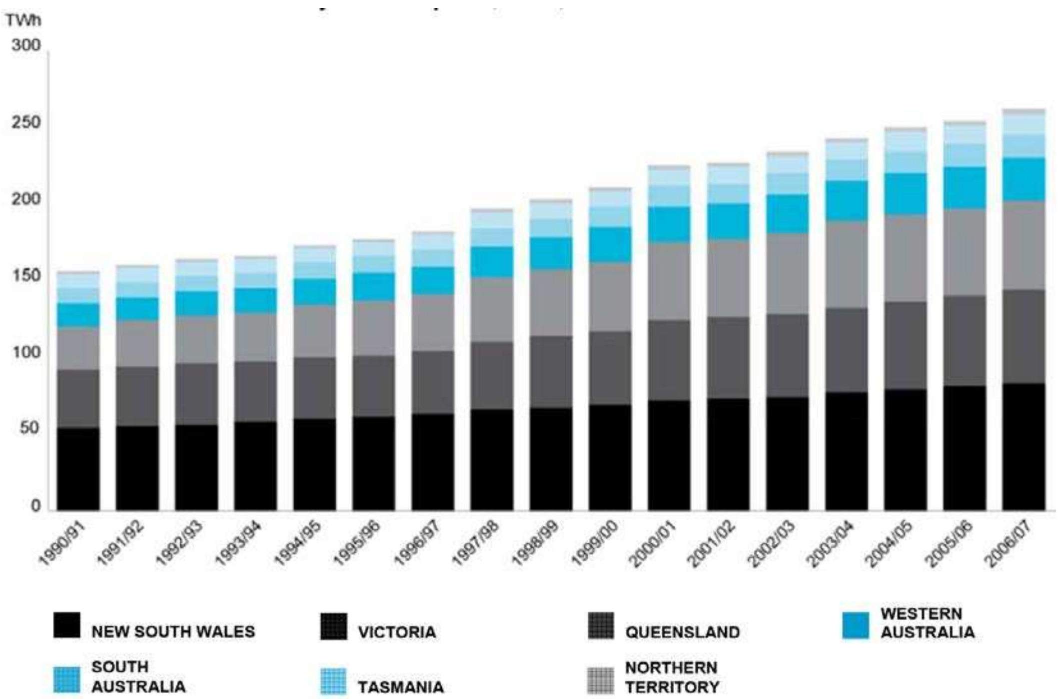
As previously discussed, Equation (1) fails to accommodate personal acclimatisation but the degree day technique using base temperatures accommodates personal acclimatisation to a location. So, there are two reasons to adopt the degree day technique over the season variable in Equation (1), being accommodating unseasonal days and acclimatisation to the local climate.

Howden and Crimp (2001) and Thatcher (2007) include a measure for humidly. Howden and Crimp (2001) found that the inclusion of humidity improved the models' predictive performance for Brisbane for both CDD and HDD and for Melbourne for CDD only. However temperature proved sufficient to model demand for both CDD and HDD for both Sydney and Adelaide.

2.4 Climate and population as long-run drivers for electricity demand

Figure 8 shows the demand for electricity increasing from 1990 to 2006 by 67%. The Chairman of the AEMC (Tamblyn 2008) expects this tend to continue, requiring further investment in generation, transmission and distribution, which is discussed in Foster et al. (2012 sec. 2.3).

Figure 8 Electricity consumption, TWh, 1990-91 to 2006-07



(Source: Tamblyn 2008, p. 15)

Some of this increase in demand is due to population growth and climate change. The mechanism for population growth increasing demand for electricity is obvious but the mechanism for climate change increasing demand for electricity is more indirect. For instance warmer temperatures encourage people to install more air conditioners and use the air conditions more often. Both population growth and climate change are long-run demand drivers and are readily modelled. However, the following long-run demand drivers are not so easily modelled for the 20 year duration of the project.

- Public engagement and the smart grid
- Acclimatisation to climate change
- Air conditioner purchases
- Real price of electricity - Price elasticity of demand
- The price of electricity relative to the price of gas
- Real income and employment status

- Interest rates
- Economic growth
- Renewal of building stock
- Households and floor space per capita
- Previous years consumption
- Commercial and industrial electricity

Foster (2012 sec. 2.1) discusses the selection of this project's *Special Report on Emission Scenario* (SRES) A1FI and three Global Climate Models (GCMs) used to produce the climate change projections for the *'Worst case'*, *'Most likely case'* and *'Best case'*. These three climate projections are used to produce demand profiles in conjunction with population projections.

This section discusses the three Australian Bureau of Statistics (ABS 2008) population projections used in this project. The ABS (2008, p. 3) states, *"Three main series of projections, Series A, B and C, have been selected from a possible 72 individual combinations of the various assumptions. Series B largely reflects current trends in fertility, life expectancy at birth, net overseas migration and net interstate migration, whereas Series A and Series C are based on high and low assumptions for each of these variables respectively"*

Table 5 shows the population projection assumptions and the expected increases in population from 2006 to 2030. The projected population percentage increase provides an indication of the expected increase in demand for electricity from population growth.

Table 4 Population projection assumptions and increase from 2006 to 2030

	Total fertility rate	Net overseas migration	Life expectancy at birth	Actual Population	Projected Population

	Babies per woman	persons	Males year	Females years	30 June 2006	30 June 2030	Increase
Series A	2.0	220 000	93.9	96.1	20,697,880	30,499,959	47%
Series B	1.8	180 000	85.0	88.0	20,697,880	28,484,167	38%
Series C	1.6	140 000	85.0	88.0	20,697,880	26,851,511	30%

(Source: ABS 2008)

However, for Series B, Table 6 shows that this population growth and induced growth in demand for electricity is unevenly spread across the NEM region with Queensland expecting significantly more growth and Tasmania the least growth. Additionally, there is marked difference in growth between the capital city and the balance of the state for Vic., NSW, Tas. and SA. Consequently, modelling population by node would better reflect the stresses induced on the NEM by this uneven population growth.

Table 5 Uneven projected population growth from 2006 to 2030 across the NEM

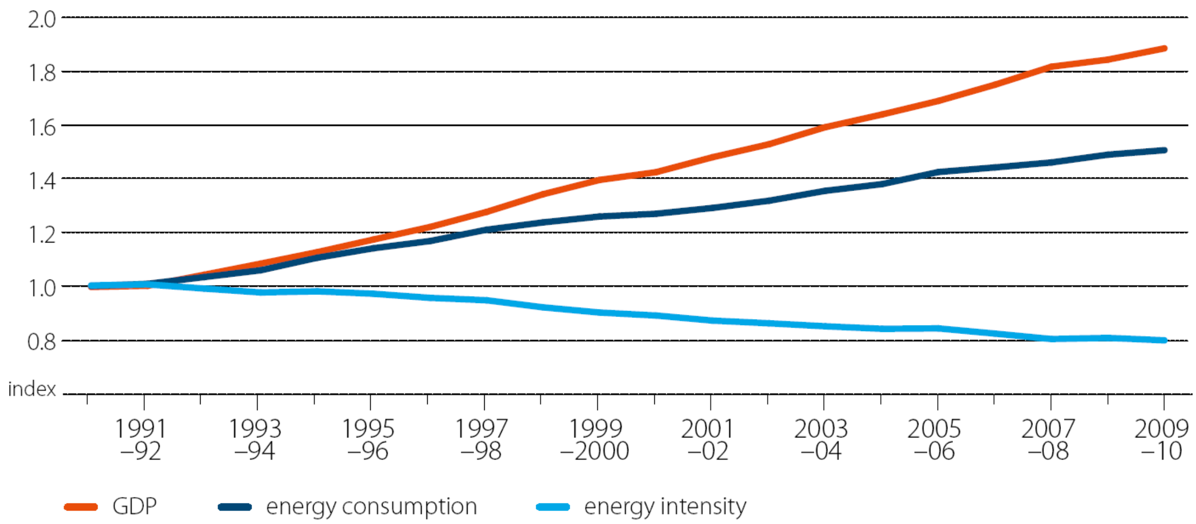
Series B	**Qld**	**NSW**	**Vic**	**SA**	**Tas**	**ACT**	**NEM**
Entire State	57%	27%	36%	24%	14%	29%	36%
Capital city	57%	32%	41%	25%	22%		38%
Balance of state	57%	20%	20%	21%	8%		32%

(Source: ABS 2008)

2.5 The link between economic growth and growth in demand for electricity

Figure 9 shows that growth in energy consumption has remained below the growth in GDP and energy-intensity has been declining. Energy-intensity is the ratio of energy used to activity in the Australian economy. Ball et al. (2011, p. 8) discuss how declining energy-intensity is a worldwide phenomenon.

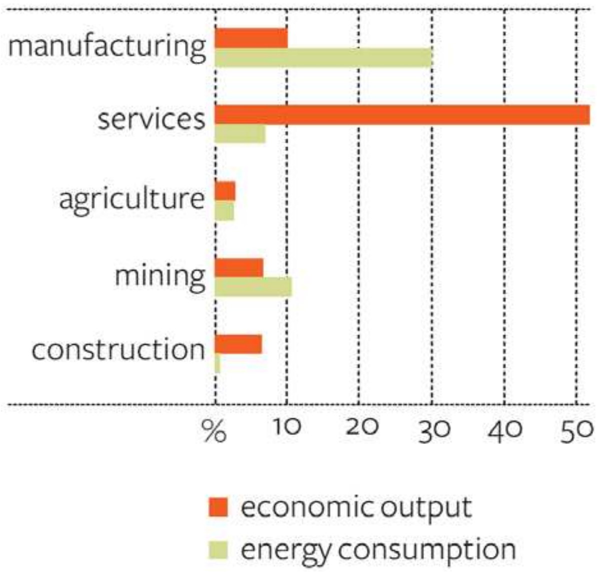
Figure 9 Intensity of Australian energy consumption



(Source: Schultz & Petchey 2011, p. 5)

Shultz and Petchey (2011, p. 5) consider the decline in energy-intensity due to two factors being the improvement in energy efficiency associated with technological advancement and a shift in industry structure toward less energy-intensive sectors. The improvement in energy efficiency is likely to continue and is further discussed in the following sections. Figure 10 compares the percentage share of economic output and of energy use for different industries. Manufacturing is the most energy intense industry and the service industry is one of the least intensive industries. The increase in the size of the service industry and decrease in the size of the manufacturing accounts for some of the decline in energy-intensity. The decline in energy-intensity requires modelling to adjust the demand profiles developed from the population and climate projections. The next section discusses why this long-run trend is likely to continue.

Figure 10 Shares of energy consumption and economic output 2005-06



(Source: Sandu & Syed 2008, p. 4)

2.6 Smart meters as long-run drivers for reducing electricity demand

This section discusses how smart meters providing customers with dynamic pricing can help customers reduce demand for electricity at peak times and increase public engagement in energy conservation.

Smart meters allow retailers to automatically collect high frequency data on customers' electricity usage and customers to monitor their own use of electricity. Smith and Hargroves (2007) discusses the introduction of smart meters, the ensuing public engagement and the substantial reduction in peak demand being achieved. Currently in Australia transmission and distribution investment is made to meet the peak demand period, which is usually between 3 pm and 6 pm in most OECD countries. Smith and Hargroves (2007) states that in Victoria the transmission investment is 20 percent bigger to meet peak demand for 1 percent of the year. In comparison, Georgia Power and Gulf power in Florida, USA, have installed smart meters resulting in Georgia Power's large customers reducing electricity demand by 20-30 percent during peak times and Gulf power achieving a 41 percent reduction in load during peak times. Zoi (2005) reports on California's experience of tackling the growing demand for peak summer power using a deployment of smart meters with a voluntary option for real time metering that uses lower tariffs during off peak times and higher tariffs during peak times with a 'critical peak price' reserved for short periods when the electricity system is really stressed. Energy consumption during peak periods was reduced by 12-35 percent. Most Californians now have lower electricity bills and that 90 percent of participants support the use of dynamic rates throughout the state.

The AEMC (2009, p. v) considers fixed priced tariffs for retail customers a risk to the NEM with the introduction of the RET and the carbon pollution reduction scheme (CPRS), so the AEMC (2009, p. v) recommends more flexible pricing for retail customers to reflect the movements in wholesale prices. In addition, recommending a national customer protection scheme be setup prior to introducing flexible pricing. A flexible retail consumer price reduces the risk for the electricity companies and transfers the risk to the retail customer. However, if the retail customers lack in-house-displays for their smart meters, the customers will be unable to readily adapt to changes in price. Introducing flexible pricing before smart meters with in-house-displays could induce a negative response from customers, so hindering consumer engagement in energy conservation. For instance the World Energy Council (WEC 2010) evaluates the residential smart meter policies of Victoria and claim the lack of an in-house-display is a major source of customer dissatisfaction amongst customers with dynamic prices. Another source of dissatisfaction is the lack of provision for the most financially vulnerable. Foster et al. (2012 Sec. 2.5.5) discusses institutional fragmentation as a cause of the slow smart meter deployment in Australia and as a source of maladaption to climate change.

2.7 Energy efficiency as a long-run driver for reducing electricity demand

Institutional fragmentation is also hindering policies surrounding energy efficiency. Hepworth (2011) reports how AGL and Origin Energy called for a national scheme rather than state based schemes because compliance across the different states legislations is costly. However the National Framework for Energy Efficiency (NFEE 2007) instituted by the Ministerial Council on Energy (MCE) claims significant progress. But in a submission to the NFEE (2007) consultation paper for stage 2, the National Generators Forum (NGF 2007) comments on the progress since stage 1 of the NFEE *"Progress in improving the efficiency of residential and commercial buildings can best be described as slow and uncoordinated, with a confusion of very mixed requirements at the various state levels. … Activities in areas of trade and professional training and accreditation, finance sector and government have been largely invisible from a public perspective"*. The NGF (2007) states that the proposals for stage 2 are modest and lack coordination and national consistency. So, there is disagreement between the MCE and participants in the NEM over coordination in the NEM. Foster et al. (2012 sec. 2.5.6) further discusses coordination problems induced by institutional fragmentation as a cause of maladaption to climate change.

In another submission to the consultation paper, Origin Energy (2007) calls for the NFEE to focus on non price barriers to energy efficiency that the price signal from the CPRS is unable to address. Claiming the public good aspect of energy efficiency provides strong justification for government funding even where there are private benefits through cost savings. Origin Energy considers the following items are suitable for direct action to remove non price barriers.

- Education/information campaigns
- Low interest or zero interest loans
- Minimum Energy Performance Standards (MEPS)
- Phasing out electric hot water systems
- Incandescent light bulb phase out
- Building standards

Stevens (2008, p. 28) identifies the need for raising public awareness of electricity demand and shaping public opinion as part of an adaptive strategy but Origin Energy (2007) considers public education/information campaigns are considerably underfunded. The star rating of appliances by Equipment Energy Efficiency (E3 2011) is an example of a campaign that is visible and easy to understand, which is moot with some success and addresses information asymmetry. As discussed, the introduction of smart meters and flexible pricing has engaged customers in other countries. This public engagement by smart meters can provoke a much wider interest in the conservation of electricity to include energy efficiency.

Additionally, Origin Energy (2007) supports interest free loans to undertake energy efficiency projects with high upfront costs, particularly for poorer individuals or smaller businesses that have difficulty accessing as finance. Foster et al. (2012 sec. 2.5.1) further discusses interest free loans and people's expectation of a much shorter payback period on an investment than is economically optimal as justification for government intervention.

Both Origin Energy (2007) and NGF (2007) acknowledge that the MEPS established for refrigerators and freezers, electric water heaters and refrigerative air conditioners are effective and support the expansion of MEPS to include other appliances. MEPS are a successful adaption to climate change.

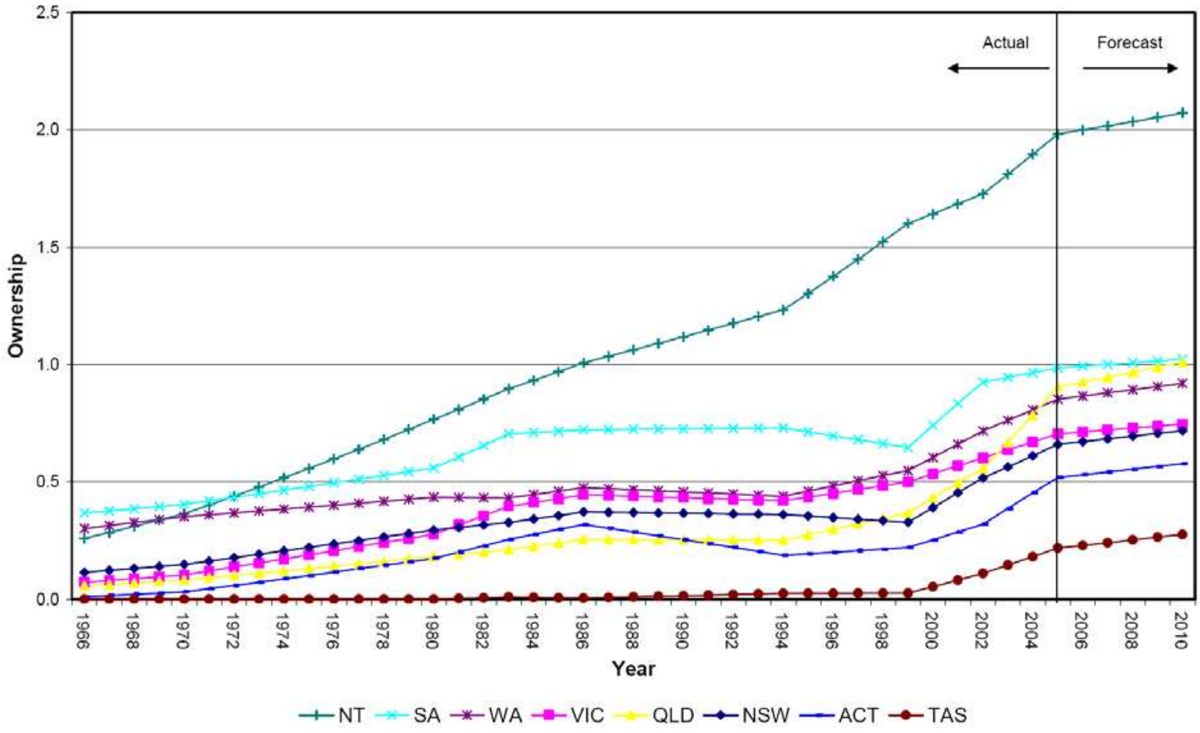
However, Origin Energy (2007) agrees but NGF disagrees with the phasing out of electrical hot water systems. NGF states that water heating accounts for 30% of household electricity use but only 6% of total stationary energy use. Additionally, NGF calls for fuller consideration of the impact of the phase-out on peak and off-peak electricity use, electricity costs and prices and water use. These electrical hot water systems provide a use for electricity generated during the off peak periods. There are strong financial incentives for coal generators and some gas generators to maintain this off peak load to avoid considerable shutdown and start up costs. Foster et al. (2012 sec. 2.3.12) discusses the requirement to maintain this off peak load or a baseload to support coal as a potential form of maladaption to climate change.

Both Origin Energy (2007) and NGF (2007) express concern about the phase out of incandescent light bulbs being in favour of the phase out but better consultation prior to the phase out may have prevented some adverse and unintended consequences, such as, the poor light rendition and high failure rate of substandard imported compact fluorescent lights (CFL), which caused some people to adopt halogen down-lights that have higher energy use than incandescent light bulbs.

The NGF (2007) breaks down the stationary energy use by sector as household 21%, commercial 12% and industrial 67%, claiming a greater focus on energy efficiency in the industrial sector may provide greater gains rather than on the household sector. However, as mentioned, the need to meet peak load drives investment in transmission and generation rather than total energy used. For instance energy use for air conditioners as a percentage of total energy is not significant but air conditioners are primarily used during peak period, which makes the additional load significant.

The MEPS will reduce the amount of energy new air conditioners use and so reduce the demand for electricity. However, Figure 11 shows increases in ownership of air conditioners across all states, which will increase demand for electricity. There was a rapid growth in air conditioner ownership from 2000 to 2005 when the growth was expected to slow from 2006. This trend is consistent with a slowing increase in demand per capita for electricity over the long-run. Northern Territory (NT) shows a considerably different trajectory to the other sates but NT is ignore as it lies outside the NEM region.

Figure 11 National Ownership of Air Conditioners by State



(Source: NAEEEC 2006, p. 9)

The changes in building standards have engendered an improvement in new housing energy efficiency. Yates and Mendis (2009, p. 121) discuss how increased urban salinity and ground movement damage induced by climate change will accelerate building stock renewal, leading to a long-run reduction in demand for electricity. However, the projected growth in the number of households exceeds the projected growth in population, which means fewer people sharing a household and resulting in an increase in demand for electricity above population growth. Table 7 shows the projected growth in the number of households across the NEM from 2006 to 2030. Table 8 shows the projected growth in the number of households above the projected growth in population, which is significant and amenable to modelling. Table 8 is the difference between Table 7 and Table 6.

Table 6 Uneven projected household growth from 2006 to 2030 across the NEM

Series II	Qld	NSW	Vic	SA	Tas	ACT	NEM

State	68%	37%	44%	31%	22%	38%	45%
Capital city	66%	40%	50%	31%	28%		46%
Balance of state	70%	32%	31%	32%	18%		43%

(Source: ABS 2010)

Table 7 Projected household growth above population growth from 2006 to 2030

Series II - Series B	Qld	NSW	Vic	SA	Tas	ACT	NEM
State	11%	10%	8%	7%	8%	9%	9%
Capital city	9%	8%	9%	6%	6%		8%
Balance of state	13%	12%	11%	11%	10%		11%

The household projection assumptions in Table 7 are those for Series II of the ABS (2010). Series II is considered the most likely growth scenario where Series I and III represent lower and higher growth scenarios, respectively. Series I, II and III household projections use the assumptions of the Series B population projection in Table 5.

While the number of people per house decreases, BRANZ (2007, pp. 28-9) discusses how there is an increase in the size of the average house in Australia where the new standard house has 4 bedrooms and 2 bathrooms. The increases in size of house will increase demand for electricity. While house size has become larger, the section size has become smaller, which increases the heat islands effect that is the reduction in greenery around a suburb to moderate temperature swings. The heat island effect will also increase the demand for electricity. But the increase in the number of swimming pools acts to moderate the heat island effect.

2.8 Higher prices and acclimatisation as long-run drivers for demand

Australia still enjoys relatively low electricity prices by international standards but the commodity boom has driven prices higher for fossil fuels, which has in turn driven electricity prices higher (Garnaut 2008, pp. 469-70). At low electricity prices people are insensitive to price rises but at higher prices people become much more sensitive to prices increases to the extent that people decrease their use of electricity. The higher price example means that the price elasticity of demand for electricity has increased or is more elastic. The price elasticity of demand is the percentage increase or decrease in quantity demanded in relation to the percentage increase or decrease in price. The higher prices for electricity could see an elasticity of demand operating, which would moderate further increases in demand for electricity.

Climate change is rapid on a geological scale but slow on a human scale, so there is ample time for people to acclimatise to changes in climate in the same location, as opposed to people moving to a new location with a different climate and acclimatising to the new climate but taking a few years to adapt to an abrupt locational change. People's ability to acclimatisation will slightly moderate the increase in demand for electricity induced by climate change.

2.9 Conclusion

The first key finding is the requirement to model demand for each node rather than by state. This finding is supported by the following five observations. There is significantly uneven projected population growth within each state, excepting Qld. Sensitivity analysis of demand to temperature shows a discrepancy between state and capital city. There is a significant difference in base temperature between the state and capital city, excepting Vic, which indicates difference in acclimatisation and heat island effects. Additionally, there are uneven weather patterns and climate change projections within each state.

This section provides sufficient information to model demand profiles from 2010 to 2030 for forthcoming reports to perform sensitivity analysis using the demand profiles. In addition to climate change, the projected growth in population and in the number of households will have a significant effect on the NEM. One research question examines the relative impact of climate change to population change whist another question examines a sensitivity analysis of differing population growth.

The second key finding is that institutional fragmentation is hindering the deployment of smart meters and of energy efficiency equipment generally but there are some successful adaptations to climate change namely, MEPS and the Equipment Energy Efficiency star rating. Furthermore, introducing smart meters with in-house-displays before introducing flexible retail pricing would be more conducive to enhancing public engagement. Foster et al. (2012 secs. 2.5.5 & 2.5.6) further discuss smart meter deployment and institutional fragmentation, respectively.

Additionally, finance is identified as a non price signal barrier to the deployment of energy efficient equipment. Foster et al. (2012 sec. 2.5.2) further discusses this issue.

3 Discussion

This section proposes solutions to the climate change adaption issues found in the previous sections. The three main issues found hindering climate change adaption are:

1. institutional fragmentation both economically and politically;
2. distorted transmission and distribution investment deferment mechanisms; and
3. failure to model and to treat the NEM as a node based entity rather than state based.

The solutions to the issues are interdependent but the issues are discussed in turn for clarity of exposition and for ease of relation to the research questions.

3.1 Institutional fragmentation both economically and politically

The NEM is extremely fragmented both economically and politically, which continues to hinder the NEM's adaption to climate change. To address political fragmentation, the states of the NEM cede legislative power to the federal government over matters pertaining to the NEM. To address economic fragmentation, the proposed solution is to transfer the ownership of all transmission and distribution in the NEM into a single holding company owned by the states, federal government and privately. This produces alignment between single company ownership and the NEM's transmission and distribution as a natural monopoly. The governments maintain a controlling minimum stake of 51 % in the monopoly. To address conflict of interest between government and private entities on connections to the NEM grid, the government privatises all generation. Similarly to address conflict of interest over retail, the government privatises all retail. Foster et al. (2012 sec. 2.5.7) discusses caveats to privatisation of generation and retail. A forthcoming report tests the proposition that the NEM's slow adaptation to climate change is due to political and economic fragmentation.

3.2 Distorted transmission and distribution investment deferment mechanisms

The accelerated deterioration of transmission and distribution due to climate change makes the deferment of investment more pressing. Mechanisms for deferment include energy efficiency, smart meters, and modified feed-in tariffs.

Other than for MEPS and the star ratings, energy efficiency in the NEM is uncoordinated and lacks a national scheme. The solution in the previous subsection addresses the lack of coordination and of a national scheme. Furthermore, people make myopic investment decisions by expecting shorter payback period than is economically optimal, which hinders the deployment of energy efficiency equipment. Foster et al. (2012 sec. 2.5.1) discusses in detail the solution of interest free loans to address this market failure. The loans will also address equity concerns.

The NEM with a single monopoly transmission and distribution company within a single legislative area as proposed in the previous section would aid a NEM wide role out of smart meters, providing monopoly buying powers and reducing coordination costs. A NEM wide rollout of smart meters is trivial compared to Italy's national rollout of smart meters.

Following the NEM wide rollout of in-house-display equipped smart meters, deregulation of retail pricing will enable a price signal for peak demand period to moderate demand during peak period and so defer investment in transmission. Smart meters and deregulated retail prices have positively engaged customers in other countries and have considerably reduced peak demand.

In this paper a prosumer is an entity that produces and consumes the same item. For example the term prosumer is particularly useful to describe a household with solar PV that produces and consumes electricity.

Foster et al. (2012 sec. 2.5.1) also discusses the requirement for a gross feed-in tariff based on the locational marginal price for prosumers to maximise generation capacity but prosumers still try to conserve electricity because prosumers will pay the normal tariff for electricity consumed. To aid transmission and distribution investment deferment, the prosumer only pays the transmission and distribution costs for electric supplied from the grid, which provides an extra incentive for the prosumer to install generation via a price signal. This price signal to install more generation is higher where the transmission and distribution cost are higher. Additionally, for the suggested gross feed-in to be effective, any solar bonus should be removed as the solar bonus causes cross subsidies generally from poorer households to richer households.

Embedded generation such as solar PV requires a substantial capital investment with a long payback period. As mentioned under such circumstances people make myopic investment decisions. Interest free loans are justified to address the market failure of myopic investment decisions, to address equity concerns and to capture the positive externalities, such as transmission investment determent.

A forthcoming report will investigate the investment deferment potential of storage, pumped hydro storage and solar PV.

3.3 Failing to model and to treat the NEM as node based entity rather than state based

Failure to model the NEM by node could lead to misguided policy causing maladaption to climate change. Section 2 discusses why there is a requirement to model the NEM by node rather by state for five reasons:

- uneven projected population growth within each state, except Queensland;
- sensitivity analysis of demand to temperature shows a discrepancy between home state and capital city;
- there is a significant difference in base temperature between home state and capital city, excepting Victoria, which indicates difference in acclimatisation and heat island effects;
- uneven weather patterns within each state; and
- uneven climate change projections within each state.

The forthcoming reports address this maladaptation by modelling the NEM by node.

Additionally, node based price signals would promote more appropriate investment decisions required in section 3.2. The recommendation in section 3.1 would help transform the state focus of the NEM to a more NEM wide and node based perspective.

4 Conclusion

The literature review in Section 2 finds three factors contributing to the NEM's maladaption to climate change:

1. institutional fragmentation both economically and politically;
2. distorted transmission and distribution investment deferment mechanisms; and
3. failure to model and to treat the NEM as a node based entity rather than state based.

Section 3 provides a set of recommendations to address these factors of maladaption and forthcoming reports will test these recommendations.

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