THE UNIVERSITY OF NEW SOUTH WALES

Demand-side participation in the NEM

Electricity Industry Operation and Control (ELEC9715)

Marianne Blikø, Silje Mork Hamre, James Ray, Matt Smith

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1 INQUIRIES

James Ray

Email: z3373869@zmail.unsw.edu.au

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3 EXECUTIVE SUMMARY

Historically electricity market operations and peak demand issues have been resolved through electrical supply side solutions. The purpose of this report is to evaluate the potential opportunities for *Demand Side Participation* (DSP) to enter the market and provide an alternative option to supply side solutions and explore opportunities for increased participation in the National Electricity Market (NEM) as a critical review.

DSP in the NEM is currently under-represented and growing as demand side participants are now presented with more control over how and when they use or generate their electricity with advancements in technology and rule changes. DSP is capable of improving the reliability of the NEM and opportunities for increased DSP are continually being trialed and explored.

Exposing more consumers to market spot prices as registered participants and scheduled loads is one such opportunity for DSP to have an increased impact on the NEM through increased involvement and responses to these peak prices helps to increase the efficiency of the market and reduce peak demand. It is not seen as practical, however, for smaller users such as households and small businesses to be registered participants.

DSP can also be used as an ancillary service to the NEM enhancing the value of spot market trading occurring when DSPs are able to respond on short notice to the market requirements. These services are sought out and utilised by electricity retailers, suppliers and distribution network service providers as spot and forward contracts in order to manage risk in the market. The *Australian Electricity Market Operator* (AEMO) uses these contracts with DSPs as a form of market security to the supply of electricity, implementation during extreme peak demands on the network. Increased options for trading in the NEM creates efficiency in the market and offers participants more opportunities to obtain cheaper prices for their required services.

The security and reliability of the NEM can be met to some degree through increased DSP as a more economical alternative to increasing generation capabilities and the capabilities of the network to cope with peak demand. DSP however, should not be chosen over supply side alternatives if it is not able to offer the required levels of reliability at a more effective cost.

Opportunities for small energy consumers such as individual households exist through assistance from *energy service companies* (ESCOs), education and the availability of pricing information to the customer. Some schemes have already been trialed and there are still opportunities to improve the way in which small DSPs can contribute best to the electricity market. Communication of pricing information to the end user is essential and NSW has begun installing start meters as part of the Smart Grid Smart City Program in 2012 to achieve this.

Many established electricity retailers and suppliers would resist increases in DSP until a decoupling between network operators revenue and their profits. Opportunities also exist in the review of rules and regulations for the electricity industry to be adjusted allowing more of the DSP opportunities now present due to technological advancements in energy efficiency, information sharing and embedded generation.

Concluding, DSP already presents many valuable opportunities for improvements in the NEM and the decision to use DSP or supply side network services should be selected on reliability and economics of the two options. Electricity industry rules and regulations should be reviewed regularly to allow new technologies that previously would have sat outside the scope of the regulations to be included for the overall benefit of NEM. Finally pricing communication and the education of DSPs is most important for an increase in DSP and smart meters should be implemented for every consumer.

4 CONTENTS

1 Inquiries 1
2 Disclaimer 1
3 Contents 5
4 Table of Figures 6
5 Executive Summary 3
6 Introduction 8
7 Trends 8
8 Demand-side opportunities 22
9 Proposed improvements 23
10 Types of DSP 24
10.1 DSP within central dispatch 43
10.2 DSP independent of central dispatch 43
11 AEMO Demand Side Security and Reliability benefits 25
11.1 Decreasing demand and increasing reliability 25
11.2 DSP barriers 26
12 Smart grids 28
12.1 Load control 29
12.2 Pricing schemes 29
12.3 Smart Grid, Smart City 32
13 Power of Choice Review 27
14 Numerical analysis .... **Error! Bookmark not defined.**
15 Impact of EEI's on Electricity Demand report 15
16 Conclusion 34
17 Appendix A 34
18 Abbreviations 44
19 Glossary 45
20 References 47

5 TABLE OF FIGURES

Figure 1: Time Series Daily Average Energy Consumption (kWh): SOUTH EAST QUEENSLAND – Domestic [2] .... **Error! Bookmark not defined.**

Figure 2: Historical and predicted annual PV Installations, Australia 2003-2012 [3] (p 46) .. 10

Figure 3: Australian system price trends [4] 10

Figure 4: Saturation level by state[5] (p 38) 11

Figure 5: Regional unserved energy (USE) for the past 10 years [16] 26

Figure 6: Residential electricity contracts in Norway [18] 30

Figure 7: The influence of different pricing schemes and automation on peak clipping [18] 31

Figure 8 Annual energy consumption in Australia [18] 32

Figure 9: Feedback Channels: Major Impact on Electricity Consumption [18] 32

Figure 10: Electricity demand breakdown by state [20] 12

Figure 11: Weekly spot electricity prices[21][21][21][21][21][21][21][21][21][21][21][21] [20] (p 45) .... **Error! Bookmark not defined.**

Figure 12: NSW Demand profile for 31 Jan – 3 Feb heatwave [20] 14

Figure 13: NSW Spot Price profile for 31 Jan – 3 Feb heatwave [20] 14

Figure 14: Summer Electricity Load Pattern – Proportion of Major Components 16

Figure 15: Winter Electricity Load Pattern – Proportion of Major Components 16

Figure 16: NSW Commercial Sector – Breakdown of Peak Summer Demand Patter by Application (Soruce EMET/ MEU) 17

Figure 17: NSW Commercial Sector – Breakdown of Peak Winter Demand Patter by Application (Source EMET/MEU) 17

Figure 18: NSW Residential Sector – Breakdown of Peak Summer Demand (Source EMET/MEU) .... **Error! Bookmark not defined.**

Figure 19: NSW Residential Sector – Breakdown of Peak Winter Demand (Source EMET/MEU) 19

Figure 20: Household energy efficiency trends 20

Figure 21: Residential Sector – Comparative Proportions of Consumption and Demand Impact by Application 21

Figure 22: Estimated Impact of Residential Sector EEIs on Peak Summer and Winter Electricity Demand Levels (4 year and 6.5 year payback periods ex. BAU)............................ 22

Figure 23: NSW Demand Profile from 13 Oct 2012 to 12 Oct 2013 [20] 36

Figure 24: NSW demand duration curve from 13 Oct 2012 to 12 Oct 2013 [20]................... 36

Figure 25: QLD demand profile from 13 Oct 2012 to 12 Oct 2013 [20] 37

Figure 26: QLD demand duration curve from 13 Oct 2012 to 12 Oct 2013 [20].................... 38

Figure 27: Victoria demand profile from 13 Oct 2012 to 12 Oct 2013 [20] 39

Figure 28: Victoria demand duration curve from 13 Oct 2012 to 12 Oct 2013 [20] 40

Figure 29: NSW demand profile from 13 Oct 2012 to 12 Oct 2013 [20]................................ 40

Figure 30: NSW demand duration curve from 13 Oct 2012 to 12 Oct 2013 [20]................... 40

Figure 31: Tasmania demand profile from 13 Oct 2012 to 12 Oct 2013 [20] 41

Figure 32: Tasmania demand duration curve from 13 Oct 2012 to 12 Oct 2013 [20] 41

6 Introduction

Supply and demand in the National Electricity Market (NEM) has been viewed as a one-way relationship with consumers as the demand and electrical generators as the supply for many years. However, advancements in technology and increased levels of demand side participation in the NEM have an increasing impact on the electricity markets operation and control. Residential solar systems, smart meters, market services, demand side contracts and increasing levels of demand-side participation (DSP) in the NEM allow an increasing impact occurring through DSP. With the opportunities for DSP increasing, changes to the way the market operates and changes to the way we think about supply and demand for electricity in the NEM need to occur in order to utilize the full potential of what DSP has to offer. This report conducts an in-depth literature analysis, with some associated quantitative analysis of DSP in electricity markets, focusing on the NEM including history, trends, smart meters and grids, the Power of Choice Review and types of DSP. Useful recommendations will be reported, which may include areas for further review and appropriate courses of action. The intended audience is for stakeholders, policy-makers and the general public.

7 Trends

Demand Side Participation (DSP) in the NEM is a growing aspect to the operation of the NEM. Residential consumers are reducing energy consumption from the grid (**Error! Reference source not found.**), due to energy efficiency, an increasing price awareness and solar PV. Hence, demand-side participation from residential users is shifting the state of play in the NEM.

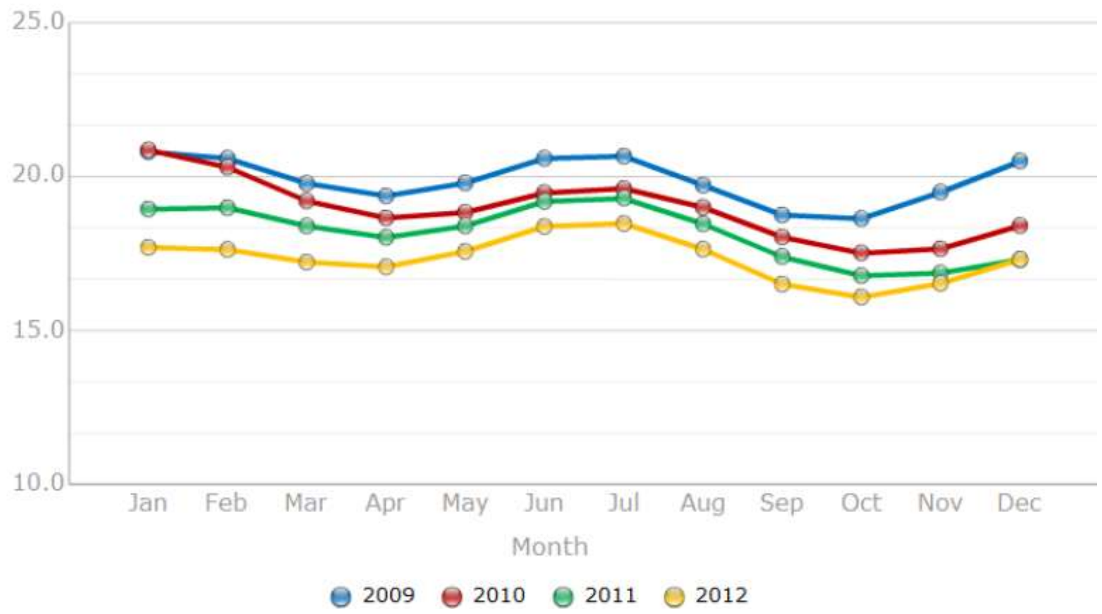

Figure 1: Time Series Daily Average Energy Consumption (kWh): SOUTH EAST QUEENSLAND – Domestic [2]

7.1 PV TRENDS

This trend seems like it will continue. Figure 2 - **Error! Reference source not found.** show trends in PV in Australia. Installed capacity has grown quickly (Figure 2) due to decreasing prices (Figure 3) and the small-scale renewable energy scheme (SRES) but is now predicted to slow down with the removal of solar credit multipliers and the carbon price.

Error! Reference source not found. shows that Queensland and South Australia have high proportions of customers with PV (16% and 18%, respectively), while NSW, Victoria and Tasmania have about the same proportions (6-8%). Understanding trends in energy consumption, PV, prices and energy efficiency is important to gain insight into what the future may hold for DSP.

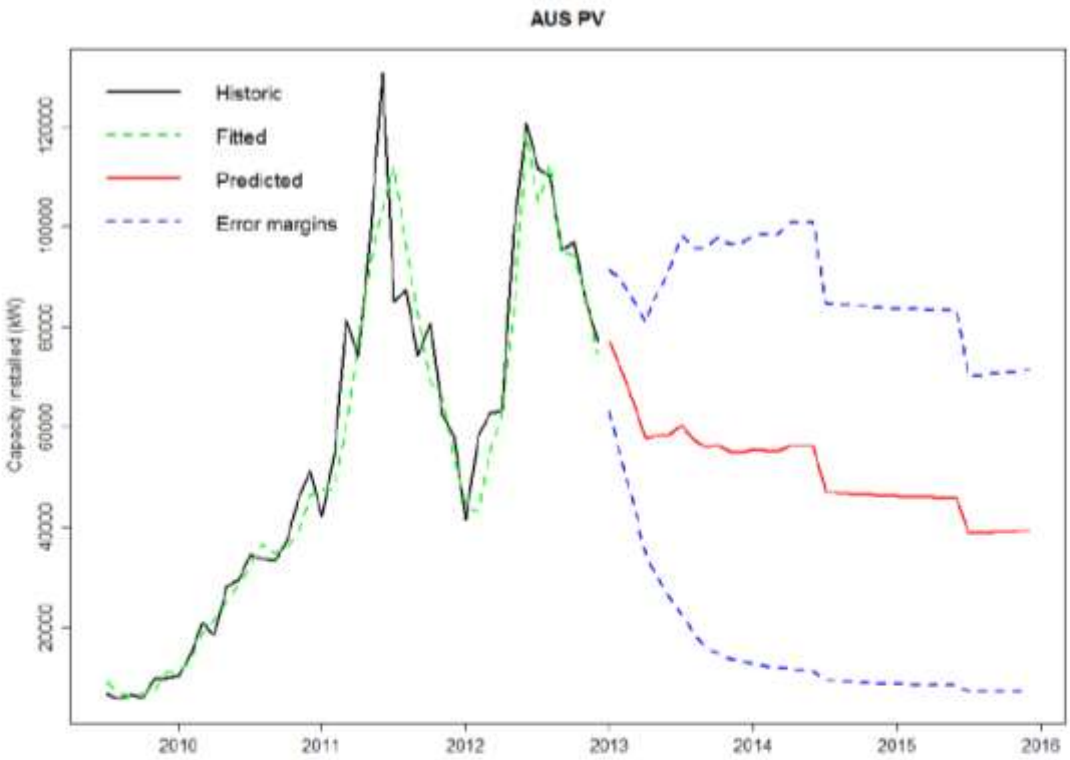

Figure 2: Historical and predicted annual PV Installations, Australia 2003-2012 [2] (p 46)

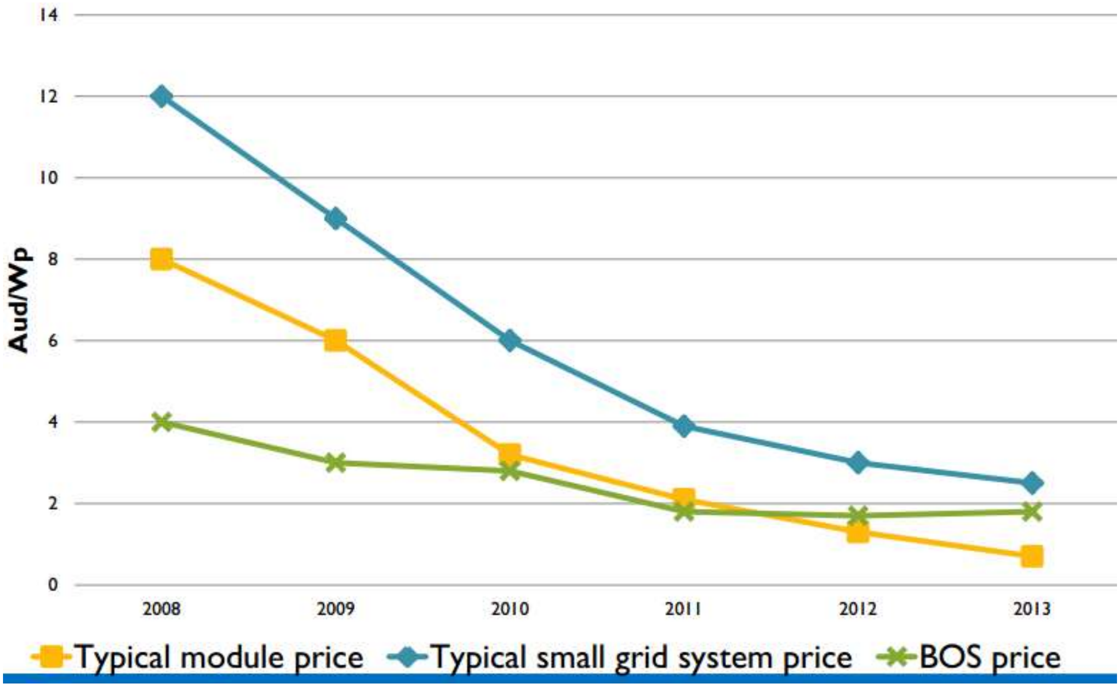

Figure 3: Australian system price trends [3]

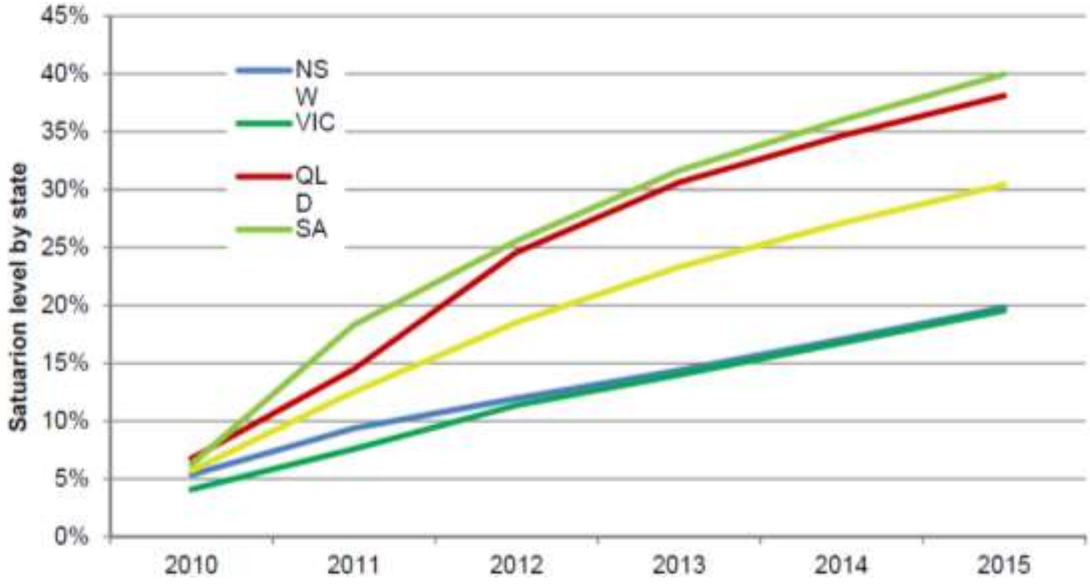

Figure 4: Saturation level by state[1][4] (p 38)

7.2 INFLUENCE OF CLIMATE AND WEATHER ON PEAK DEMAND AND PRICE

Demand-side participation plays a more important role for electricity industry operation and control during peak times, since price generally reflects demand (or at least it is meant to) and it is during these times of high demand that price is high, hence when generators make most of their revenue. Correspondingly, there is more opportunity for consumers to save by reducing loads at times of high demand. Periods of very high demand and hence price events in the NEM are often caused by the use of air conditioning in heatwaves, or less extreme daily afternoon peaks in summer, or through a combination of hot water, space heating, cooking and lighting in morning and evening peaks in winter, which is discussed in section 7.3.

The nature of demand-side participation varies seasonally and with climate. **Error! Reference source not found.** presents Figures **Error! Reference source not found.** - **Error! Reference source not found.** with a discussion which show the variation in regional demand for the different states in the National Electricity Market (NEM) over 365 days. In winter, demand appears to be more predictable. The cooler the climate the more heating is required and hence the higher the demand in winter, while less air conditioning is required so air conditioning is less frequent and with less demand if it is used. The reverse is true for the warmer the climate. Therefore, it can be seen that the nature of demand, and hence demand-side participation varies with climate and season.

Figure 5 gives an indication of the amount of demand in each state. NSW has the highest overall demand, followed by Queensland and Victoria. The curves for South Australia and Tasmania overlap so it is difficult to determine from this graph which has a higher overall

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[1] Saturation rate represents the cumulative proportion of systems installed as a

proportion of owner occupied houses (separate and semi-detached dwellings).

amount of demand. The total potential amount of demand-side participation corresponds to the total amount of demand.

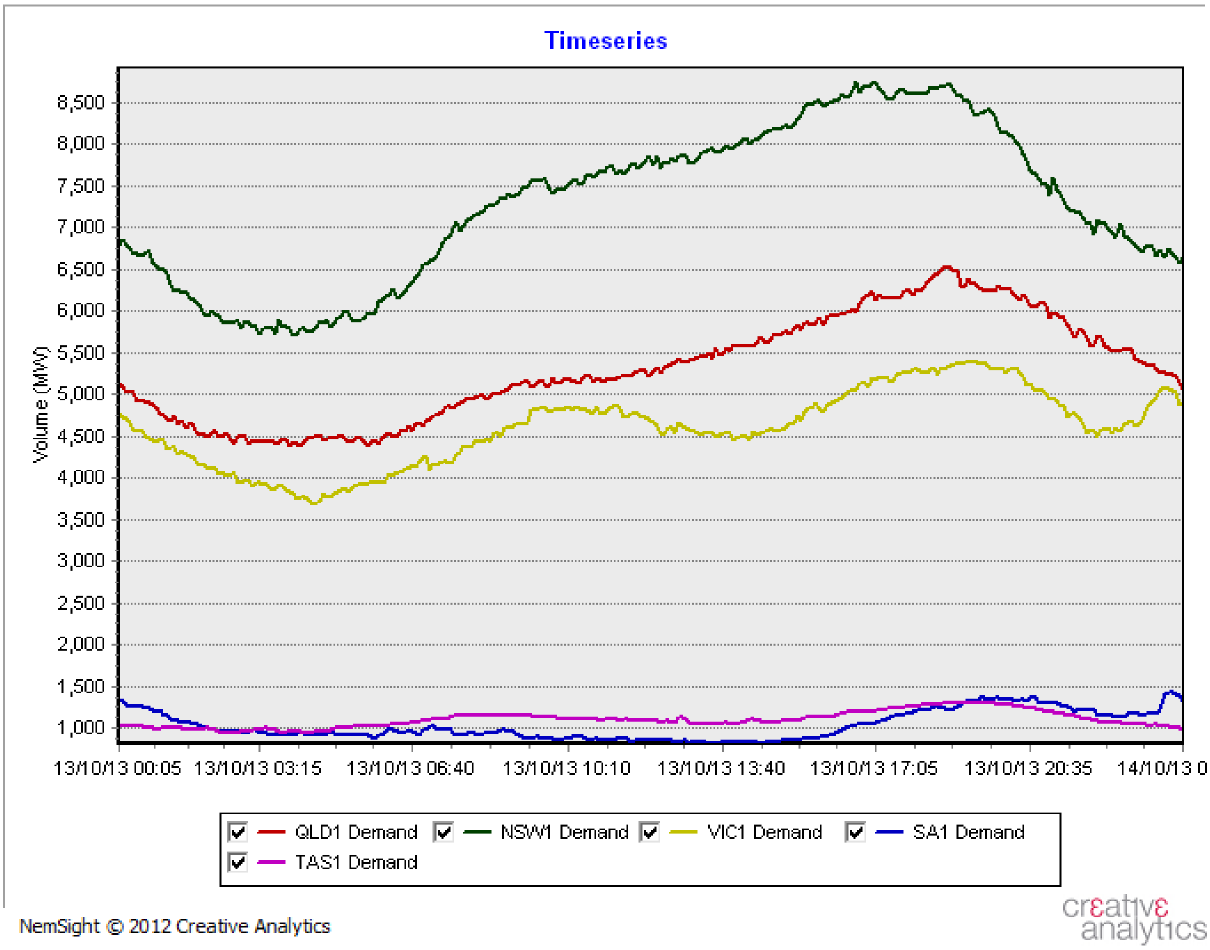
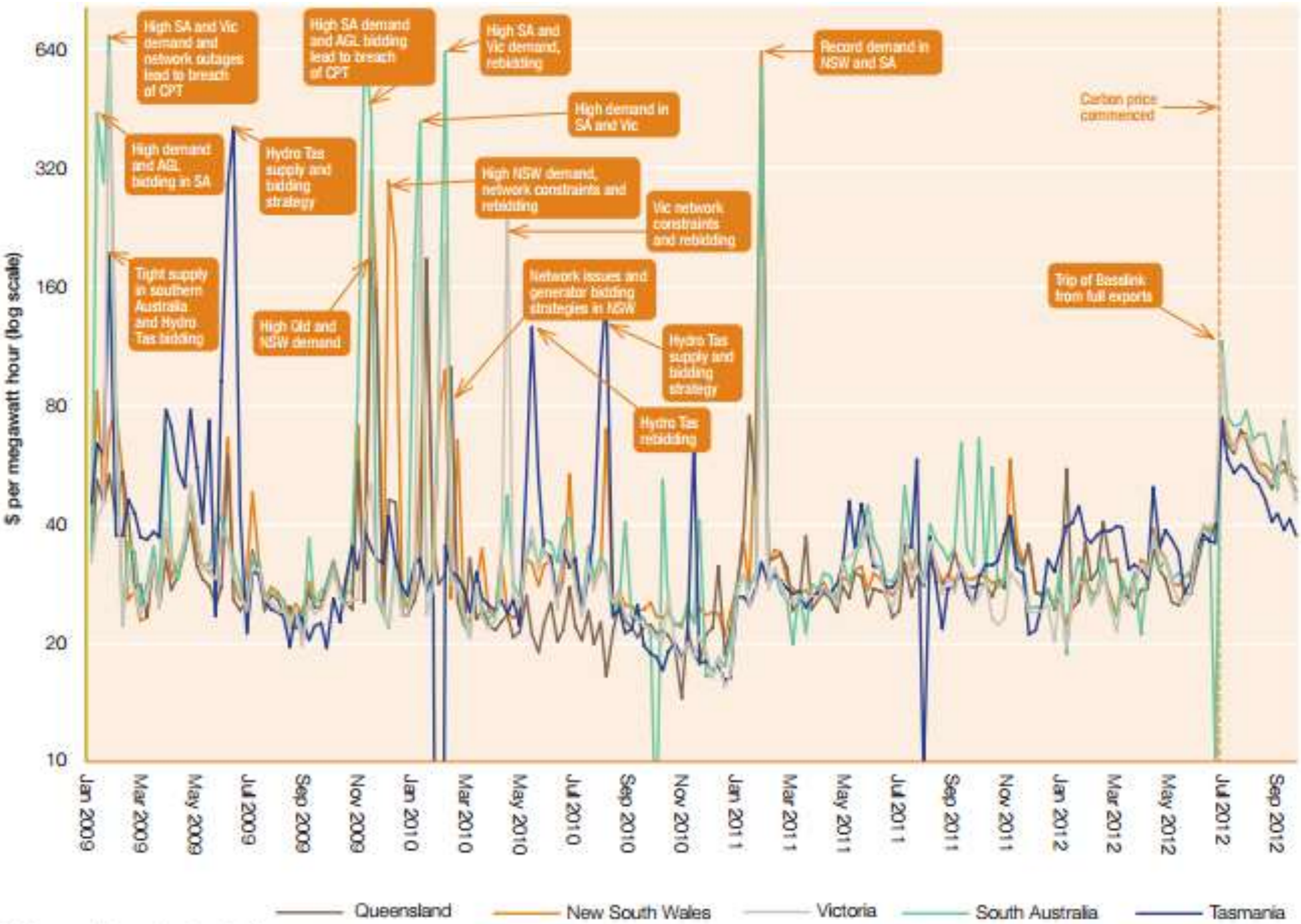


Figure 5: Electricity demand breakdown by state [5]

Error! Reference source not found. shows the variation in weekly spot electricity prices from January 2009 to September 2012. The latest price spike on record is in early 2011. Figures Figure 5 - Figure 7 show the demand and spot price in NSW over four days from 31 Jan 2011 – 3 Feb 2011. The spot price goes very high each day at time of peak demand, with the highest peak having a spot price of $12,000/MWh, which is close to the value of lost load (VOLL) at $12,900 MWh. The reason for these price spikes is likely due to air conditioning in the event of a heat wave, as confirmed by BOM 2011[2]. Thus we can see why air conditioning is a disruptive technology in the NEM, which has been the principal driver for ensuring security and reliability of supply, which has traditionally been done through network augmentation. DSP can be a more cost effective alternative.

[2] "Temperatures warmed during the second half of the month, particularly in the last week of January, with record highs on the 26th and 27th in the Hunter Valley. These warm conditions persisted over the remainder of the month, with well above average temperatures on the 31st leading to an extended heatwave in the Metropolitan and Hunter in the first week of February." (BOM 2011)



CPT, cumulative p rice threshold.

Note: Volume weighted average prices.

Figure 6: Weekly spot electricity prices [6]

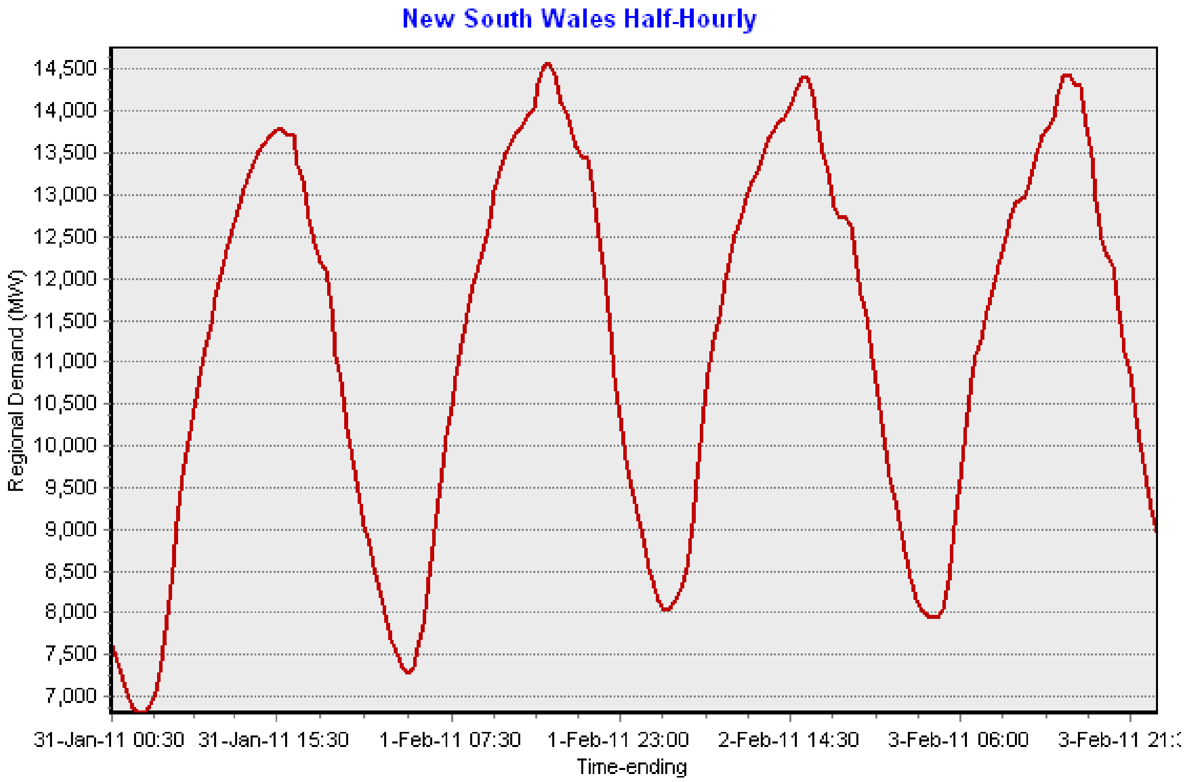


Figure 7: NSW Demand profile for 31 Jan – 3 Feb heatwave [5]

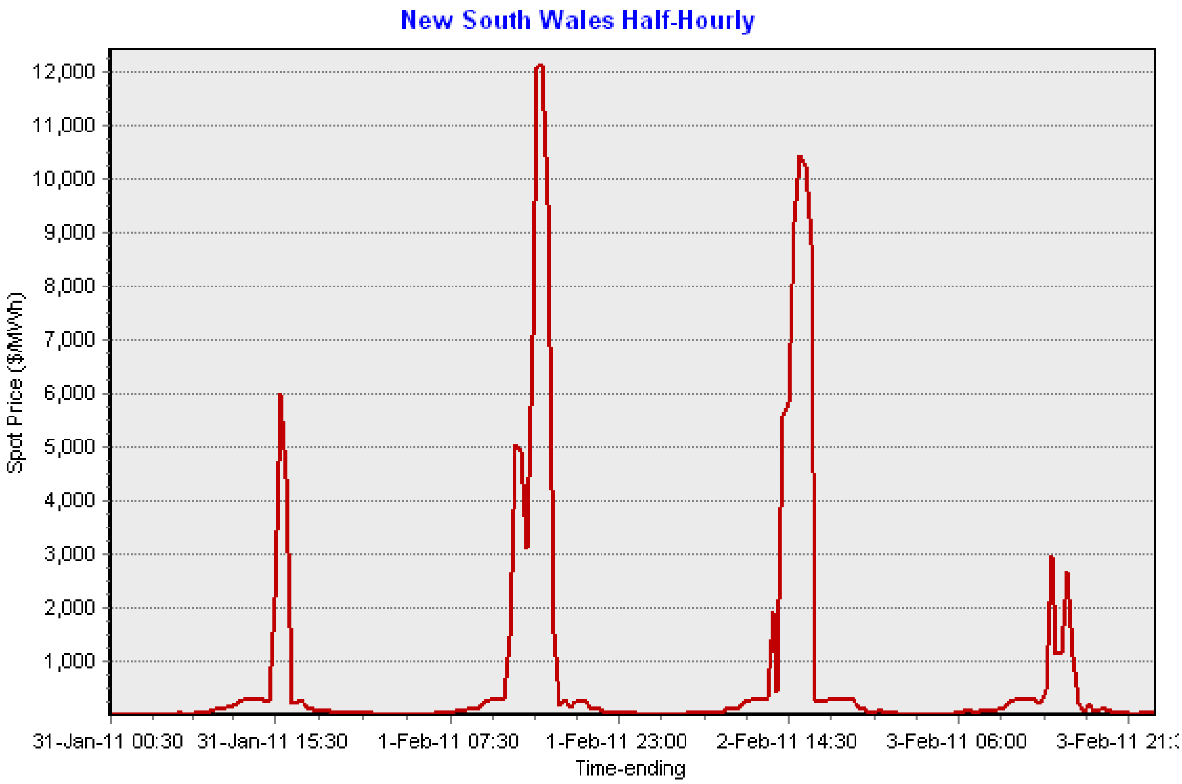


Figure 8: NSW Spot Price profile for 31 Jan – 3 Feb heatwave [5]

7.3 Impact of Energy Efficiency Improvements (EEIs) on Electricity Demand

It is important to analyze trends in demand by sector and application in order to assess where DSP can contribute to electricity industry operation and control and in what way. EMET [7] has done such an analysis through energy efficiency.

Figure 9: Summer Electricity Load Pattern – Proportion of Major Components

represents a generic pattern of consumption for peak summer demand. The industrial sector has the greatest potential to contribute to demand-side participation (at 54.1% of the peak load), followed by the commercial and residential sectors (25.8% and 20.1%, respectively) [7].

Figure 17 shows that for peak winter demand at roughly 1800 hours the industrial sector takes the lion's share in its potential to contribute to demand-side participation (at 53.0%), followed by the residential sector (30.3%) and the commercial sector (16.6%) [7].

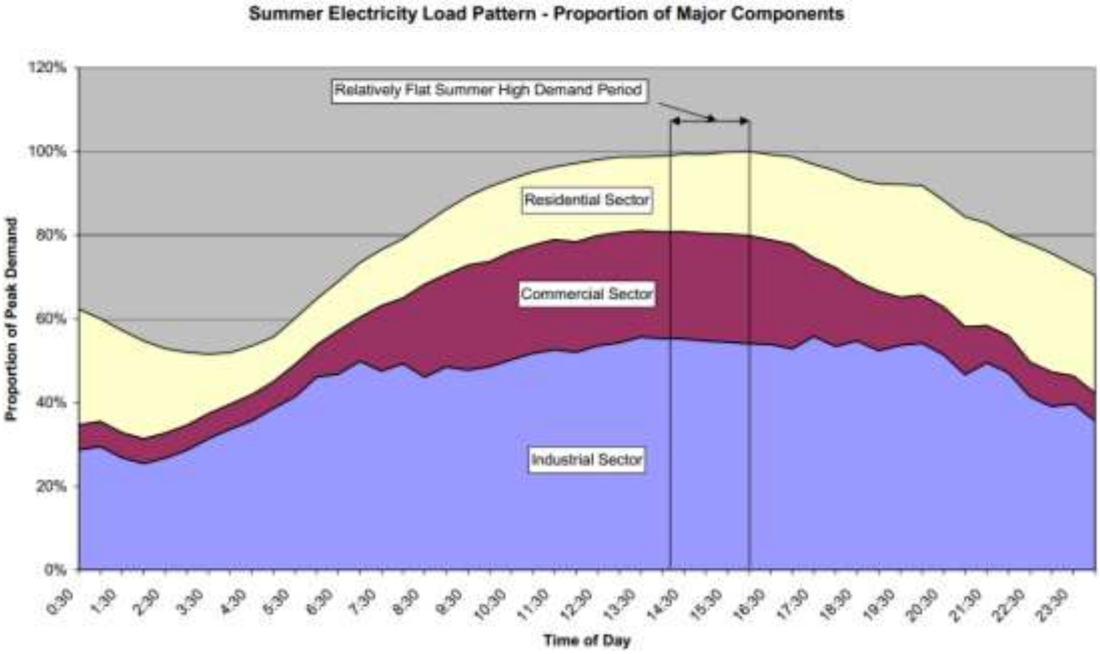


Figure 9: Summer Electricity Load Pattern – Proportion of Major Components

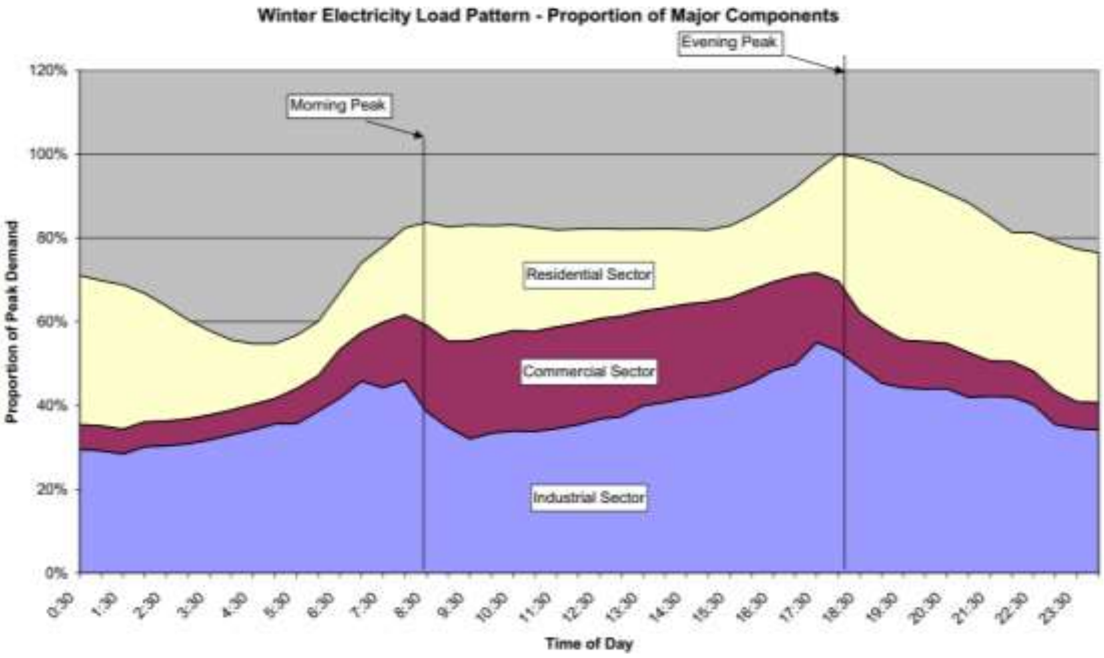


Figure 10: Winter Electricity Load Pattern – Proportion of Major Components

Figure 11: NSW Commercial Sector – Breakdown of Peak Summer Demand Patter by Application and Figure 12 show the breakdown of peak demand by application for the NSW commercial sector in summer and winter, respectively. Clearly cooling and interior lighting dominate the share of peak demand in summer. Interestingly, some heating is required in

the afternoon, presumably because the building is overcooled. In winter, interior lighting contributes the most to peak demand. Heating has a significant share of peak demand. Now that the key areas have been identified a better understanding can be gained of possible solutions, which will increase DSP.

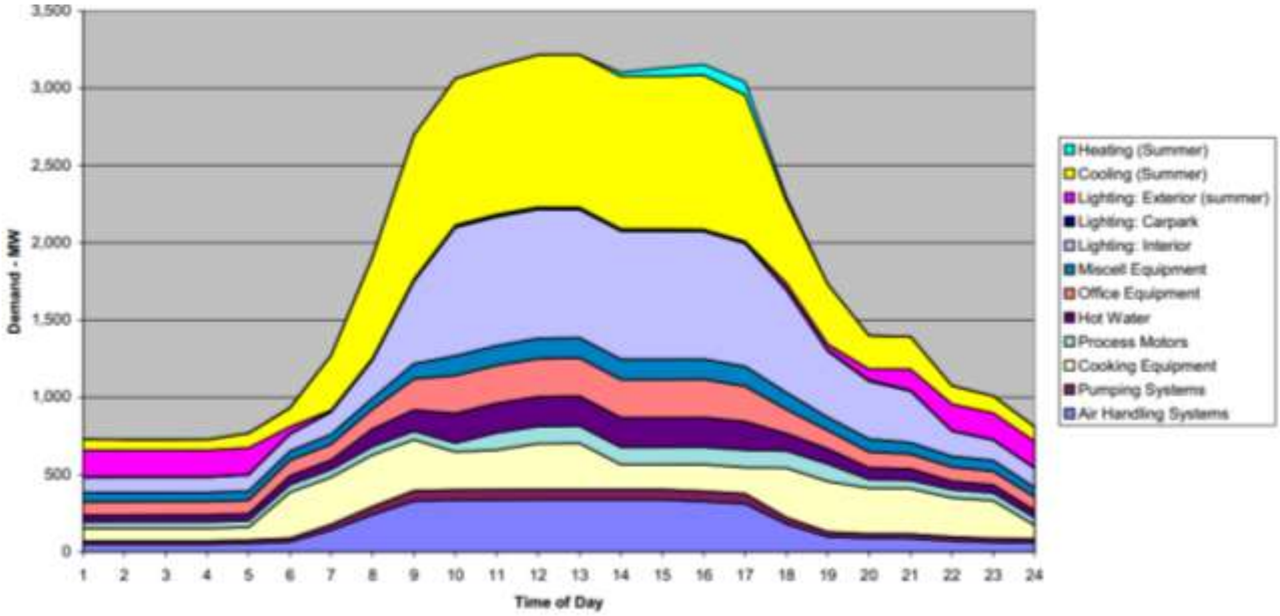


Figure 11: NSW Commercial Sector – Breakdown of Peak Summer Demand Patter by Application [7]

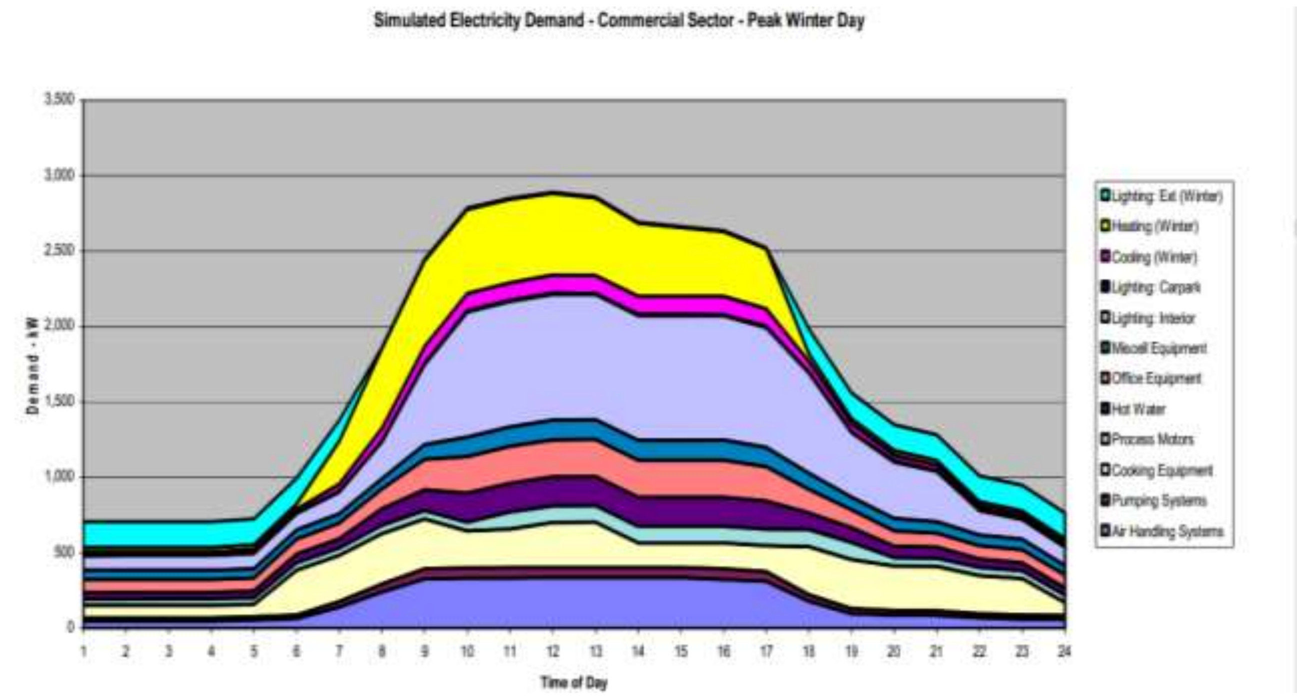


Figure 12: NSW Commercial Sector – Breakdown of Peak Winter Demand Patter by Application [7]

End-use energy efficiency in all sectors (industrial, commercial and residential) is important for DSP. Multiple energy schemes such as higher compulsory NABERs ratings are increasing household energy efficiency, with housing stock that was connected within the last two years since the time of the study (July 2012) being up to 30% more efficient than older housing stock (Figure 15).

Error! Reference source not found. and **Error! Reference source not found.** show the breakdown of demand in the NSW residential sector by application in summer and winter, respectively. The peak and overall demand is higher in winter than summer. In summer, air conditioning and off peak hot water contribute the most to peak demand even though the peaks for each individual application is at different times of the day (about 1730 hours and 0100 hours, respectively) to the time of peak demand. Note that there are several peaks in the evening – all within the range of about 3,300 MW-3,500 MW. The highest peak of just over 3,500 MW is at about 2200 hours while the other peak at midnight is also at 3,500 MW and two other peaks exist at about 1900 hours and 2030 hours, respectively. The two peaks at 3,500 MW are due to the concentration of off-peak hot water while the peak at 7 pm is due to the use of the range, or stove, for cooking dinner. The peak at about 8:30 pm is also due to off peak hot water.

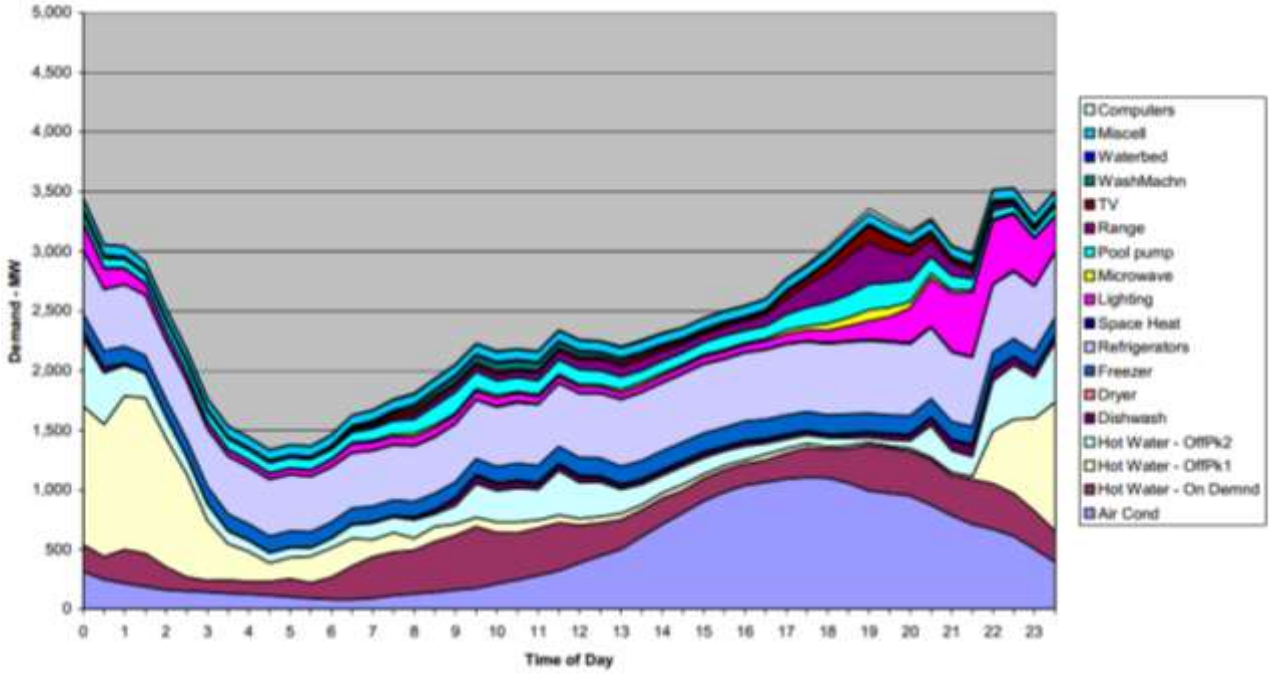


Figure 13: NSW Residential Sector – Breakdown of Peak Summer Demand [7]

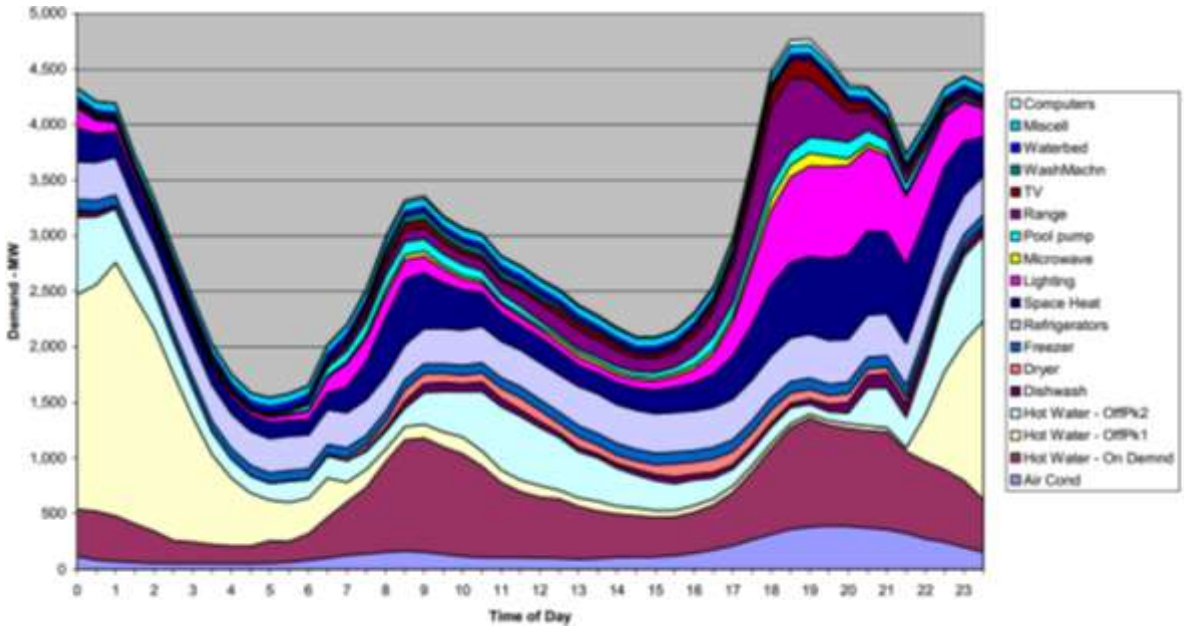


Figure 14: NSW Residential Sector – Breakdown of Peak Winter Demand [7]

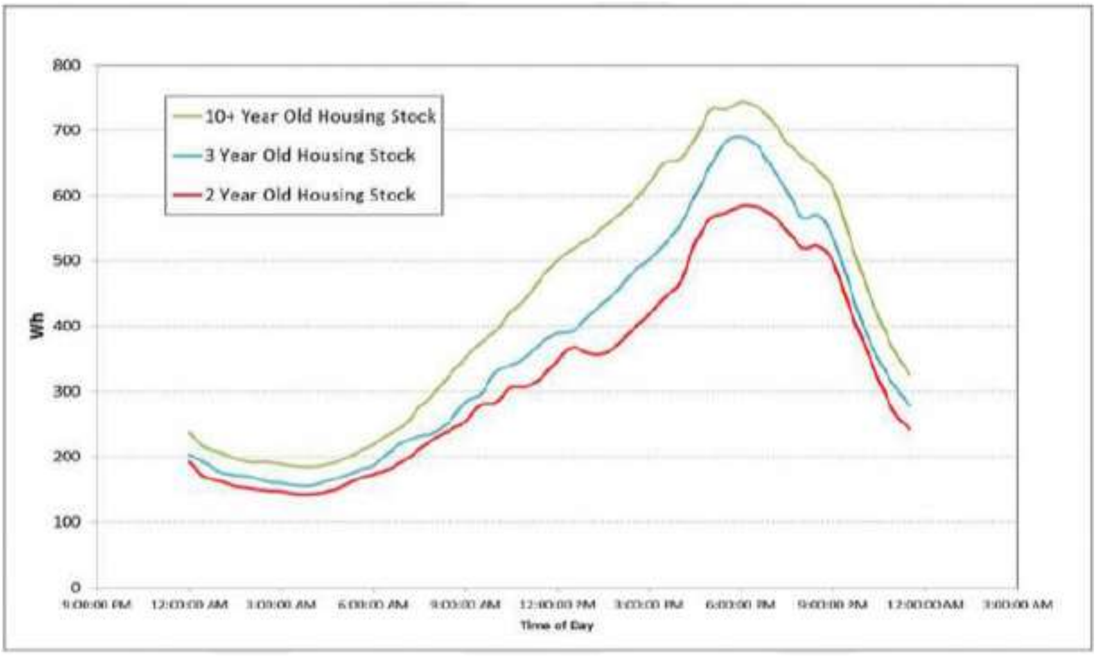


Figure 15: Household energy efficiency trends [8]

Figure 16 illustrates the difference in impact made by each major application of electricity on the summer and winter demand levels compared to the annual proportion of electricity consumption. For example, the intensity of the impact of air conditioners on the summer peak (39%) is disproportionate to its proportion of annual electricity consumption (5%). In contrast, hot water services are responsible for 42% of total electricity consumption; however their summer and winter peak contributions are only 14% and 22% respectively. This leads onto the potential of each application to contribute to demand-side participation through energy efficiency improvements (EEIs).

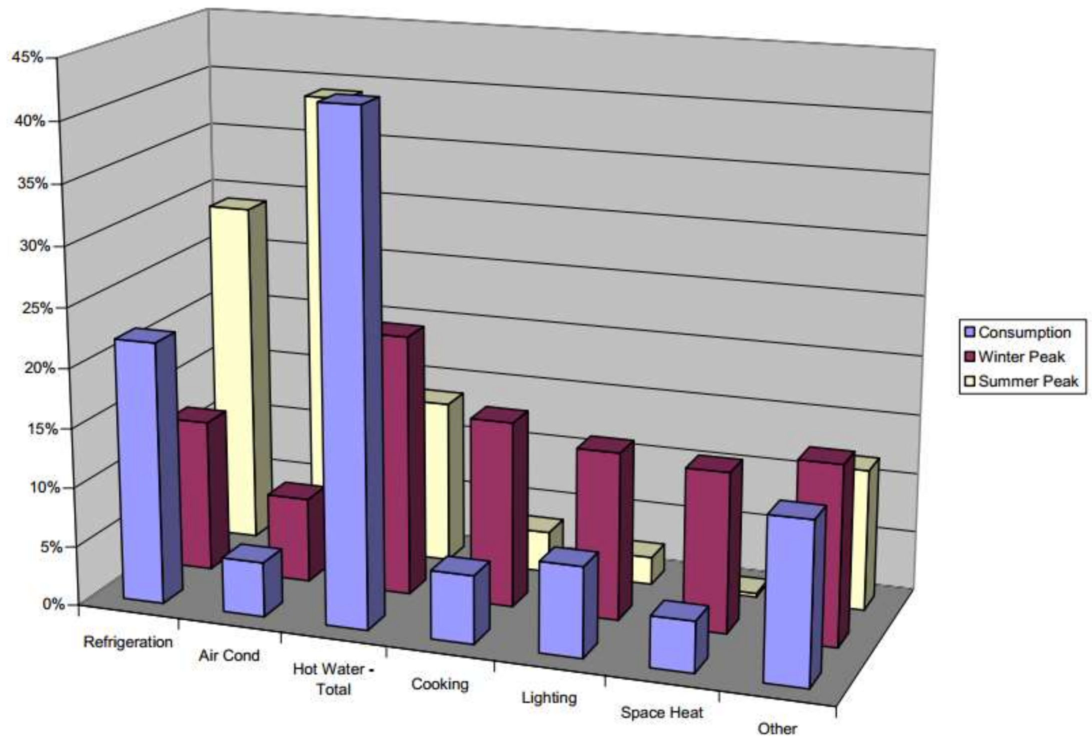


Figure 16: Residential Sector – Comparative Proportions of Consumption and Demand Impact by Application [7]

Each of the demand impact factors was applied to the EEIs identified in the EMET/SEAV [9] and GWA/SEAV [10] studies for the residential sector and an estimate of the electricity demand reduction potential was made for each case. Also, Figure 17 compares the results for both the 4 year and 6.5 year payback cases (ex. BAU). Improvements are ranked by their peak demand reduction in descending order as follows for 6.5 year payback times:

- building shell in summer (almost 1 GW)
- building shell in winter
- cooking in winter
- lighting in winter
- on demand hot water in winter
- refrigeration in summer

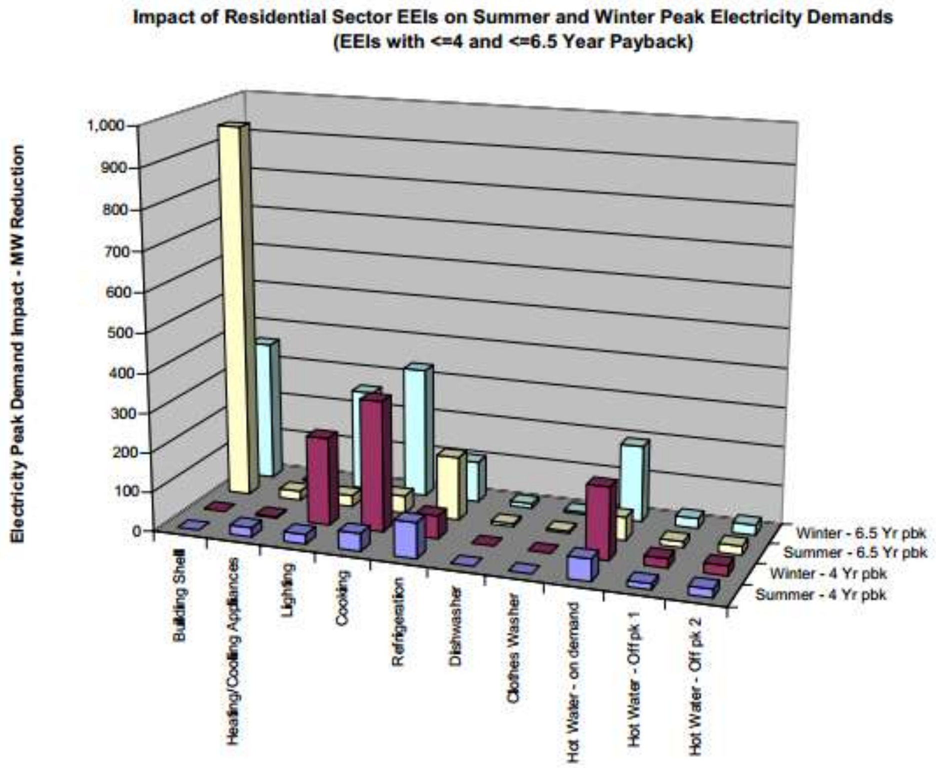


Figure 17: Estimated Impact of Residential Sector EEIs on Peak Summer and Winter Electricity Demand Levels (4 year and 6.5 year payback periods ex. BAU)

8 DEMAND-SIDE OPPORTUNITIES

DSP has a greater role to play in the NEM, which currently has a strong supply side focus with the demand side relatively under-represented [11 p vi]. Concerns have been perceptively expressed that under current market arrangements an undue focus has been placed on the expansion of generators and the network capacity, overlooking more cost effective DSP alternatives [11, p 1]. Since DSP is capable of improving reliability in a more economically efficient way, having the transmission and reliability standards be economically derived would allow increased DSP to occur [11]. AEMC's Power of Choice Review [12] states:

> While consumers are able to physically reduce their consumption in response to the spot price under specific contractual arrangements such as interruptible tariffs, spot pass-through and scheduled demand, these involve a degree of risk and transaction costs that for most commercial and industrial users cannot be efficiently managed. For various reasons, these arrangements have only been partially effective in exploiting the many opportunities for efficient demand response to spot prices.

Such opportunities include an increasing awareness of price increases, improvements in energy efficiency technologies, metering technologies, network management practices and distributed generation technologies. Traditionally decisions relating to market operation and control are made by representatives from generators, transmission, distribution, retailers and regulators where consumers are simply treated as a load that needed to be served [13]. However, new market entrants known as energy service companies (ESCOs) are a way of increasing DSP.

In a sense, the NEM is not truly a market[3]. MacGill [15] perceptively states that the electricity industry has poor end user engagement; buyers seek energy services, not energy (a good); and a tariff (a schedule of fees) is imposed, so prices where supply meets demand seldom exist. DSP through ESCOs has the potential to make the NEM more truly like a market through better customer engagement, provision of energy services and prices where supply more closely meets demand.

According to the National Electricity Rules large end-users are allowed to respond to wholesale market price risks directly by being registered market participants. In this way they can choose to respond to high/low prices through shutdowns and through manipulation of the manner in which they use energy.

Registered participants are also allowed to bid demand side reductions into the market however for small end users this is not the case and is not always possible. Smaller users have less ability to influence the operation and control of the NEM and fewer incentives are available to them to respond on wholesale market prices.

9 PROPOSED IMPROVEMENTS

To improve DSP small end-users should be given the option to see the wholesale price and to respond to variances by changing their consumption and demand [16]

In addition to the EEIs identified in [9] and [10], DSP options for the residential and commercial sectors exist. Given the overcooling identified for commercial buildings, solutions (which are also applicable to residential buildings) include incorporating weather forecasting, having a heating and cooling system that actively responds to changing condtions, and having a higher temperature minimum set-point for air conditioning. For heating, a lower minimum temperature set-point for heating is another option. Having better daylighting would reduce the need for artificial lighting. Air handling systems and pumping systems should be appropriately sized and configured and measures made to increase the overall system efficiency. All of these solutions would help to reduce peak demand and thus be effective demand-side participation measures.

A proposal to aid increased DSP is through smart metering through “The Council of Australian Governments (COAG) at its April 2006 meeting has committed to a mandatory

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[3] “A market is any place where the sellers of a particular good or service can meet with the buyers of that good and service where there is a potential for a transaction to take place” [14] M. Moffat. (2013, 7 November). *Definition of Market* [Online]. Available: <http://economics.about.com/cs/economicsglossary/g/market.htm>

rollout of smart metering to all small use customers across Australia, where the benefits outweigh the costs" [17].

Smart meters record consumption every 30 minutes and data can be remotely collected creating a basis for implementing time of use pricing during the day and during any network peak periods that may occur during the year [16]. This gives the ability for Network Service Providers to use time of use tariffs *critical peak pricing* or control directly high energy using appliances allowing increased market price signals to be communicated to Demand Side Participants [16].

Smart meters allow consumers access the current price on the market, which gives them the option of shifting their consumption from a high-price period to a low-price period.

If consumers do not receive market price signals or if they purchase electricity at a fixed price, they will not have the knowledge or opportunity to be flexible with their electricity use and there will be no incentive to modify their behaviour in response [13]. Only when the consumers are exposed to variable prices will they consider taking short run actions to maximize the value they get from their consumption [13].

Exposure to the spot price brings a lot of risk, which small consumers may not have the expertise or the time to deal with. Consumers may prefer to have an energy retailer manage spot price risk when consuming. Appropriate metering technology can be coupled with a specialist intermediary such as an aggregator who acts on the behalf of residential consumers to offer their demand response to the wholesale electricity market directly.

Empirical evidence suggests that demand does decrease in response to a short-term price increase, but that this effect is relatively small [13]. Having one small-scale consumer change their electricity consumption pattern in response to price will not have a noticeable change in the NEM's operation however, if a large number of consumer's are all changing the way in which they use their electricity then this will begin to have a significant effect.

The market can then begin to respond to price spikes with the presence of new adjustable loads. These loads can be easily adjusted or moved to different times to create flexibility when the demand peaks appear with load shedding as a consumer response to demand.

Other improvements include:

- Amalgamate state-based energy efficiency schemes into a National Energy Savings Scheme (NESI)

10 Types of DSP

Demand-side resources that participate in the NEM can be divided into:

- DSP within central dispatch
    - DSP as a scheduled load in the energy market

- DSP as a market Frequency Controlled Ancillary Service (FCAS)
  - DSP as an ancillary service to enhance the value of spot market trading
- DSP independent of central dispatch.

For more information see Appendix 2.

11 AEMO Demand Side Security and Reliability benefits

DSP is often able to improve security and reliability in a more economically efficient manner than network augmentation. AEMC [11] insightfully states: "While the threshold for the regulatory tests required to meet the requirements of the NEM to become a registered participant should not be reduced for DSP, there is currently a lack of transparency in the arrangements that limits the potential inclusion of DSP". Compared to incumbents, new entrants in the NEM are bound to be under closer scrutiny. Even though market arrangements support incumbents by their inherent nature, there is a need for greater transparency in order to support DSP.

11.1 Decreasing demand and increasing reliability

Some Demand Side Response (DSR) concepts are aiming to reduce energy price volatility by decreasing peak demand. A wide-scale deployment of this concept enables increasing grid reliability, reducing energy cost, and optimising energy consumption, avoiding or delaying investments in new infrastructure [18]. One potential source of increased DSP in support of power system reliability is the greater strategic use of small generation units. The ability for this to occur efficiently may by substantially improved by smart grids [11].

Security is AEMO's primary role and is obligated to purchase a "standing reserve," a set amount of capacity to be used in limited prescribed circumstances when capacity is tight [11]. This required capacity can be withdrawn from the market to be on standby [11]. It is in this way that Demand Side Participation is able to contribute to the security and reliability of electrical supply in the NEM.

Potential also exists for DSPs to receive financial remuneration through direct participation in the wholesale, ancillary services market or through selling financial contracts to retailers [11]. Retailers have an interest in minimizing their exposure to volatile spot prices; to help manage this risk retailers can contract with demand side providers to change their consumption decisions during times of high spot prices [11]and again prices are a key element in signalling the value of demand side participation to consumers and other market participants.

Reductions in demand may help reduce the need for investment in the network infrastructure that would otherwise be required in the long term [12]. AEMC [12] states:

> It is estimated that around $11 billion of electricity infrastructure is used for only 100 hours a year but it must be in place so that power is available for the few hours on our hottest and coldest days when everyone wants to switch on at the same time.

The NEM is designed for peak demand rather than average load in order to ensure a high reliability and robustness [19]. This can result in under-utilized power generation and distribution systems [19]. Installed capacity must be used more efficiently such that there is no need to install more generation/transmission [19]. DSM can reduce or shift consumption .

Suggestions have also been made that that the NEM may be too reliable (Figure 18) and AEMC has treated the transmission and distribution networks as natural monopolies with DSP, EE, DE as add-ons. Comparing to network upgrades, DSP can be a more economically efficient way of ensuring an appropriate level of reliability.

Sending the appropriate pricing signal is an effective measure, such as changing from a tariff to a floating spot price or a spot-tied contract. Alternatively, the ESAA suggests that "a higher proportion of network charges could consist of costs that are related to peak demand or fixed, and a lower percentage could be paid through simple variable (use) charges (c/kWh)."

Year	Queensland	New South Wales	Victoria	South Australia	Tasmania[8]
2011-2012	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
2010-2011	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
2009-2010	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
2008-2009	0.0000%	0.0000%	**0.0040%**	**0.0032%**	0.0000%
2007-2008	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
2006-2007	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
2005-2006	0.0000%	0.0000%	0.0000%	0.0000%	0.0000%
2004-2005	0.0000%	**0.00005**	0.0000%	0.0000%	0.0000%
2003-2004	0.0000%	0.0000%	0.0000%	0.0000%	
2002-2003	0.0000%	0.0000%	0.0000%	0.0000%	
Average	**0.0000%**	**0.0000%**	**0.0004%**	**0.0003%**	**0.0000%**

Figure 18: Regional unserved energy (USE) for the past 10 years [20]

11.2 DSP BARRIERS

Barriers contributing to poor demand side participation addressed in 2010 with a review of demand side participation in the NEM and a review of regulations for energy saving technologies and the inclusion of embedded generators into the Demand Management Incentive Scheme (DMIS) [20].

The updated rule changes were based on the aim to "promote efficient investment in, and efficient operation and use of electricity services for the long term interest of consumers of electricity with respect to price, quality, safety, reliability and security of supply of electricity and the reliability, safety and security of the national electricity system" [20].

12 Power of Choice Review

The mechanisms proposed by the AEMC in the Power of Choice (PoC) Review to the Standing Council on Energy Resources (SCER) for rewarding DSP in the NEM include [12] (p. 130) (I MacGill 2011, pers. comm., 16 October):

- A demand response (DR) mechanism is introduced that pays demand resources via the wholesale electricity market i.e. that rewards changes in demand. Under this mechanism demand resources would be treated in a manner analogous to generation and be paid the wholesale electricity spot price for reducing demand. AEMC recommends that the Australian Energy Market Operator (AEMO) develops the details for a rule change proposal and required procedures, including the baseline consumption methodology.
- The National Electricity Rules (NER) is clarified regarding AEMO's role in demand forecasting for its market operational functions.
- Consideration of the benefits of network operators owning and operating distributed generation (DG)
- Consumers be able to source their electricity from, and sell their DSP to, entities other than their retailer (also known as portability)
- A new category of market participant for non-energy services is introduced in the National Electricity Rules (NER) to unbundle the sale and supply of electricity from non-energy services, such as ancillary services.
- The National Energy Customer Framework be amended to include a framework which governs ESCOs.
- Introducing time varying network tariffs. Retailers can decide how to incorporate offers
- Protecting vulnerable consumers with a limited capacity to respond
- Enhancing consumers' ability to access consumption information
- Transparent arrangements for how parties directly engage with consumers
- Enabling technology: encourage investment in better metering
- Distribution network incentives: making DSP part of the network planning and investing process. (Integrated Resources Planning is a suitable mechanism for this although it is not explicitly mentioned in the review).
- Establishing formal consultation when setting network tariffs

- A greater coordination between DSP and energy efficiency government policies so that the consumer can be rewarded for the full value of their DSP action

AEMC [12] states:

> The proposed DR mechanism would mainly assist large electricity users, such as C&I users that prefer to have an energy retailer manage spot price risk when consuming, but wish to offer their demand response to the wholesale electricity market directly, or via a specialist intermediary such as an aggregator. In the future this mechanism could be adapted by aggregators to include demand responses from residential consumers who have appropriate metering technology in place.

"Many different economic models are used to represent Demand Side Response programs (DSR). DSR is divided into two basic categories, namely: the time based program and the incentives based program" [18]. However both of these options need increased data and real-time feedback from the grid on time, price and the use of electricity during peak demand periods.

While some of these mechanisms are more electricity industry planning and investment, they do have an impact on operation and control. Because demand-side participation has generally had a limited role to play in the NEM and in most other electricity industries worldwide, much investment and planning is required in order to more fully harness operation and control measures.

The limitations to the PoC review include (Passey, 2013):

- Treatment of DG, EE and DSM as 'add-ons' to the existing market (which remains essentially unchanged). Integrated resource planning (IRP) is an alternative to network augmentation that encompasses DSP.
- Lack of practical suggestions for decoupling network operators' revenue from electricity use, e.g. a revenue cap, rather than the standard volume-weighted price cap.

Greater facilitation of ESCOs is also worthwhile. A full suite of regulatory, market

We expect these recommendations will result in efficiently meeting supply and demand for electricity in the wholesale electricity and ancillary services markets. In particular, the demand response mechanism allows consumers to capture the value of their reduction in consumption.

With Power of Choice NEM proposes more opportunities for customers to make informed choices about the way they use electricity and manage expenditure. One such opportunity is Smart Grids.

13 SMART GRIDS

There are many varying perspective on smart grids.

The concept of smart grid combines monitoring, control and communication. This is to improve connection and operation of generators, get consumers involved in optimizing by better information and options for choice of supply, reduce environmental effects and maintain or improve system reliability, quality and security of supply.

“Demand side response (DSR), an integral part of a smart grid, is a cost effective, rapidly deployed resource that provides benefits to utilities and consumers.” [18]. There are lots of possibilities of improvements regarding consumer participation and DSP.

Smart Grid Australia rightly emphasize the importance of consumer engagement in the statement [21]: “Modern energy consumers are contradictory, price sensitive and yet are demanding choice, convenience and a greater degree of knowledge of their household energy usage”. In smart grids demand side management must be included.

13.1 LOAD CONTROL

Direct load control is one DSM option, where through an agreement between a utility and customer, the utility remotely controls the operation of certain household appliances [19]. The success of DSM programs is strongly influenced by how much of the total load is controllable [19]. Plug-in hybrid electric vehicles (EVs) are an example of new types of demand-side equipment, which have the potential to increase the amount of controllable load [19]. EV batteries may charge and discharge, respectively drawing from and supply energy to the grid. EVs should be charged and discharged in the most efficient way, which would be at peak and trough demand, respectively.

13.2 PRICING SCHEMES

Another option is pricing schemes where consumers individually and voluntary can control their load to reduce their energy cost in response to prices [19]. Pricing schemes proposed for DSM include peak load pricing and adaptive pricing [19]. Two-way digital communication capabilities of future smart grid systems enable DSM programs to use real time pricing, which can more efficiently show fluctuations in spot prices to end-users [19]. A barrier for utilizing the benefits of real time pricing and DSM is poor knowledge about how to react on varying prices among end-users [19]. This problem can be improved in many ways, including ESCOs and automatic energy consumption scheduling [19]. The concept of smart pricing should give enough incentives for end-users to participate in DSM, such as through discounting in their electricity bills [19].

Spot-tied contracts are a pricing scheme, which is essentially a call option. Figure 6 shows various pricing schemes for residential consumers in Norway. There is the usually fixed price tariff however; there is also a floating spot price and a call option.

Spot-tied contracts make up 55.4% of all residential electricity contracts in Norway, so clearly these contracts are quite popular and shows that customers do not all need flat tariffs, but rather that calculated risk is increasingly seen as preferable [22].

Figure 19: Residential electricity contracts in Norway [22]

Another study shown in Figure 20 illustrates how much customers reduced peak demand under different pricing schemes with and without automation. *Critical peak pricing* was found most effective, followed by a *critical peak rebate*, *time-of-use pricing* and *real time pricing*. Automation was more effective than no automation for all pricing schemes except real-time pricing with customer satisfaction varied between 75-95%.

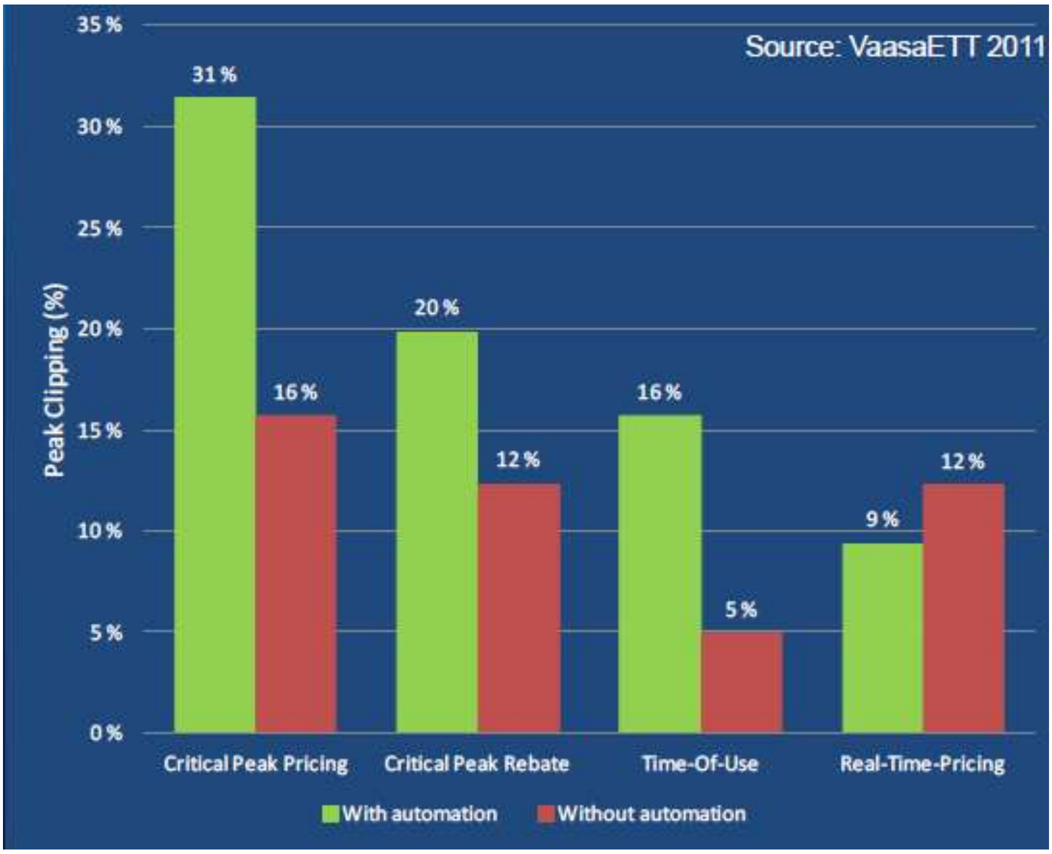

Figure 20: The influence of different pricing schemes and automation on peak clipping [22]

Falling consumption for residential households is partly due to increasing electricity prices (Figure 21).

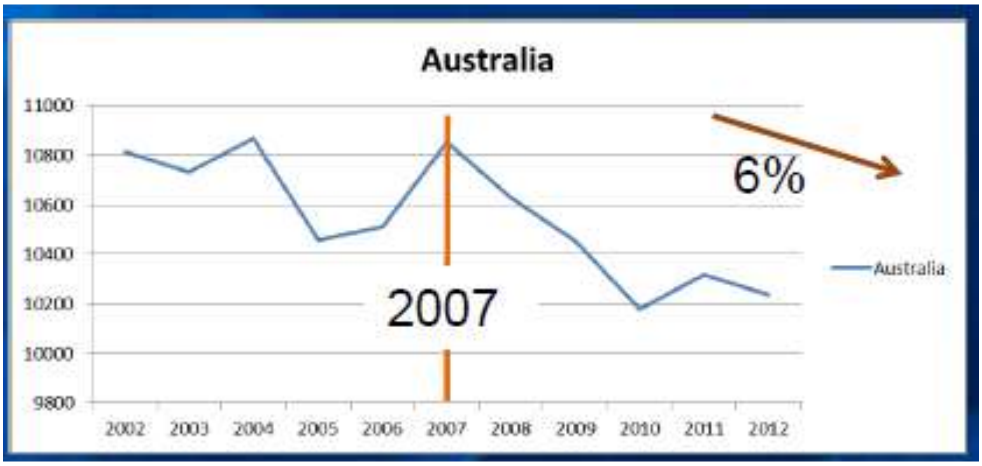

Figure 21 Annual energy consumption in Australia [22]

Figure 22 illustrates how communication of information on pricing has a strong influence on DSP through the reduction in overall energy consumption. Ambient displays have the greatest reduction (11%), followed by in-home displays (IHDs) (8%), an informative bill (6%) and a webpage (4%).

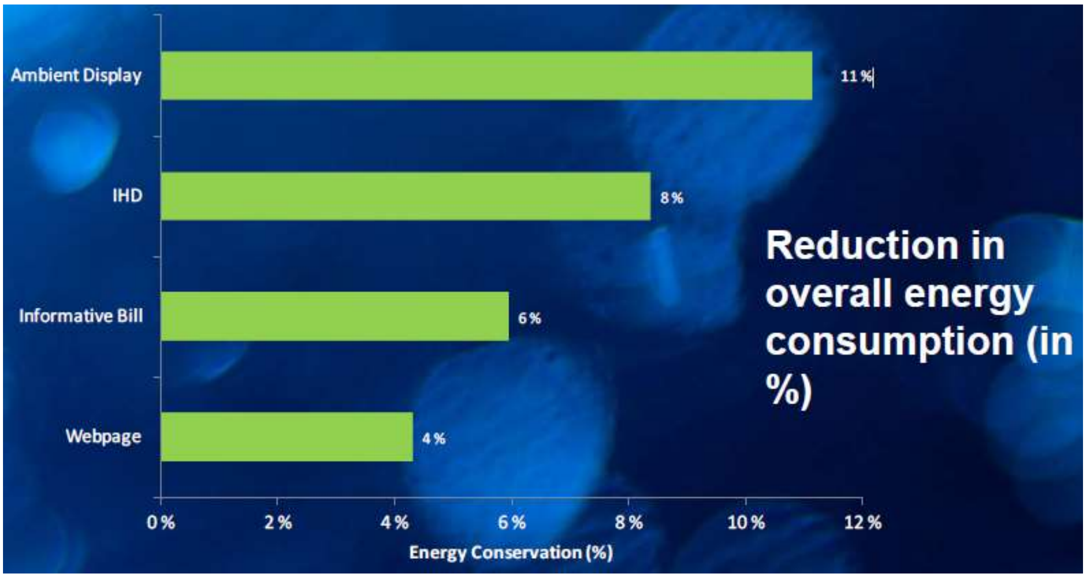

Figure 22: Feedback Channels: Major Impact on Electricity Consumption [22]

13.3 Smart Grid, Smart City

Following the global economic crisis, which began in 2008 the Smart Grid, Smart City Program was implemented in New South Wales from October 2010 [23]. This program is a part of the Australian Government's National Energy Efficiency Initiative, and they have committed up to $100 million in support to the project. "The Smart Grid Smart City project reflects the high level of coordination and support between government and industry, which appears to be a key characteristic of the Australian smart grid movement." [23] The Smart Grid, Smart City and is the first commercial-scale project with smart grids in Australia and it is run by the energy sector [24]. This project has tested a range of different technologies and the aim is to help the government, electricity and technology providers and customers make future decisions [24].

The project has a customer engagement component. This part of Smart Grid, Smart City is designed to look at how consumers respond to information about pricing and technology, in relation to their electricity usage over the long-term and also during peak events [25] (p 9). Two customer trials were undertaken: one for network customers and another for retail customers. The network customer trials tested feedback technologies[4], distributed storage and generation, dynamic peak rebates and lifestyle audits[5] while measuring consumer behaviour and the effectiveness of these products. The retail customer trial tested dynamic peak pricing, seasonal time-of-use pricing, interruptible load-tariff for air-conditioning and a top-up plan. The trial measured consumer behaviour and the effectiveness of tariffs in combination with feedback technologies.

Some of the benefits that are mentioned for the distribution network are that it potentially could reduce load on the electricity network, particularly during peak times [25]. Consumers were able to better understand and manage electricity use and reduce electricity consumption and bills, providing options including the ability to compare energy use to similar households, view current and accumulated electricity use and monitor electricity use for up to ten electrical appliances costs and greenhouse gas emissions [25]. The project details many lessons learnt from the network trial which are useful for further deployment of smart grids and hence for DSP [25] (pp. 54-57).

14 REFOCUS DSP

The following argument in this section has been developed from MacGill (2011, pers. comm., 16 October).

The definition of DSP by the MCE (see glossary) is limiting. One limitation is that DSP decisions are not made with respect to the value of electricity (a good) but electricity services. Another limitation is that it assumes that "consumers will always make the best decision from their viewpoint, based on the prices they face, the technology and equipment they have access to, the information they have and their individual transaction costs. …This will also allow third parties to assist consumers make optimal decisions under innovative business models".

There is too much focus on the role of energy consumers directly undertaking DSP [26]. A reshift in focus is recommended to how to facilitate third-parties driving DSP. Incumbents

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[4] Feedback technologies: in-home display and home-area network devices and a customer online portal are being tested in the network and retail customer trials, to help customers better understand and manage their energy use and costs.

[5] Lifestyle audits were offered to high energy-use customers to help educate them on how to reduce their overall and peak energy usage, and subsequently reduce their energy costs

such as generators, retailers and network service providers are unlikely to drive DSP, or at least a sufficient uptake of it, due to their current business model being based upon supply of energy. However, recommendations such as IRP and a revenue cap may facilitate greater facilitation of DSP options by these parties.

The aim of ESCOS is to support end-users in meeting energy service needs in the most appropriate way. Since ESCOs are equipped with the expertise and motivation to overcome the complexity of the NEM and DSP options, they are much better placed to optimize the level of DSP for end-users. However, ESCOs require appropriate market, regulatory and policy frameworks that recognize the wider value of DSP options. (This value encompasses not only traditionally maintaining energy security and reliability and more recent concerns of economic efficiency but also societal and environmental benefits.) Thus, ESCOs are the missing key institutional interface in the NEM.

There is also a key missing physical interface in the NEM – that of advanced metering infrastructure (AMIs)

15 Conclusion

Significant opportunities exist for DSP to help improve network security, reduce electricity prices and improve the efficiency of operation and control of electrical supply. New DSP technologies are offering opportunities for consumers to have increased control over when and how they use or supply their electricity creating a shift in the way the electricity industry thinks about the operation of the NEM. When DSP is a more economical option than supply side participation for market services, care still needs to be taken to ensure that DSP services can meet the reliability security required when becoming a registered market participant with AEMO and no special concessions should be made to DSP in order to maintain the security of electrical supply.

The best-practice from DSP programs around the world should be continually examined to develop and continually refine a strong set of recommendations to unleash the potential of DSP in the NEM in order to have the most economically efficient combination of demand-side and supply-side option that incorporates wider social and environmental externalities, which in turn meets the long-term interests of consumers.

16 Appendices

16.1 Appendix 1

Error! Reference source not found. shows the regional demand in New South Wales in half-hourly intervals over the year from 13-Oct-2013 to 12 Oct 2013. The higher peaks in January are likely to correspond to hotter days where air conditioning is used. The lowest peak demand appears to be around April (the middle of autumn) and October (the middle of spring) where temperatures tend to be comfortable and hence less heating and cooling is required.

Error! Reference source not found., **Error! Reference source not found.Error! Reference source not found.Error! Reference source not found.** and**Error! Reference source not found.** show the load-duration curve for regional demand in NSW, Queensland, Victoria, South Australia and Tasmania, respectively over the same period as above. The shapes of the curves are quite similar to one another. The slope of the left part of the load-duration curves gives an idea of how long and high peak demand is, while the slope of the right part of the load-duration curves gives an indication of how long and low troughs in demand are. The broader the part of the curve the longer the duration and the sharper or steepness of a part of the curve indicates a greater variation in demand, and a higher peak demand or a lower trough demand. Queensland, Victoria and South Australia appear to have relatively more peaks than the other states which is indicated by a broader left part of the curve. Victoria and South Australia appear to be very peaky, followed by Queensland, New South Wales and Tasmania. Hence, demand-side participation may have more to contribute in these states.

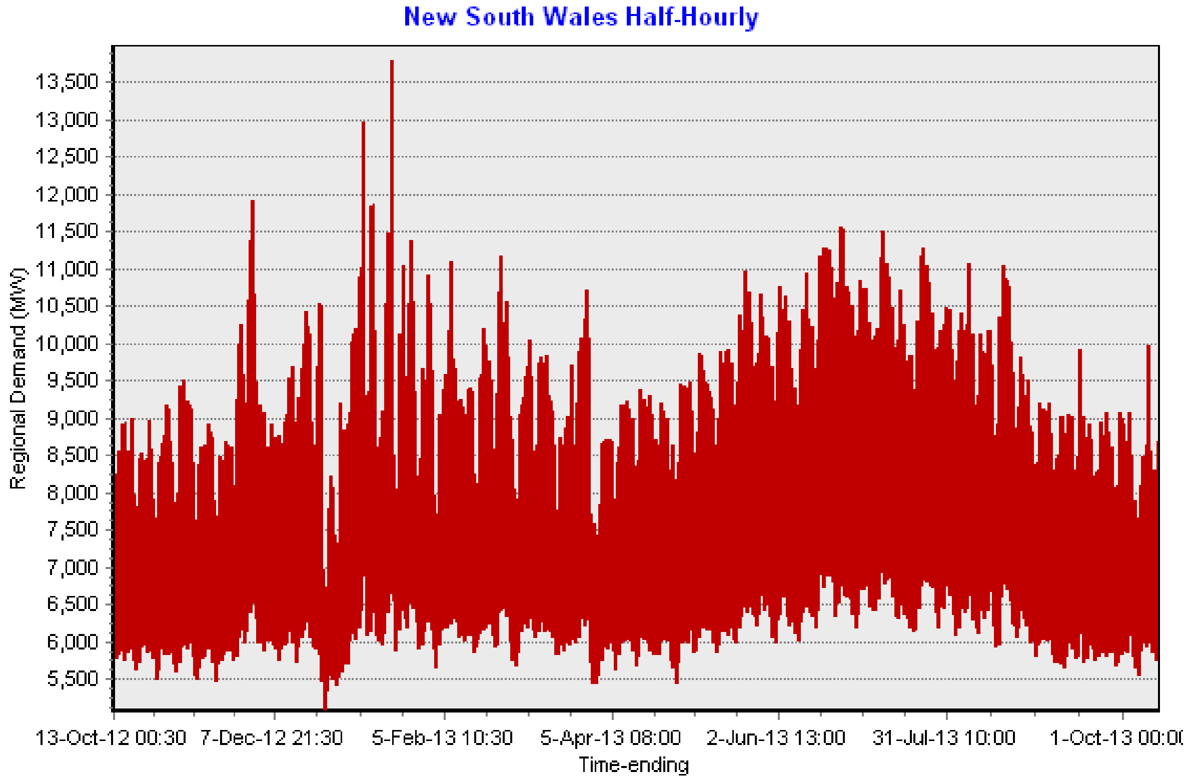

Figure 23: NSW Demand Profile from 13 Oct 2012 to 12 Oct 2013 [5]

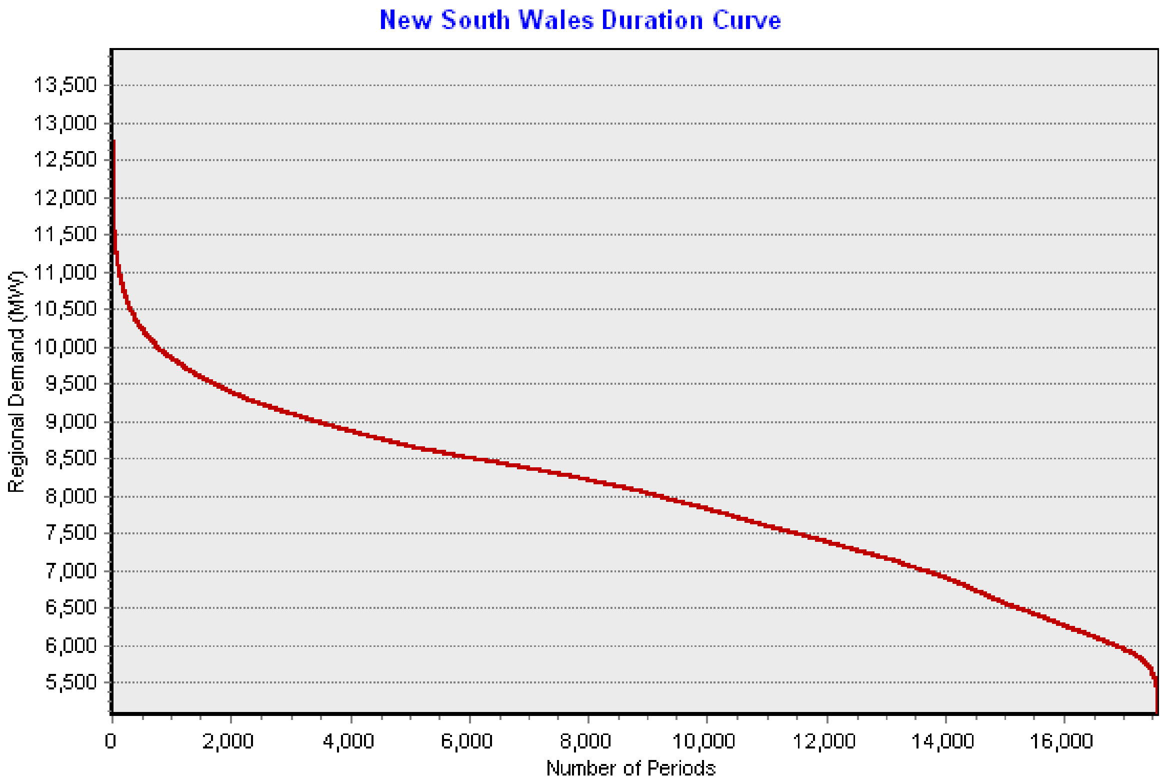

Figure 24: NSW demand duration curve from 13 Oct 2012 to 12 Oct 2013 [5]

Compared to NSW, Queensland has markedly different variation in regional demand across the year (**Error! Reference source not found.**). There is very little variation in average demand from about March to October. In summer however several extreme peaks occur, again likely due to air conditioning on hotter days in the warmer climate of Queensland. Interestingly the second large peak of the time period is followed by a very sharp drop in demand to a band with a maximum of about 5,600 MW (the lowest maximum demand across the year) and a minimum of about 4,200 MW (the lowest minimum demand across the year). The reason for this is unclear and needs to be investigated.

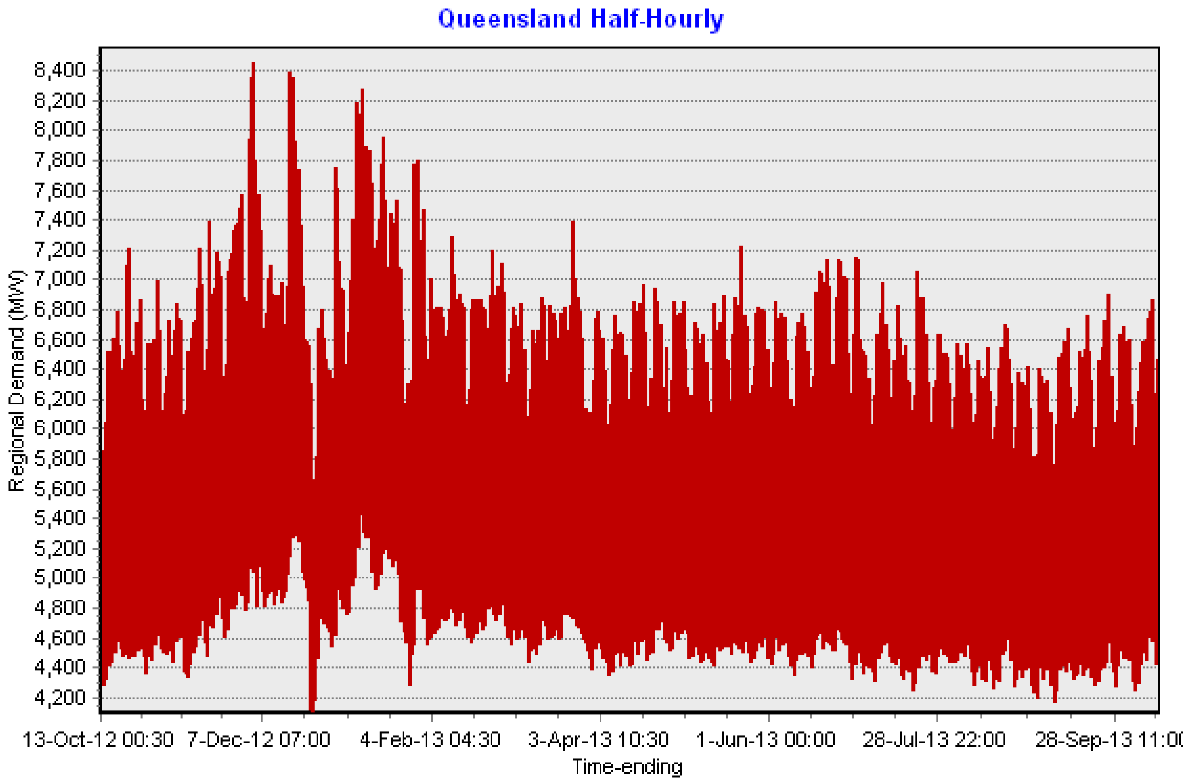

Figure 25: QLD demand profile from 13 Oct 2012 to 12 Oct 2013 [5]

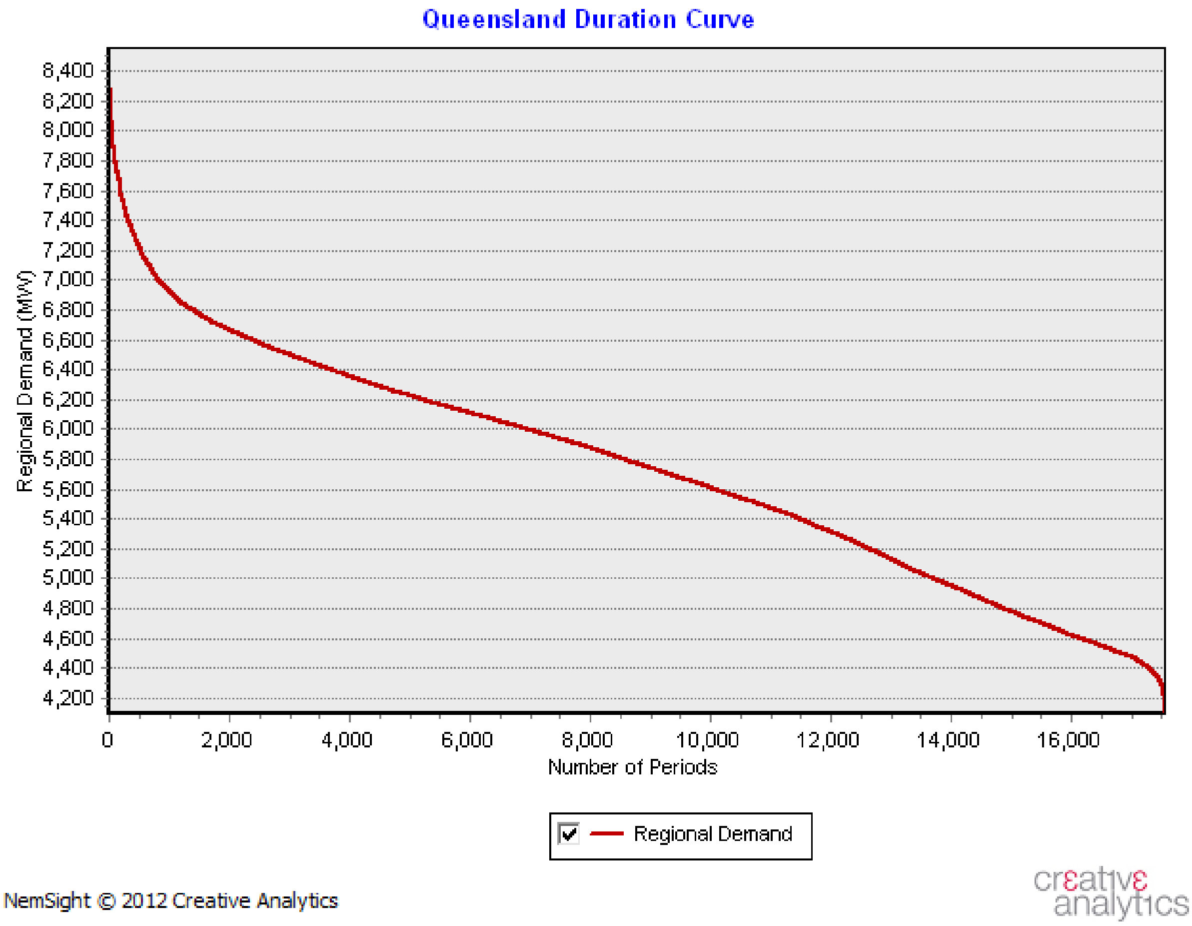

Figure 26: QLD demand duration curve from 13 Oct 2012 to 12 Oct 2013 [5]

Victoria, being a cooler climate than NSW and Queensland, has relatively higher demand in winter due to heating than NSW and Queensland (**Error! Reference source not found.**). Demand during summer has many sharp high peaks up to about 8,000-9,500 MW; however the average or median demand appears to be lower than in winter.

South Australia has a similar variation in regional demand across the year as Victoria, however the winter demand is relatively less higher compared to the maximum demand over the year (**Error! Reference source not found.**).

Tasmania, being a cool climate, has a much higher demand from heating in winter than in summer.

Note that the nature of demand-side participation varies seasonally and with climate. In winter, demand appears to be more predictable. The cooler the climate the more heating is required and hence the higher the demand in winter, while less air conditioning is required so air conditioning is less frequent and with less demand if it is used. The reverse is true for the warmer the climate. Therefore, it can be seen that the nature of demand, and hence demand-side participation, will vary not only with the time of day but also with climate and season.

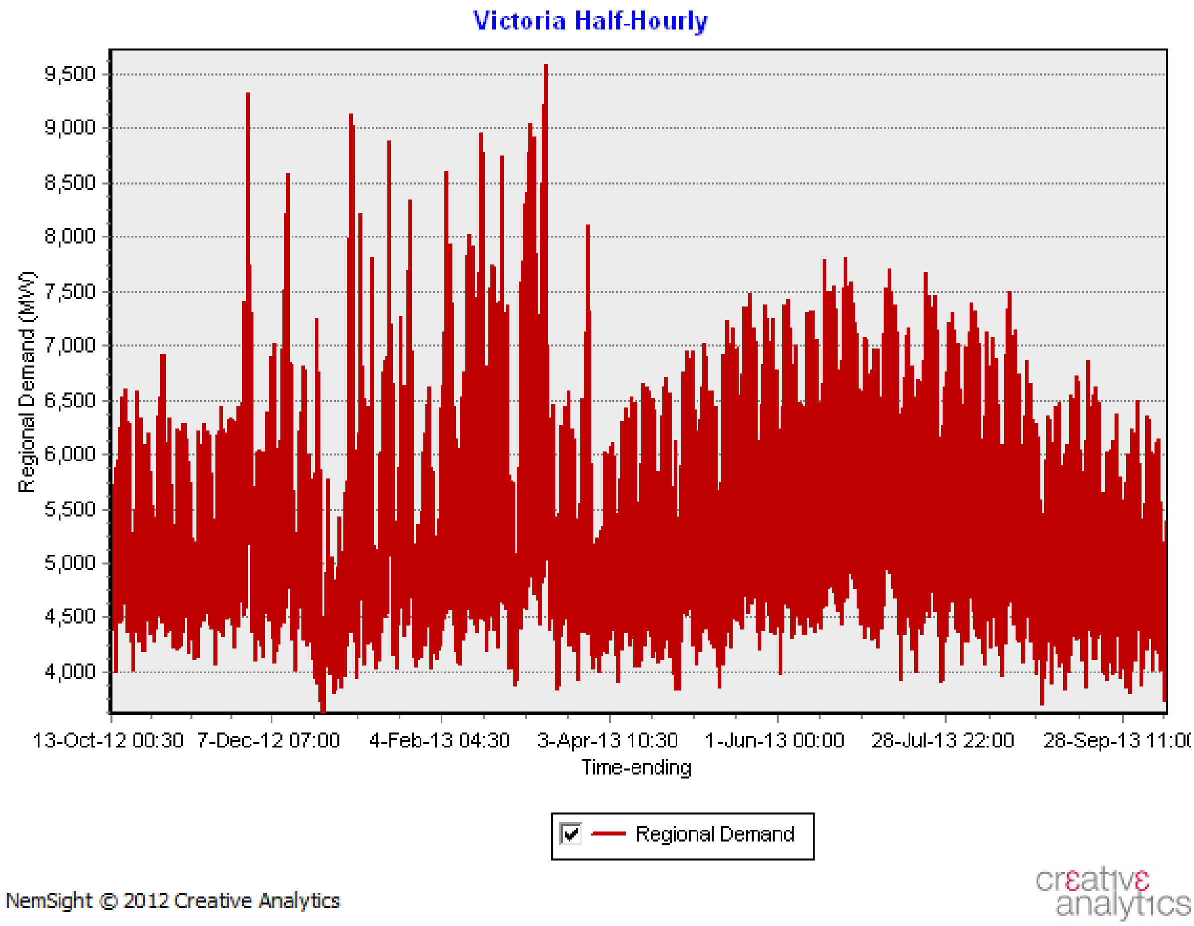

Figure 27: Victoria demand profile from 13 Oct 2012 to 12 Oct 2013 [5]

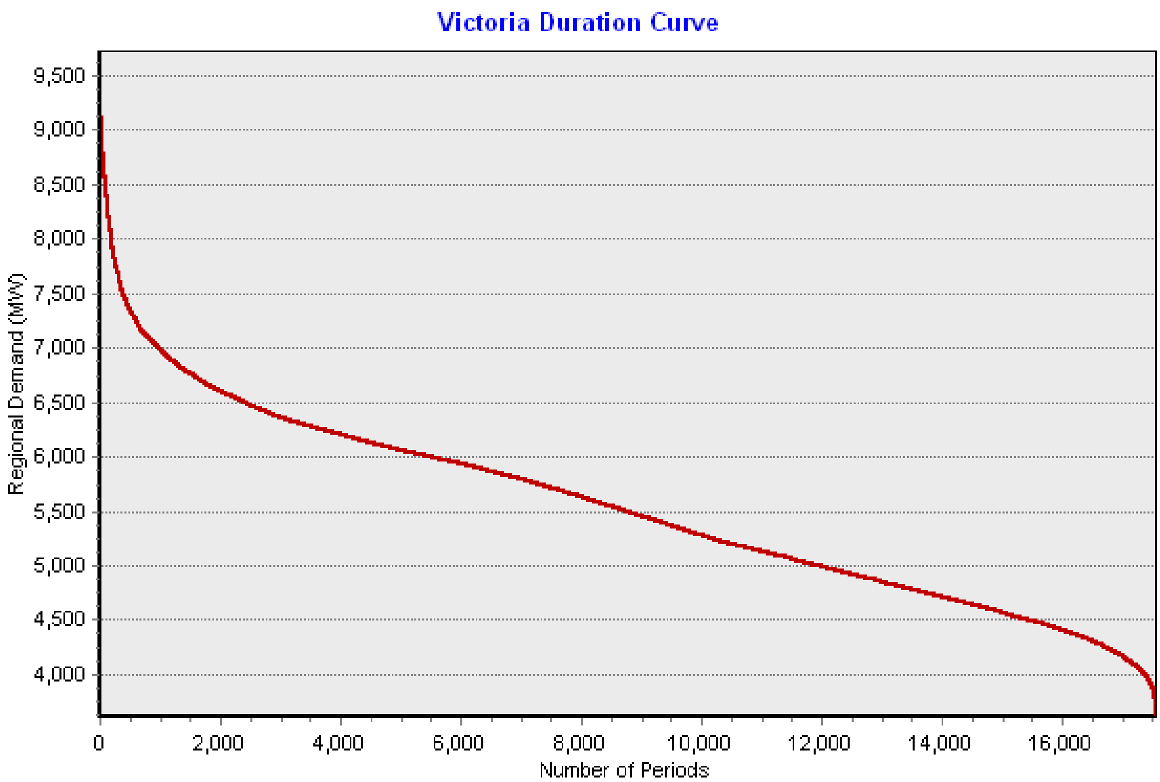

Figure 28: Victoria demand duration curve from 13 Oct 2012 to 12 Oct 2013 [5]

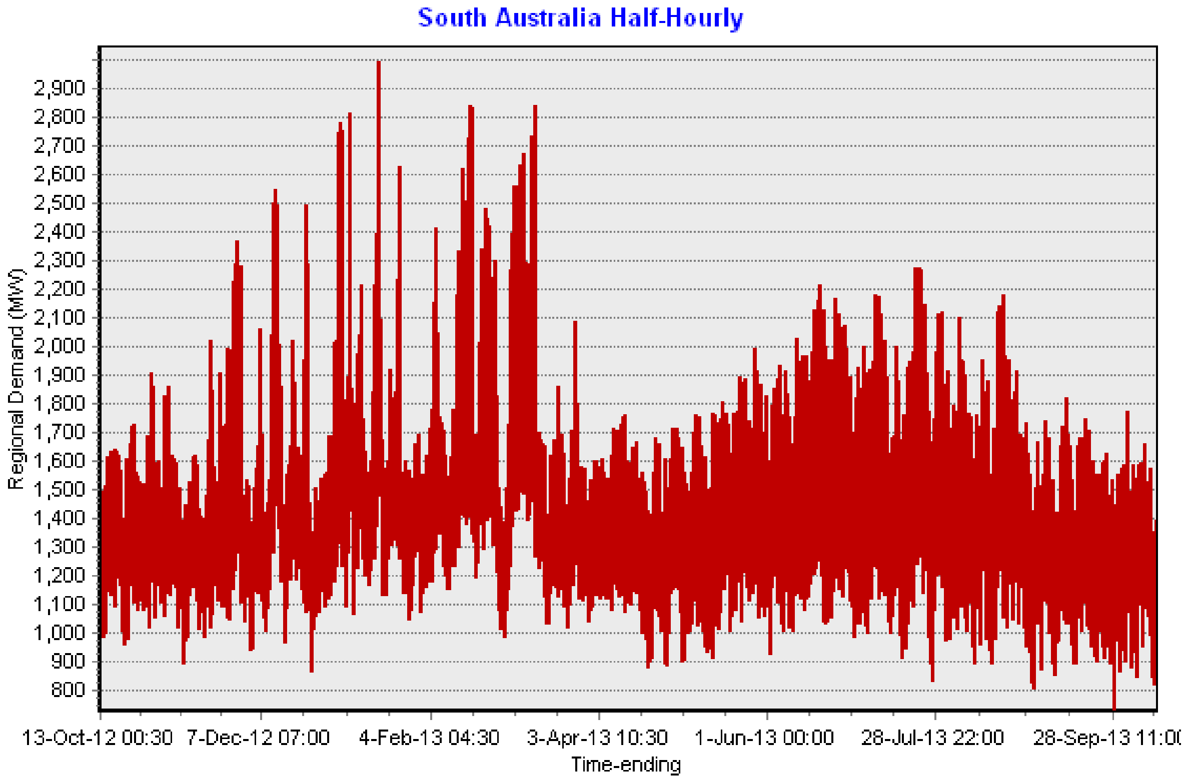

Figure 29: NSW demand profile from 13 Oct 2012 to 12 Oct 2013 [5]

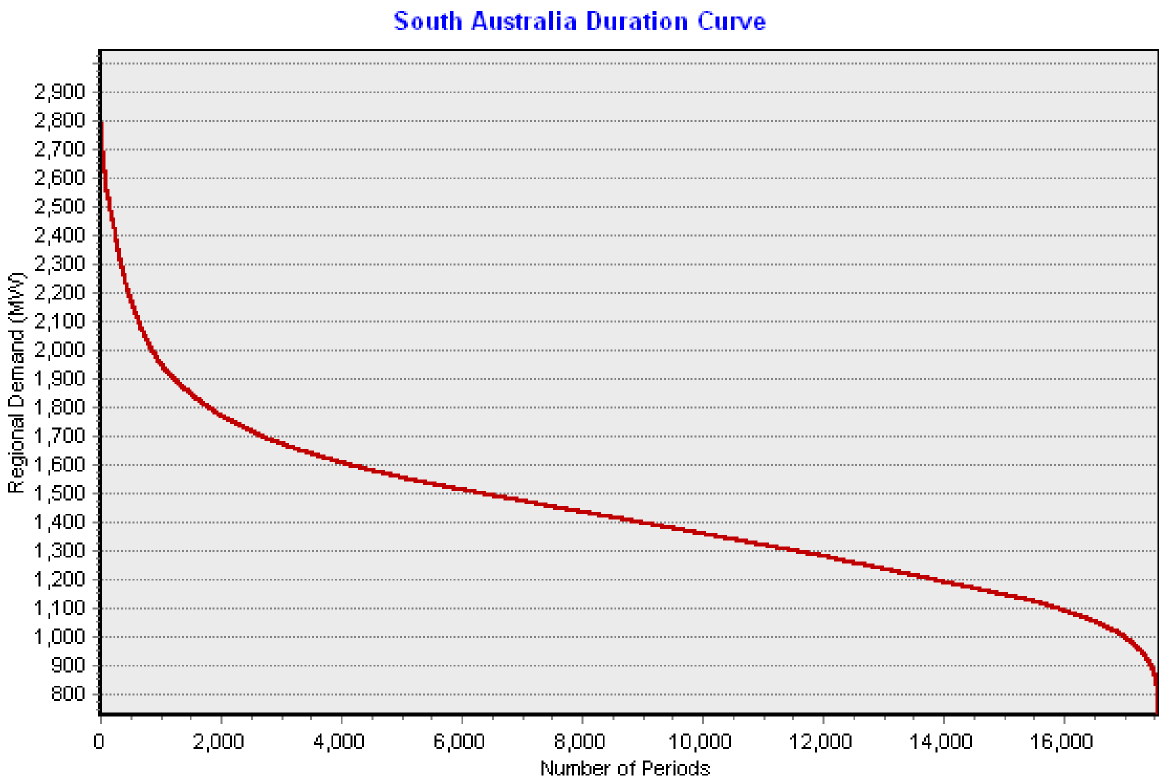

Figure 30: NSW demand duration curve from 13 Oct 2012 to 12 Oct 2013 [5]

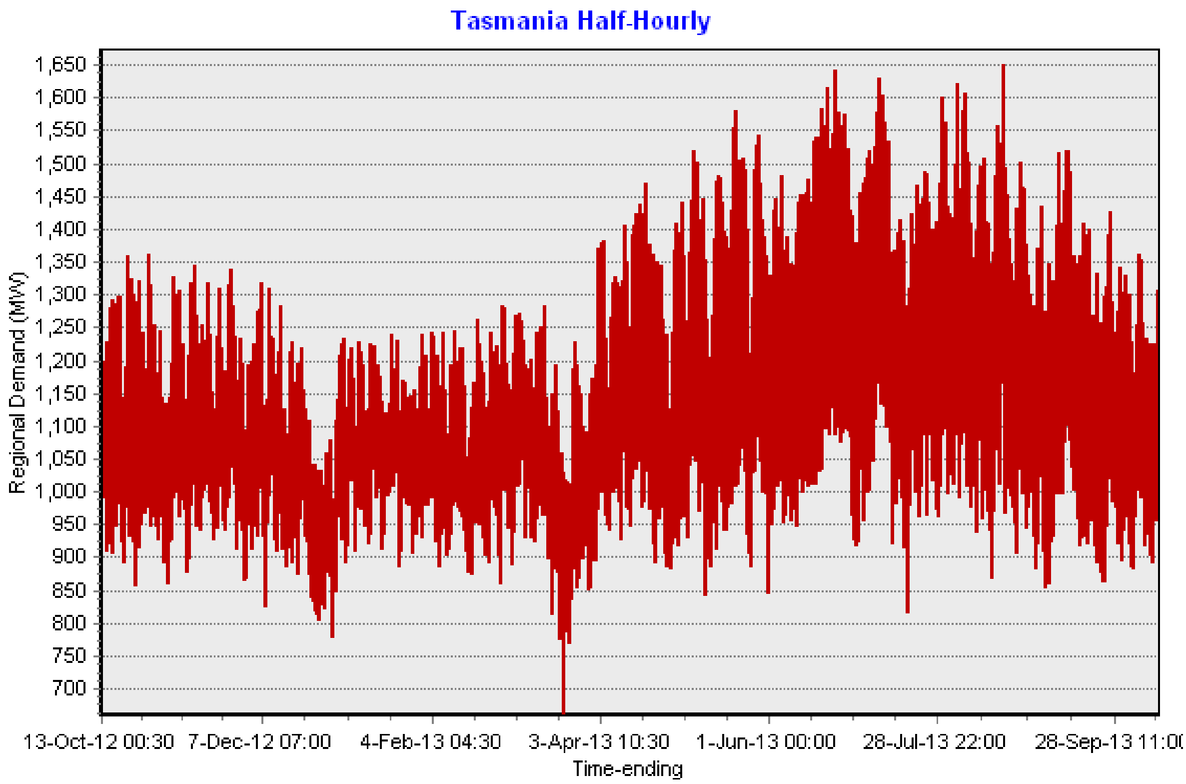

Figure 31: Tasmania demand profile from 13 Oct 2012 to 12 Oct 2013 [5]

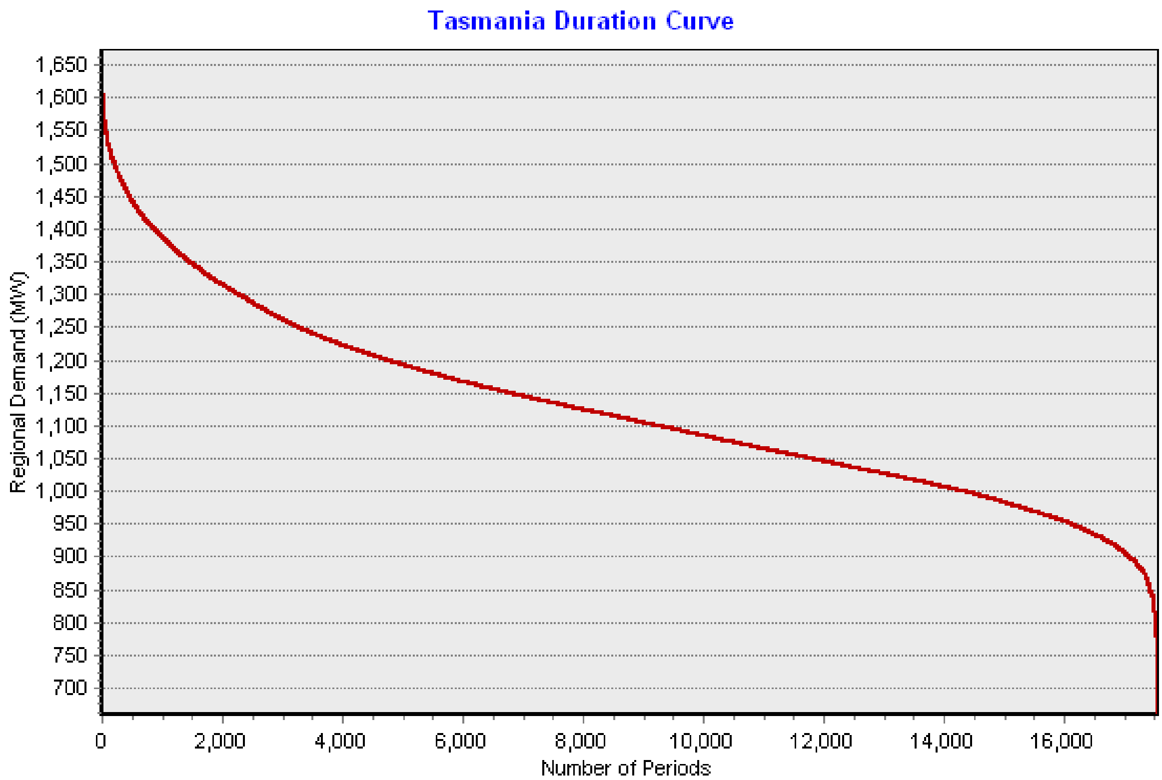

Figure 32: Tasmania demand duration curve from 13 Oct 2012 to 12 Oct 2013 [5]

16.2 Appendix 2

The following section on Types of DSP has been paraphrased from [27].

16.2.1 DSP within central dispatch

A DSP operating as a scheduled load means the load is registered with the AEMO and managed in the same way as scheduled generation. The same requirements for electrical security and reliability apply to the loads as for the generators, they must be able to respond accurately to dispatch instructions and have proper telemetry for communication.

DSP as an FCAS in the market operates with a controllable load that can participate in the provision of market ancillary services as one of the types of FCAS provided through regulation of the load as a means to provide this service.

DSP can also behave as an ancillary service enhancing the value of spot market trading occurring when configured loads are able to assist in the management of network capability.

There are several potential rationales for managing network capability, however AEMO has obligations of increasing benefits in this case. “Where practicable to enhance network transfer capability whilst still maintaining a secure operating state when, in AEMO's reasonable opinion, the resultant expected increase in non-market ancillary service costs will not exceed the resultant expected increase in benefits of trade from the spot market” all new market services should offer a net benefit to the NEM.

16.2.2 DSP independent of central dispatch

DSP that is independent of central dispatch can be used as a tool for system reliability by AEMO with improved reliability and emergency reserves behaving as a trader. This DSP allows AEMO to contract extra reserves up to 9 months before a known reserve shortfall.

AEMO’s offered reserve capacity cannot be contracted to another market participant and is paid by AEMO due to availability or usage. DSP has the ability to assist in the management of network loading and can be used in many different ways as a net benefit to the operation of the NEM.

DSP is used as a tool for hedging and provides a means of managing risk for participants in the NEM. Customers with the ability to reduce consumption upon request are identified and retailers are then able to form commercial agreements with them.

Electricity retailers use DSP to create arbitrage opportunities or to reduce the pool price and retailers can use DSP to exploit opportunities between the contract and pool price. Electricity retailers will often use DSP as physical hedge or alternative to financial hedge to manage their risk and exposure to peak electricity prices in the NEM.

Retailers and distributors can motivate consumers to demand response by the right price signals. In this way consumers can participate by responding to the price signals, or if they do not respond they have to pay a more cost reflective price. Examples are real-time pricing or pool price where the customers can see the price in the spot market in half hourly fluctuations. This gives a clear price signal to the consumers, and they can decide their consumption in relation to this.

Other price mechanisms include critical peak pricing where electricity prices are established in advance known to the end-user. The price however, can rise by a factor of 5 to 7 times under particular conditions so there is significantly more risk to the price.

17 ABBREVIATIONS

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
COAG	Council of Australian Governments
DG	Distributed Generation
DSR	Demand-side Response
DSP	Demand-side Participation
DSM	Demand-side Management
EE	Energy Efficiency
ESAA	Energy Supply Association of Australia
FCAS	Frequency Control Ancillary Services
MCE	Ministerial Council on Energy
NEM	National Electricity Market
NER	National Electricity Rules
SCER	Standing Council on Energy Resources
SRES	Small-scale Renewable Energy Scheme
TOU	Time of Use

18 GLOSSARY

Australian Energy Market Operator (AEMO)

"In 2009 the Australian Energy Market Operator (AEMO) was established. AEMO was established to manage the NEM and gas markets and is the market operator for the NEM" [28].

Crossley [29] states:

> Today AEMO operates both the retail and wholesale gas markets in southeast Australia as well as the NEM. Among AEMO's areas of responsibility are generator dispatch, reliability management, and financial settlements in the NEM. AEMO is owned 60% by government members and 40% by industry members.

Critical peak pricing [30]:

> When utilities observe or anticipate high wholesale market prices or power system emergency conditions, they may call critical events during a specified time period (e.g., 3 p.m.—6 p.m. on a hot summer weekday), the price for electricity during these time periods is substantially raised. Two variants of this type of rate design exist: one where the time and duration of the price increase are predetermined when events are called and another where the time and duration of the price increase may vary based on the electric grid's need to have loads reduced

Critical Peak Rebates [30]:

> When utilities observe or anticipate high wholesale market prices or power *system* emergency conditions, they may call critical events during pre-specified time periods (e.g. 3 p.m.—6 p.m. summer weekday afternoons), the price for electricity during these time periods remains the same but the customer is refunded at a single, predetermined value for any reduction in consumption relative to what the utility deemed the customer was expected to consume.

Demand side participation (DSP)

MCE [27] states:

> DSP refers to the ability of energy consumers to make decisions regarding the quantity and timing of their energy consumption that reflect their value of the supply and delivery of electricity. These decisions include both short-run decisions in response to specific events, and longer-run investment decisions about energy efficiency. DSP can take many forms including: Energy Efficiency, Demand Side Response and Distributed Generation.

Demand side response (DSR):

MCE [27] states:

> DSR refers to actions by energy users to reduce their demand for network supplied energy in response to pricing signals during periods of peak demand or network

stress. This may include the use of distributed generation, shifting consumption to off-peak periods or simply choosing to consume less and foregoing a level of activity

Marwan [18] states: "A tariff or program established to motivate change in electricity consumption by end-users in response to change in the price of electricity over time".

Distributed Generation (DG) [27]:

MCE [27] states:

> Also called embedded generation, refers to generation units that connect to the distribution network (close to load), rather than to the transmission network. This may include co-generation units, back-up generation or renewable energy generators, including residential solar.

Energy Efficiency (EE):

"Energy efficiency refers to the use of less energy for the same outcome or level of output, or increasing the level of output from the same amount of energy." [27]

Energy Service Companies (ESCOs):

ESCOs, also known as aggregators, are third parties (non-retailers and non-regulated network services) providing energy services to residential and small business consumers [12].

Energy Service: A useful output provided by energy, e.g. lighting, heating and cooking.

National Electricity Market (NEM)

Crossley [29] states:

> Since December 1998 a wholesale market for the supply of electricity has been operating in Queensland, New South Wales, the Australian Capital Territory, Victoria and South Australia. Tasmania joined the network in 2005 and currently the network consists of five interconnected regions supplying electricity to retailers and end-users (AEMO, 2010). This network is the National Electricity Market (NEM) and operates the world's longest interconnected power system. End-to-end the distance of the network is around 5000 kilometres and includes approximately 46000 MW of installed generation with more than eight million end-use consumers.

Real-time pricing (RTP):

An hourly rate which is applied to usage on an hourly basis [30].

Smart Grid:

GSGF [23, p 4] states:

> The European Union Commission Task Force for Smart Grids defines "smart grid" as an electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it in a manner which ensures an economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety.

The U.S. Department of Energy Smart Grid Task Force goes into further detail, specifying that smart grids anticipate and respond to system disturbances in a self-healing manner, enable active consumer participation, accommodate all generation and storage options, enable and provide the power quality needed in a digital economy. The smart grid brings together the idea of grid modernization and the closer integration of all actors in our electricity system.

Time-of-use pricing (TOU):

"Typically applies to usage over broad blocks of hours (e.g., *on-peak*=6 hours for summer weekday afternoon; *off-peak*= all other hours in the summer months) where the price for each period is predetermined and constant" [30].

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