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Environmental implications of increasing demand management in the National Electricity Market

Discussion paper

November 2012

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Executive summary

The potential economic benefits of peak load demand management (DM) are widely recognised. However, the environmental implications are unclear. This discussion paper is a first step towards clarifying the environmental benefits and costs of DM measures as they apply to Australia's National Electricity Market (NEM).

Demand management (DM) activities can provide environmental benefits where load shifted from periods of peak demand is supplied by cleaner, more modern and more efficient baseload generators. DM will also have a net environmental benefit if it displaces spinning reserves from coal- and gas-fired power stations, since they produce emissions without generating energy. In the long term, DM appears to be important as an enabler of other technologies that will lead to a cleaner energy system, i.e. renewable energy technologies and electrical vehicles, as it helps to balance out intermittency.

DM may result in a reduction in total energy usage (load shedding rather than shifting), which provides clear environmental benefit. This effect is likely to be weaker with industrial users, as they will generally need to use the same level of energy at a different time, and stronger with residential consumers, who appear less likely to make up for foregone energy later. Businesses may also forego energy usage in certain situations, such as in an 'end of the day' scenario.

DM may have a neutral or negative environmental impact if peaking plants are low emission, and load displaced from these generators is generated instead by less clean baseload energy sources. Likewise, if fossil fuelled local or distributed generation increases as a result of a DM program (e.g. by running a diesel-fuelled backup generator), this will result in increased emissions.

Overall, the extent of environmental benefits depends heavily on the precise characteristics of an energy system and consumer base – especially the generation mix – and the design and target audience of a DM program.

In Australia, the environmental impacts of DM on the NEM will vary greatly according to a range of factors, and according to how the NEM develops in the future. Because at present, under existing NEM rules and generation mix, increasing DM is likely to increase overall emissions due to the heavy reliance on coal-fired baseload generation, decisions about DM policies should be designed to enhance environmental outcomes. It is also likely that negative impacts will be offset to some extent (for residential consumers in particular) by the 'conservation effect'.

It is feasible and probably cost-effective to introduce DM initiatives that also ensure improved environmental outcomes – in general, by better integrating the former with climate, renewable energy, energy efficiency and urban planning policies. This will ensure that peak demand is lower even without DM measures; that some load is shed rather than shifted; and that non-peak generation is cleaner.

The current National Electricity Law (NEL) and Rules (NER) do not support such a holistic perspective, however. TEC's reform agenda, which begins, at the highest level, with rewording of the National Electricity Objective to include a quantitative environmental criterion for determining the long term interest of consumers, would rectify this deficiency.

Total Environment Centre's National Electricity Market Advocacy

Established in 1972 by pioneers of the Australian environmental movement, Total Environment Centre (TEC) is a veteran of more than 100 successful campaigns. For nearly 40 years, we have been working to protect this country's natural and urban environment, flagging the issues, driving debate, supporting community activism and pushing for better environmental policy and practice.

TEC has been involved in National Electricity Market (NEM) advocacy for eight years, arguing above all for greater utilisation of demand side participation — energy conservation and efficiency, demand management and decentralised generation — to meet Australia's electricity needs. By reforming the NEM we are working to contribute to climate change mitigation and improve other environmental outcomes of Australia's energy sector, while also constraining retail prices and improving the economic efficiency of the NEM — all in the long term interest of consumers, pursuant to the National Electricity Objective (NEO).

Project overview

The potential benefits of demand management (DM), particularly peak load management, are widely recognised. However, the extent to which these benefits accrue in practice may depend on a number of factors. Importantly for Australia, it is possible that DM may increase greenhouse gas emissions, as it is thought that some of the electricity saved through DM programs will simply be used at a different time, where it will be generated using older and dirtier baseload power sources.

This project aims to clarify the environmental benefits and costs of DM measures in the NEM. This is a complex issue which requires much attention. This initial scoping report intends to clarify the nature of the issues and identify areas where further research is required to inform policy and advocacy in the NEM.

A global literature review was conducted to identify research already undertaken into the environmental effects, positive and negative of DM. A bibliography containing summaries of the literature reviewed is included as an appendix, separated into two categories based on whether they directly address the issues of concern. A range of papers initially identified were excluded from further analysis as they simply assumed, rather than assessed or evaluated, environmental benefits.

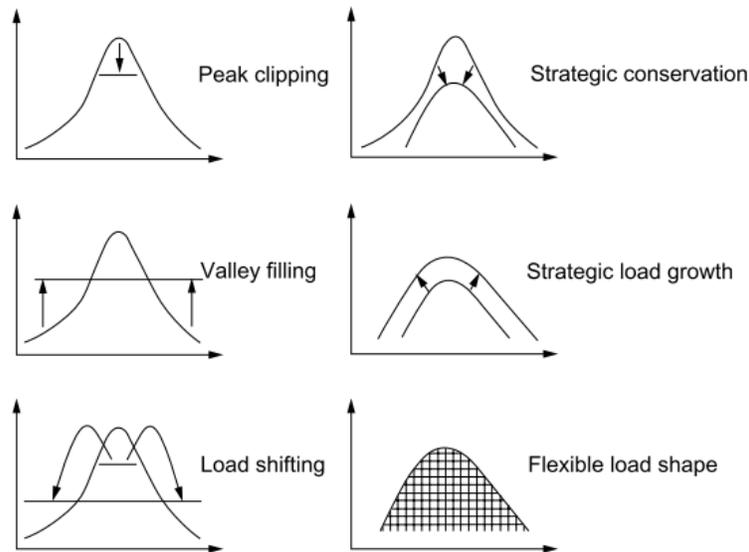
About demand management

DM refers to the modification of consumer demand for electricity. DM can be one element of the broader spectrum of decentralised energy or demand side participation, which also includes energy efficiency and local or distributed generation. DM is usually conducted with the goal of encouraging lower usage during peak hours, and/or moving energy use to off-peak times, the ultimate aim being to defer expensive network investment needed to meet a very small number of hours of peak demand each year.

DM programs can also be used for other purposes. For instance, 'valley filling' can be used to increase off-peak loads which can decrease the cost to customers in those times of the year where the long-run incremental cost is less than the average price of electricity.¹ Utilities categorise DM activities according to the effect the activity has on load profile:²

¹ For a summary of the types of DM, see Clark Gellings, "The Concept of Demand-Side Management for Electric Utilities" (1985) 73(10) *Proceedings of the IEEE*, 1468–1470.

² I.e. the time pattern and magnitude of a utility's load. Ibid



Source: G Bellarmine, *Load Management Techniques* (2000).

Customers participating in a DM program can respond in three ways:

1. Forego some electricity consumption (peak clipping/load shedding).³
2. Shift electricity consumption to a time period outside the peak period (peak clipping/load shifting)
3. Self-generate electricity using onsite renewables or standby generating equipment (peak clipping/flexible load shape).

Given the foregoing, the most relevant forms of DM in the present context, i.e. those that relate to reducing peak demand, are peak clipping and load shifting.

Potential environmental implications

The International Energy Agency estimates that about 60% of the reduction in carbon pollution required globally by 2050 will come from gains in energy efficiency.⁴ DM could reduce overall energy usage and therefore increase energy efficiency. In Australia, DM currently accounts for less than 1 per cent of capacity of the NEM, although it has the potential to deliver over half of peak demand capacity.⁵

DM can theoretically provide a range of environmental as well as economic benefits, including:

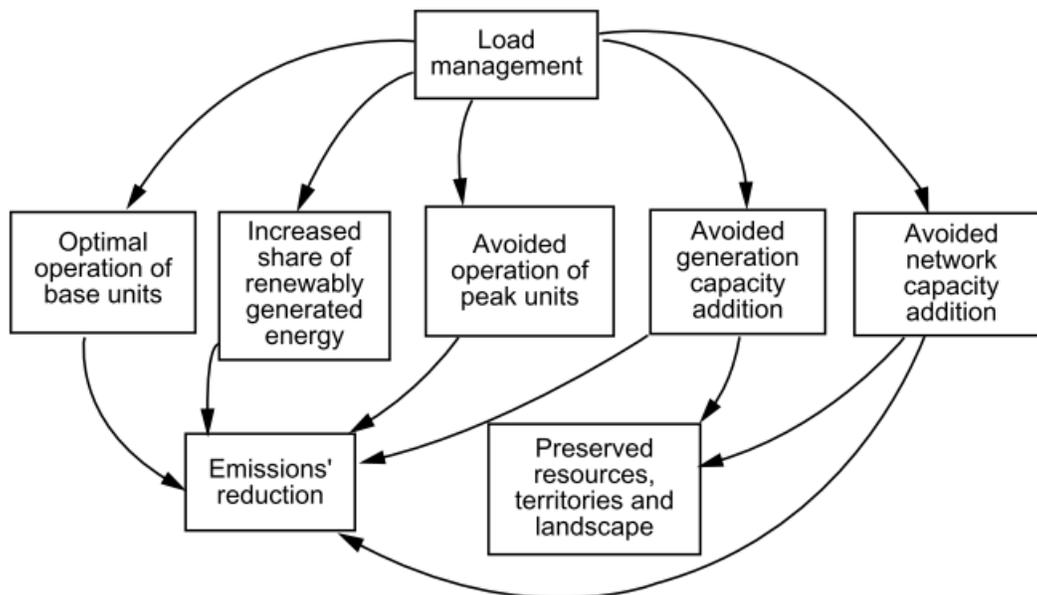
- Emissions reductions as a result of reduced overall demand where peak clipping is not accompanied by load shifting, i.e., the demand response results in overall consumption reduction.
- Lower urban air pollution (because this tends to track peak energy demand patterns).
- Lower overall consumption due to greater awareness and incentivisation for conservation as a result of advanced metering and retail pricing.

³ E.g. "Raising thermostat settings, reducing the run time of air conditioners, dimming or reducing lighting levels, or taking some elevators out of service are common customer load curtailment strategies". Charles Goldman et al., *Coordination of Energy Efficiency and Demand Response* (2010) 2–8.

⁴ See IEA Energy Technology Perspectives 2010, Executive Summary.

⁵ Dunstan, C, et al, 2011, *Think Small: The Australian Decentralised Energy Roadmap: Issue 1, December 2011*. CSIRO Intelligent Grid Research Program. Institute for Sustainable Futures, University of Technology Sydney, 11.

- Lower overall consumption where actions are both energy efficient and shift load at peak times. E.g. newer air-conditioners have lower overall consumption and could be able to respond to demand signals from the grid (direct load control).
- Responsiveness to fluctuating supply, facilitating integration of intermittent renewable generation and electric vehicles (EVs).
- Limiting infrastructure spending can avoid localised land-clearing for transmission lines, and conserve resources.
- Lower total demand, which lowers the amount of energy lost through transmission loss.
- Lower electricity prices as a result of deferred or displaced infrastructure investment. This offsets some of the costs associated with the transition to a low-emission electricity supply and will therefore facilitate this transition.



Source: Juozas Abaravičius & Jurek Pyrko, “Load Management from an Environmental Perspective” (2006) 17(4) *Energy and Environment* 583–601, 589.

However, these theoretical benefits will vary widely in practice depending on the characteristics of a particular jurisdiction’s energy system.

Studies of the environmental impacts of DM

There are conflicting reports as to the extent to which the environmental effects of DM have been considered. One commentator states that assessing DM from an environmental perspective is difficult as it has traditionally been “evaluated from the economic and technical viewpoints”,⁶ while another states that “one of the most important yet inadequately investigated elements of DR is its impact on the environment”.⁷ Yet another states: “The environmental benefits [DM] provides by deferring construction of new power supply resources and by backing off the operation [of] marginal generating units have been

⁶ Juozas Abaravičius, *Environmental Aspects of Load Management* (2004) i. See also Juozas Abaravičius, *Load Management in Residential Buildings: Considering Techno-economic and Environmental Aspects* (2004).

⁷ Robin Roy, David Nemtsov & Graham Mawer, *Demand Management and the National Electricity Market* *Energy* (2004) 43.

thoroughly studied”.⁸ To a large extent, this difference in opinion appears to be due to justification of the authors’ chosen research agenda.

Various impacts resulting from DM have been studied, however:

1. Assessment of the environmental aspects of DM has not been the main focus of evaluations, largely because this has not been the driving rationale for DM activities.⁹
2. A holistic approach has rarely been taken whereby an attempt is made to comprehensively detail all environmental effects of DM to determine the net overall effect.
3. Research has not been applied or replicated in the Australian context.

Environmental impacts

Load shedding

Where peak clipping occurs through load shedding, i.e. the shed load is not made up at a later time, there will be a reduction in emissions because, regardless of the fuel mix, “the greenest unit of energy is the one saved rather than the one used no matter how cleanly it is generated”.¹⁰

Given this fact:

1. What is the environmental outcome where peak clipping is achieved through load shifting rather than shedding? I.e. where reduced consumption at a peak time is met with increased consumption at a later off-peak period?
2. To what extent do consumers increase their consumption after responding to a peak event and what factors influence this?

Load shifting

The literature suggests that DM can provide an environmental benefit because peak clipping and load shifting decreases generation from peaking plants, which are often older, marginal units:

*The resulting reduction in peaking loads will reduce the need to produce electricity using the most inefficient, high cost generating units. The reduction of such inefficient electricity production will not only reduce the cost of generation but also will have a positive environmental effect since most of these plants tend to produce higher level of pollution than newer, more efficient units.*¹¹

However, it is also clear that this will depend to a large extent on the generation mix. A US study showed that in different states, load shifting from RTP could both decrease and increase emissions:

*Since fuel costs are a large component of marginal costs, low-cost generating units of a given fuel type generally are newer, use fuel more efficiently, and pollute less per megawatt-hour (MWh). In this case, decreasing the variance of load then causes the more efficient, cleaner units to generate more and the less efficient, dirtier units to generate less, thereby reducing total emissions. On the other hand, real-time pricing may increase pollution. This occurs, for example, if base-load generation is met by coal-fired units while peak load generation is met by more expensive, but cleaner, gas-fired units.*¹²

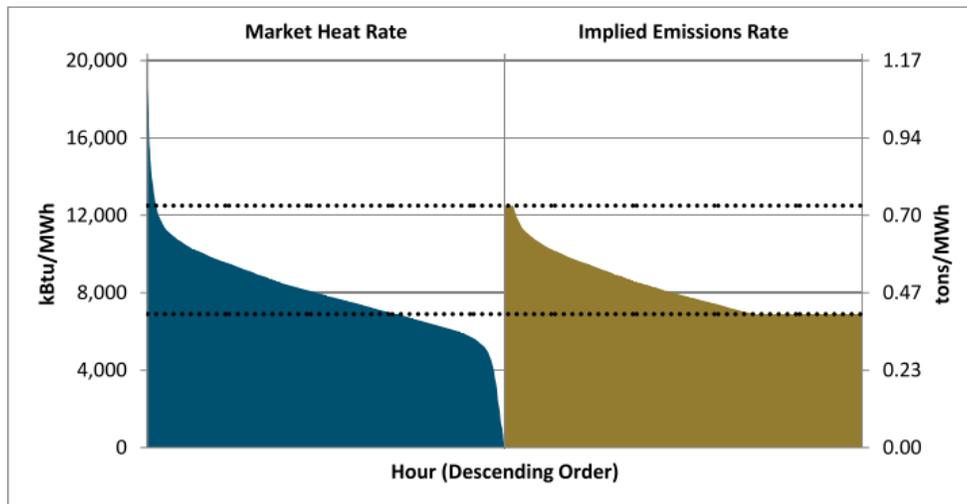
⁸ Steve Bernow et al., “Direct Environmental Impacts of Demand-Side Management” in *Summer Study on Energy Efficiency in Buildings* (1992) 19–31, 19.

⁹ King and Delurey, “Efficiency and Demand Response: Twins, Siblings or Cousins?,” above n , 54.

¹⁰ Xavier Lemaire, “Energy efficiency and Demand Side Management.”

¹¹ Chua Liang Su, “Optimal Demand-Side Participation in Day-Ahead Electricity Markets” (2007), 33.

¹² Stephen P. Holland & T. Mansur, Erin, *Is Real-Time Pricing Green?: The Environmental Impacts of Electricity* (2004) 2.



Hourly emissions rates derived from market prices.

Source: Energy+Environmental Economics & StrateGen, *Statewide Joint IOU Study of Permanent Load Shifting* (2010) A-22.

This is the case in Sweden, where load management measures provide little environmental benefits in because hydro provides emissions-free peaking power.¹³ Nonetheless, in the context of California, one report, assuming that marginal generation will be gas-fired, states:

*The link between higher market prices and higher emissions rates is intuitive: higher market prices enable lower-efficiency generators to operate, resulting in increased rates of emissions at the margin.*¹⁴

This suggests that, in the Californian market, load shifting can deliver environmental benefits, even where the marginal generation is provided by gas. Whether this can be extrapolated to the Australian context depends on how similar the generation mix is to that of California.

This suggests the need for detailed assessment of likely environmental effects on a regional/local basis, as environmental impacts will be:

*...heavily dependent upon the relative cleanliness of the production technologies available in each region. For example, if a region has peak load generation with low emissions rates, e.g., hydro or gas-fired, a reduction in load variance may increase emissions. However, in a region with dirty peak capacity (e.g., oil-fired), a reduction in load variance may decrease emissions.*¹⁵

In summary, if load shifting occurs, then environmental benefits may not accrue where efficient peak generators have been displaced. However, if load shifting does not occur there may be environmental benefits as a result of lower overall consumption. Emission reductions due to DM during peak periods therefore needs to be balanced against the possible increases in emissions during off-peak periods, as well as from the increasing use of on-site generation.

At present, the generation mix of the NEM is such that load shifting will result in an increase in power generated from coal-fired power stations. While the exact effect is hard to quantify, an increase in

¹³ Abaravičius, "Environmental Aspects of Load Management," above n , i.

¹⁴ Energy+Environmental Economics and StrateGen, "Statewide Joint IOU Study of Permanent Load Shifting," above n , A-21.

¹⁵ Holland and Mansur, Erin, "Is Real-Time Pricing Green?: The Environmental Impacts of Electricity," above n , 2.

renewable energy generation, spurred by the Renewable Energy Target (RET), would mediate this effect. This is because renewable energy generation will displace some coal-fired power. This effect will strengthen over time as more renewables are brought online, and particularly in the long-term as emerging technologies for large scale renewables and storage give renewables the potential to provide consistent and controlled baseload power.

Reducing Consumption: the relationship between DM and energy efficiency

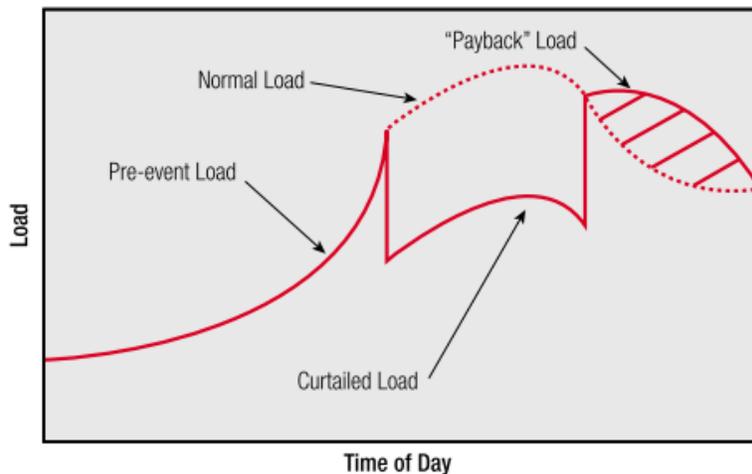
Given the foregoing, a concern of the literature is whether participation in peak DM programs leads to lower consumption overall, i.e. whether peak clipping/load shifting lead to energy efficiency, and can therefore have a net positive environmental impact, even where more efficient peaking power is displaced.

The rebound, snap-back or payback effect

The rebound effect is well documented in the more general efficiency literature and is uncontroversial, though there is debate over its strength and applicability to DM.

The effect postulates that gains in efficiency at one point in time or from one demographic/location will be negated by higher consumption at another.¹⁶ There are three possible gradations of this effect:

1. savings are higher than expected, i.e. there is no rebound effect
2. The actual savings are less than expected savings, i.e. there is some increase in consumption, but an overall reduction on the business-as-usual baseline.
3. The actual resource savings are negative, i.e. increased efficiency is entirely negated by increase in consumption.



Source: Chris King & Dan Delurey, "Efficiency and Demand Response: Twins, Siblings or Cousins?" [2005] *Public Utilities Fortnightly* 54–61, 56.

In terms of DM, the literature identifies at least two ways that this effect can occur:

1. DM measures can lower the price of electricity, encouraging some consumers to recommence electricity usage; this will depend on customers' price elasticities; and
2. Consumption foregone at a peak time may be made up later at a non-peak time; i.e. "after the load reduction is over, the customer consumes more electricity to catch up for the suppressed use".¹⁷

¹⁶ Steve Sorrell, *The Rebound Effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency* (2007).

While the former is theoretically valid, it does not appear to be backed by evidence in practice. As to the latter, while some rebound effect takes place, the effect overall does not appear to be significant. For example, an analysis of two peak reduction programs in California found that only 22 per cent of participants increased off-peak payback usage to offset peak reductions.

The conservation effect

Conversely, and backed by more concrete evidence, there is an argument that involvement in DM is a gateway to greater energy efficiency overall, for two reasons:

1. “the most significant and positive relationship between DR and energy consumption is that DR increases energy awareness and provides feedback for consumers on their usage behaviour”;¹⁸ and
2. consumers do not make up for the entirety of their shed load. Certain types of DM do not involve loads that may need to be made up at a later time, e.g.:¹⁹
 - o dimming of lights or switching off certain fixtures: a building will not need to be compensated for less light by overlighting later on;
 - o load shedding taking place at the end of the work day, which often coincides with summer peaks: e.g. reduced air conditioning is used for DR late in the work day of an office building and when the peak period is over, the workers have left; and
 - o where the consumer chooses to not (or forgets to) to shift the load, e.g. home-owner that reduces air conditioning but doesn’t fully re-cool afterwards.

Two articles, *Efficiency and Demand Response: Twins, Siblings or Cousins?* and *The Green Effect: How demand response programs contribute to energy efficiency and environmental quality* conduct a meta-review of the literature and study this argument in detail, concluding that:

although the primary intended effect of demand response programs is to reduce electricity use during times of peak load, the vast majority of demand response programs also yields a small conservation effect²⁰

They assess the effect according to three main program types: dynamic-pricing programs, reliability programs,²¹ and information/feedback programs. These programs were found to generate an average conservation effect of 4, 0.2 and 11 per cent respectively.²²

The researchers found that the conservation effect varies significantly among the 100+ programs studied, from -5 per cent (i.e., an increase in consumption) in one program to more than 20 per cent in others. No clear variables were identified to correlate with the conservation effect; though combining the types of program types produces a greater conservation effect than a single factor alone.²³

The authors later updated these findings based on new data, finding that the data:

¹⁷ Goldman et al., “Coordination of Energy Efficiency and Demand Response,” above n , 2–13.

¹⁸ David Nemtzw, Dan Delurey & Chris King, “The Green Effect: How demand response programs contribute to energy efficiency and environmental quality” [2007] *Public Utilities Fortnightly* 40–46, 42.

¹⁹ Ibid 42.

²⁰ King and Delurey, “Efficiency and Demand Response: Twins, Siblings or Cousins?,” above n , 59.

²¹ These operate for less than 100 hours per year and typically include automated controls (air conditioner cyclers, pool pump cyclers or energy management systems).

²² Ibid 54–55.

²³ Ibid 55.

further increases confidence in the conclusion that DR reduces total electricity consumption, principally (but not exclusively) during peak periods, but consistently, and has the potential to be a major indirect factor in increasing overall energy efficiency nationally

Displacement of spinning reserves

A further complication is added by the presence of spinning reserves. DM can lower the need for coal- and gas-fired spinning reserves, i.e. power plants that run offline, continuously burning fuel in order to be ready to generate online at short notices.²⁴

While load shifting may result in higher emissions due to switching from more efficient peaking plants in some jurisdictions, the negative effect may be offset by a reduction from spinning reserve emissions. This is obviously a complex calculation requiring detailed information regarding the generation mix and the nature of spinning reserve emissions in a given jurisdiction.

Integration of renewables, EVs and nuclear

Renewables present some challenges to a traditional electricity system:

*Operational issues include the effect of intermittent power non-intermittent output into (conventional) networks, operating reserve requirements, unit commitment and economic dispatch. Planning issues concern the appropriate modeling and evaluation of intermittent [resources] compared to conventional resources.*²⁵

DM has the potential to assist in the integration of renewables as it can “mitigate issues such as required reserve, network congestions and higher/lower voltage profiles and thus results in less operation cost”.²⁶ The IEA identifies “enhanced uptake of efficient demand-side response mechanisms” as one of six areas of structural change that will directly benefit renewables.²⁷

One study modelled the effect of responsive demand in relation to intermittent renewables, specifically wind generation, and found:

*Responsive demand in networks with high penetration of intermittent generation can have a positive effect on operational, planning and environmental characteristics. It provides the opportunity for load growth and enhanced robustness with minimal addition growth of the transmission system, make greater use of renewable such as wind systems, increases energy efficiency and reduce pollution and emissions and increases the level of local reliability to ensure the necessary power quality standards.*²⁸

While another states:

If demand response is used to integrate intermittent renewable generation in the future, it can have a net environmental benefit because the additional wind, solar, and other renewable sources are likely to displace fossil fuel-fired generation with higher emissions of pollutants (e.g. NOx, SOx and CO2).^{28F}²⁹

²⁴ Smart Energy Demand Coalition, *The Demand Response Snap Shot: The Reality For Demand Response Providers Working In Europe Today* vol. 32 .

²⁵ V Hamidi, F Li & F Robinson, *Responsive Demand in Networks with High Penetration of Wind Power* (2008) 1.

²⁶ Ibid 1.

²⁷ IEA, *Variability of Wind Power and Other Renewables – Management Options and Strategies* (2005) 47.

²⁸ Hamidi, Li, and Robinson, “Responsive Demand in Networks with High Penetration of Wind Power,” above n , 6.

²⁹ Goldman et al., “Coordination of Energy Efficiency and Demand Response,” above n , 2–13.

Although the benefits are relatively well established, further research is required in this area, particularly in relation particular system characteristics. The IEA Implementing Agreement for Wind Energy, discussing R&D needs for wind, stated: “demand-side management will be essential when large quantities of electricity from wind will need to be transported through a grid”.³⁰ Likewise, an Australian-led paper stated that further R&D is needed on:

*Distributed resource systems consisting of embedded generators and possibly reversible storage and flexible demand that can contribute to efficient use of distribution network assets through the management of energy flows and quality and availability of supply attributes.*³¹

The literature specifically regarding integration of EVs using DM is less developed, though a cursory search would suggest that this is because the EV literature focuses more on the EV perspective, rather than on integration of DM per se. DM garners a mention in many reports on EVs. E.g.:

*Without intelligent grid technologies, the necessary management tools such as DR, variable charging rates, and renewable generation pairing will be difficult to attain. In this capacity, the Smart Grid will have a strong influence on the environmental impact reductions realized by an EV fleet.*³²

The integration of nuclear is also less discussed, though at least one study extrapolated the benefits of DM in relation to renewables and EVs to facilitating an increase in nuclear generation.³³ This, however, is immaterial for Australia.

DM from fossil-fuelled local generation

Some DM capacity is generally provided by back-up generators, which may be fossil-based. It was not possible to determine the level of such generation, though this must be considered. When a customer reduces load as a demand response but utilises fossil-fuelled backup generation, there will be emissions produced even if there is a net emissions reduction from grid-based generation.

Direct negative environmental impacts

While not discussed extensively in the literature, there are obviously negative environmental effects attributable directly to the manufacture, installation and operation of DM-enabling technologies, for example smart meters.

One comprehensive study looks at a range of DM programs: building shell tightening; fuel switching; efficient air conditioners and refrigerators; efficient motors. Perhaps unsurprisingly, the study found that direct impacts “varied widely, from combustion pollutants in fuel switching programs to CFC emissions from increased appliance foam insulation to increased metals requirements for efficient motors”.³⁴ The study compared different programs by assessing the pollutant emissions/emissions reductions per kWh of electricity saved, allowing for direct comparisons of the environmental impacts of DM and the impacts of peaking plants.³⁵

³⁰ IEA (2001), Long-term Research and Development Needs for Wind Energy for the Time Frame 2000 to 2020, Ad Hoc Group Report to the Executive Committee of the International Energy Agency Implementing Agreement for Cooperation in the Research and Development of Wind Turbine Systems, 2 October.

³¹ Hugh Outhred, Stanley Bull & Suedeem Kelly, *Meeting the Challenges of Integrating Renewable Energy into Competitive Electricity Industries* (2007) pxii.

³² Dennis Huber, Zephyr Taylor & Steven Knudsen, *Environmental Impacts of Smart Grid* (2011) 24.

³³ UK Energy Research Council, *The Role of Demand Side Participation in Managing Generation Intermittency* (2012) 8.

³⁴ Bernow et al., “Direct Environmental Impacts of Demand-Side Management,” above n , 19.

³⁵ Ibid 19.

Importantly, the study found that the “vast majority of the severe direct impacts of DSM technologies can be mitigated or eliminated through careful program design and implementation”.³⁶

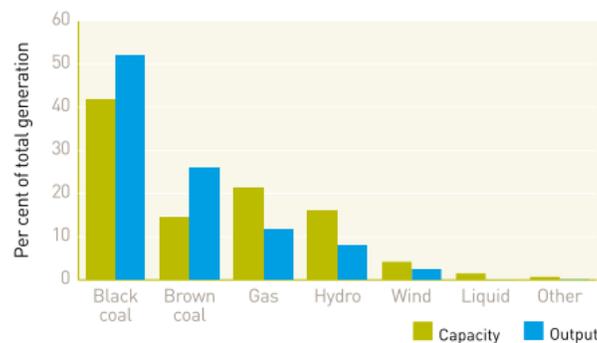
Variation in environmental benefits

The following key themes relating to the environmental impacts of DM are borne out in the literature:

- Variability of benefits:
 - *None of the experiences in place can be exported in toto to other systems, in view of the particularities that characterize each. The potential of any given electricity demand response mechanism depends largely on... the specific physical properties of the electricity system in question.*³⁷
- Generation mix: the generation mix is crucial to how beneficial DM is environmentally..
- Data: “hourly load data is essential when analysing load questions”³⁸ and “One of the key complications for good estimation of the environmental effects is unavailability of the hourly data, divided according electricity production source”.³⁹
- DM in context: DM cannot be viewed in isolation, but instead as part of a more general energy shift. Considered alone, DM may have negligible, or negative, impacts, but viewed holistically, it can be an essential part of reducing overall energy usage and facilitating the integration of distributed generation, large-scale renewables and EVs.

Increasing DM in the NEM

As discussed above, the generation mix of an electricity system is important in determining the environmental effects of increasing DM. The NEM is largely fossil-fuelled, with coal (black and brown) accounting for around 56 per cent of generation capacity. This is the NEM’s main baseload plant and supplies around 78 per cent of output. Gas fired generation accounts for around 21 per cent of registered but supplies only about 12 per cent of electricity.



Source: Australian Energy Regulator, *State of the Energy Market 2011* Energy (2011) 27.

³⁶ Ibid 19.

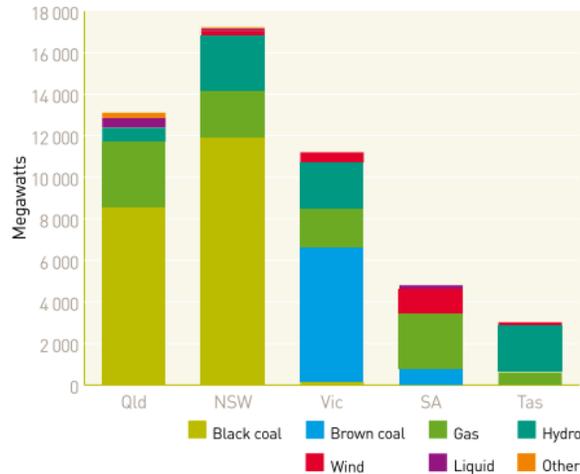
³⁷ Carlos Batlle & Pablo Rodilla, “Electricity demand response tools: current status and outstanding issues” (2009) 3(2) European Review of Energy Markets 1–27, 18.

³⁸ Abaravičius and Pyrko, “Load Management from an Environmental Perspective,” above n , 586.

³⁹ Abaravičius, “Environmental Aspects of Load Management,” above n , i.

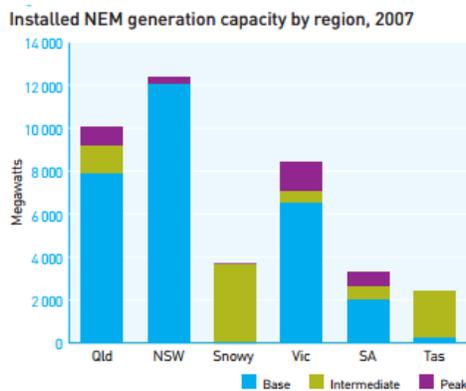
Hydroelectric generation accounts for around 16 per cent of registered capacity but less than 8 per cent of output. Its contribution to output is highly variable depending on weather conditions, and was therefore low during the drought, but has increased recently with greater rainfall in Tasmania and eastern Australia. Wind still plays a minor role in the market, accounting for 4 per cent of capacity and 3 per cent of output, but its role is expanding.

The generation mix varies considerably across NEM jurisdictions, with NSW, Qld and Victoria being heavily coal-dependant, and Tasmania and South Australia relying more on hydro and gas respectively. The mix is also changing with new investment trends (see below).



Source: Ibid 28.

Most peaking power in the NEM is provided by gas, though some is also provided by hydro. Gas is also used in intermediate generators, which operate more frequently than peaking plants, but not continuously. The distribution between baseload, intermediate and peak varies by jurisdiction, as shown below.



Source: AER, State of the Energy Market 2007

It was noted above that many electricity systems use older, more polluting plants as peak power, and that reducing peak demand could also reduce the use of these generators and the pollution they generate. However, in the NEM this tendency is reversed: peaking and intermediate plant comprises much of the cleaner generators in the NEM. There is a risk that in this coal-dominated market, shifting the load to non-peak times will not reduce emissions and could actually result in an increase.

It is difficult to precisely outline how increasing DM will affect the emissions profile of the NEM. However, some assumptions can be made regarding the effects of DM in principle.

It is likely that increasing DM will cause some increase in emissions in the NEM, as it is currently constituted, as some load will be shifted from cleaner gas and hydro peak generation to coal-fired generators. This impact is will vary according to a number of factors. In particular:

- The generation mix in a jurisdiction and the extent to which electricity it imports electricity from other regions during peak times.
- The extent of load shifting and conservation. If all load shifted away from a peak period was used at a later time, this would result in a substantial increase in emissions. At the other extreme, if the conservation effect proved to be very strong, increasing DM would have a neutral or positive impact on emission. This will depend on the type of DM implemented. Consumer DM, such as peak pricing, has a stronger conservation effect than industrial load shifting, for example.
- The time that shifted load is later used. As gas and hydro also provides some intermediate generation, shift of usage from peak to shoulder periods may not result in increased emissions as the source remains gas or hydro. However, shifting from peak to baseload would increase coal use and emissions.

These factors introduce considerable uncertainty and without extensive modelling and further information, for example regarding which type of generation is used at a given time and how strong the conservation is in the NEM, it is not possible to be more precise about the impacts of increasing DM in the NEM. Overall it seems likely that increasing DM will increase emissions in the short-term, however, as previously noted, the NEM is undergoing a number of changes at present which mean that DM may be more positive in the longer-term.

Future trends

Changing investments

Most new investment over the past decade was in gas peaking plant, and current investment interest is focused on renewable and peaking generation from open-cycle gas turbines (OCGT), with over 13,000 MW of wind generation and over 11,000 MW of OCGT publicly announced. Meanwhile, “signals for base load generation investment are muted”.⁴⁰

A renewable energy future

A UNSW study into how Australia’s National Electricity Market could operate with 100 per cent renewables suggests that the entire ‘baseload’ concept is redundant in a renewable-powered electricity system as the needs of the grid are met with renewable sources, assisted by solar storage acting and gas-turbines (running on biofuels) that act as peaking plant.

South Australia provides a glimpse of this future:

*In the space of 5 years, wind power started producing a significant fraction of South Australia’s electricity requirements, substantially reduced CO2 emissions, did not require extensive amounts of peaking plant as “back-up”, and did so without significantly affecting wholesale electricity prices.*⁴¹

In this context, DM would reduce peak demand, with any load shifting later being met by renewables.

⁴⁰ Australian Energy Regulator, *State of the Energy Market 2011* Energy (2011).

⁴¹ <http://climatechangeauthority.gov.au/sites/climatechangeauthority.gov.au/files/SUB-RET-2012-037.pdf>

DM initiatives

There are a range of DM initiatives currently being proposed in the NEM. These initiatives are outlined below along with a brief assessment of the potential environmental outcomes.

Demand aggregation: the AEMC's Power of Choice review is proposing to allow third party companies to aggregate the demand response of consumers in order to deliver increased DM to the NEM. This demand response mechanism will pay consumers for changes in demand via the wholesale electricity market. This proposal is likely to significantly reduce peak demand, however participants will initially be large commercial and industrial consumers. These users are likely to only shift load to be used at a later time, though some conservation, such as the 'end of the day' scenario discussed above, will take place.

Direct load control: a program whereby networks remotely cycle high-usage equipment, such as pool pumps and air conditioners, will reduce emissions, because these programs generally have a conservation effect, i.e. a consumer will not overcool their house to compensate for air conditioner cycling.

Cost-reflective pricing: there are currently calls for implementation of cost reflective pricing originating from a number of different reform processes. Cost reflective pricing provides a strong environmental benefit as most consumers use less energy overall, rather than simply deferring their energy use away from peak times.

Improving environmental outcomes

Aside from the fact that some DM results in lower overall demand and thus lower emissions, the main initiative that will ensure that increasing DM leads to positive environmental outcomes in the NEM is increasing the mix of renewable energy generation types in a variety of scales and locations to help overcome the problem of intermittency. This is already happening with wind energy and, under the influence of the RET, is expected to increase with the commissioning of utility scale solar PV and solar thermal plants from now to 2020.

Given that peak demand is largely a function of domestic consumption, anything that will reduce this without increasing baseload demand will also have a positive environmental outcome. For instance, orienting rooftop PV panels to the north-west or west, while producing less energy, will help to better match load profiles in the majority of cases and will therefore reduce peak demand on the grid during late afternoons and early evenings.⁴² Improvements in storage technology and pricing should also allow increasing amounts of peak demand to be met onsite rather than through the grid.

There are also options beyond the electricity market that could be implemented to reduce peak demand, including improved building energy efficiency standards to planting trees the sunny sides of buildings so as to maximise shade and thus reduce the need for air conditioning on hot summer days.⁴³ Unfortunately, the current narrow economic focus of the NEM regulatory framework does not encourage such holistic solutions.

It is feasible and probably cost-effective to introduce DM initiatives that also ensure improved environmental outcomes – in general, by better integrating the former with climate, renewable energy, energy efficiency and urban planning policies. This will ensure that peak demand is lower even without DM measures; that some load is shed rather than shifted; and that non-peak generation is cleaner.

⁴² See, e.g., the article by Mike Sandiford of the Melbourne Energy Institute at <http://reneweconomy.com.au/2012/whos-afraid-of-solar-pv-38844>.

⁴³ See E. Gregory McPherson, Evaluating the cost effectiveness of shade trees for demand-side management, *The Electricity Journal*, 6, 9, November 1993, 57–65.

The current National Electricity Law and Rules do not support such a holistic perspective, however. TEC's reform agenda, which begins, at the highest level, with rewording of the National Electricity Objective (NEO) to include a quantitative environmental criterion for determining the long term interest of consumers, would rectify this deficiency.

Recommendations

1. In order to properly understand the environmental impacts of increasing DM in the NEM, further research is required into the following areas:
 - Data requirements. A range of raw data is available in the NEM, however this data needs to be synthesised in order to be useful in making better DM decisions. In particular, further research is needed on:
 - a. the overall composition of the fuel mix in the NEM at different times of the day and year;
 - b. the aggregate fuel mix of peaking plants across the NEM and when peak generators are dispatched;
 - c. how peak demand is met in different jurisdictions and the extent to which electricity is traded across jurisdictions during peak times;
 - d. a precise breakdown of baseload, intermediate and peak generation capacity, including what proportion of peak and intermediate is provided by gas, hydro and coal-fired spinning reserves.
 - Modelling of a variety DM uptake scenarios. In particular, which DM options are likely to result in greater load shedding rather than load shifting.
 - Modelling load curves with generation dispatch and information regarding load shifting to determine to what extent load is shifted to intermediate and/or baseload generation.
 - A cost-benefit analysis of installing rooftop and commercial PV systems oriented to the north-west or west instead of the most energy-efficient option, due north.
2. Current and future NEM regulatory processes should consider the most environmentally effective as well as economically efficient DM solutions.
3. The NEL (including the National Electricity Objective) and NER should be amended where necessary to facilitate this consideration, where it is in the long term interest of consumers.

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The following papers directly address the question of the environmental impacts of DM.

Abaravičius, J. (2004a). Environmental Aspects of Load Management. Lund: Lund University.

This study approaches load management from an environmental perspective. It identifies and discusses the possible environmental benefits of load management and evaluates their significance, primarily focusing on CO₂ emissions reduction. The analysis is carried out on two levels: national – the Swedish electricity market, and local – one electric utility in southern Sweden.

Abaravičius, J. (2004b). Load Management in Residential Buildings: Considering Techno-economic and Environmental Aspects. Lund: Lund University.

The key objective of this study is to analyze load demand variation and load management possibilities in residential sector, particularly detached and semi-detached houses, to experimentally test and analyze the conditions and potential of direct load management from customer and utility viewpoint. Techno-economic and environmental aspects are investigated. The results show the importance of considering the influence of site-specific or level-specific conditions on the environmental effects of load management.

Abaravičius, J., & Pyrko, J. (2006). Load Management from an Environmental Perspective. Energy and Environment, 17(4), 583–601.

Discusses the possible environmental benefits of load management and evaluate their significance, primarily focusing on CO₂ emissions reduction.

Behrangrad, M., Sugihara, H., & Funaki, T. (2011). Effect of optimal spinning reserve requirement on system pollution emission considering reserve supplying demand response in the electricity market. Applied Energy, 88(7), 2548–2558. doi:10.1016/j.apenergy.2011.01.034

Emission reduction and optimal spinning reserve scheduling cannot be studied separately. Analysis of the system effects of pollution reduction should be performed considering the ancillary service market, specifically the optimal spinning reserve scheduling. This problem is addressed in this paper by incorporating optimal spinning reserve scheduling in a combined environment economic dispatch (CEED) in one objective function.

Bernow, S., Biewald, B., Fulmer, M., Shapiro, K., & Wulfsberg, K. (n.d.). Direct Environmental Impacts of Demand-Side Management.

Little attention has been given to the direct environmental impacts of DSM technologies, which can in some instances, such as asbestos or urea-formaldehyde foam insulation, be significant. This paper quantifies and discusses the direct environmental impacts of several broad DSM categories, including: building shell tightening, fuel switching, efficient air conditioners and refrigerators, and efficient motors. We also discuss how DSM programs can be implemented to minimize any direct environmental impacts or take advantage of any potential environmental benefits..

Capgemini. (n.d.). Demand Response: a decisive breakthrough for Europe: How Europe could save Gigawatts, Billions of Euros and Millions of tons of CO₂. Capgemini.

Explores the current development of DR throughout the EU-15, to quantify its future potential, and to identify the pre-requisites for the efficient fulfilment of its potential by 2020. The outcome is a dynamic scenario which is ambitious albeit theoretically compelling. In this scenario, calculations show

that DR alone achieves 25-50% of the EU's 2020 targets concerning energy savings and CO2 emission reductions, as well as pre-empting the need for the equivalent of 150 medium size thermal plants in EU-15.

Energy+Environmental Economics, & StrateGen. (2010). Statewide Joint IOU Study of Permanent Load Shifting.

The purpose of this study is to investigate cost-effectiveness and program design to expand the use of permanent load shifting (PLS) within the SCE, PG&E, and SDG&E service territories ("Joint Utilities"). E3 and StrateGen Consulting (the "project team") used a collaborative stakeholder process with two workshops, numerous stakeholder interviews and meetings, and the release of a publicly available cost-effectiveness tool to develop the study results.

Goldman, C., Reid, M., Roger, L., & Silverstein, A. (2010). Coordination of Energy Efficiency and Demand Response. National Plan for Energy Efficiency.

Summarizes existing research on the relationship between energy efficiency and demand response. Using information gathered through interviews with program administrators, customers, and service providers, this paper discusses the coordination of energy efficiency and demand response programs, with a particular focus on current practices and opportunities. It also discusses barriers to coordinating these two types of programs.

Hamidi, V., Li, F., & Robinson, F. (2008). Responsive Demand in Networks with High Penetration of Wind Power.

In this paper, the value of wind generation without responsive demand is quantified first, by introducing responsiveness in the demand side, the reduction in operation cost is quantified.

Holland, S. P., & Mansur, Erin, T. (2004). Is Real-Time Pricing Green?: The Environmental Impacts of Electricity. Center for the Study of Energy Markets, University of California Energy Institute.

Argue that real-time pricing will reduce variance of electricity load and estimate the short-run impacts of a reduction in variance on emissions of SO₂, NO_x, and CO₂.

Holland, S., & Mansur, E. (2005). The Distributional and Environmental Effects of Time-Varying Prices in Competitive Electricity Markets. Center for the Study of Energy Markets, University of California Energy Institute.

This paper analyses the short-run effects of time-varying retail electricity prices on wholesale prices, consumer surplus, generator profits, efficiency, and emissions.

Huber, D., Taylor, Z., & Knudsen, S. (2011). Environmental Impacts of Smart Grid. National Energy Technology Laboratory.

This paper focuses on the particulate and gaseous emission pollutants that are byproducts of electricity generation, and on how the Smart Grid infrastructure will affect this environmental impact. This paper evaluates the impact that the Smart Grid will have on reducing the production of these pollutants in the following major areas: Demand response; Electric vehicles; Demand side management; Renewables and distributed energy resources; Transmission and distribution systems.

Inage, S.-I. (2010). Modelling Load Shifting Using Electric Vehicles in a Smart Grid Environment. International Energy Agency.

Focuses on the potential role of electric vehicles (EVs) as a dispatchable, distributed energy storage resource to provide load shifting in a smart grid environment

Keith, G., Biewald, B., White, D., & Drunisc, M. (2003). Modeling Demand Response and Air Emissions in New England. US Environmental Protection Agency.

Develop a methodology for estimating the emissions impacts of actual DR events retrospectively.

Lemaire, X. (n.d.). Energy efficiency and Demand Side Management. REEEP.

Assesses whether energy efficiency be fully integrated into the energy supply system or whether it needs instead to be stimulated by special incentives and subsidies.

Moura, P. S., & de Almeida, A. T. (2010). The Role of Demand-side Management in the Integration of Wind Power. Applied Energy, 87(204), 2581–2588.

The study estimated electricity consumption throughout a workday in Portugal in January 2020 under two scenarios: firstly if business continued as usual, with a consumption increase of 3 per cent per year, and secondly, if measures were implemented to reduce demand by 1 per cent per year. The results indicated that if peak consumption is reduced by demand management then wind power has a much better chance of supplying the needs of the country. Wind power would then be more likely to contribute significantly to helping reach the targets that Portugal has set for the proportion of electricity produced from renewables.

Nemtzow, D., Delurey, D., & King, C. (2007). The Green Effect: How demand response programs contribute to energy efficiency and environmental quality. Public Utilities Fortnightly, 40–46.

As global climate change heightens the profiles of energy efficiency and renewable energy, two questions stand out: 1. Does DR increase or decrease overall electricity usage, or just shift it to another time with no impact on energy efficiency? 2. What is, or can be, DR's effect on emissions and other environmental impacts? To understand these inter-related issues we look at theory, modelling, and empirical evidence, some of which is as-yet unpublished and some of which goes back three decades. We find that in nearly all cases, DR decreases overall usage—several per cent on average—and DR improves energy efficiency; the evidence refutes the perception that DR only shifts, rather than decreases, consumption.

Nichols, A. L. (1995). Demand-side management: an Nth-best solution? Annual review of energy and the environment, 20, 556–561.

Many economists have criticized DSM programs—particularly those relying upon rebates (subsidies) for the purchase of energy-efficient equipment—as economically inefficient. Paper argues for more explicit environmental measures for emissions reduction.

Outhred, H., Bull, S., & Kelly, S. (2007). Meeting the Challenges of Integrating Renewable Energy into Competitive Electricity Industries. Australian Government, Renewable Energy & Energy Efficiency Partnership, Renewable Energy and International Law.

This report arises from an IEA workshop held in Paris on 20 November 2006 to consider the challenges of integrating renewable energy resources into electricity industries. This addresses the question of renewable energy integration.

Papagiannis, G., Dagoumas, a., Lettas, N., & Dokopoulos, P. (2008). Economic and environmental impacts from the implementation of an intelligent demand side management system at the European level. Energy Policy, 36(1), 163–180. doi:10.1016/j.enpol.2007.09.005

This paper presents the results of an analysis on the economic and environmental impacts of the application of an intelligent demand side management system, called the Energy Consumption Management System (ECMS), in the European countries.

Pina, A., Silva, C., & Ferro, P. (2012). The impact of demand side management strategies in the penetration of renewable electricity. Energy, 41(1), 128–137. doi:10.1016/j.energy.2011.06.013

This work analyzes the impact of demand side management strategies in the evolution of the electricity mix of Flores Island in the Azores archipelago which is characterized by high shares of renewable energy and therefore the introduction of more renewable energy sources makes it an interesting case study for testing innovative solutions.

Segtnan, I. L. (2011). Assessing the Environmental Costs and Benefits of Households Electricity Consumption Management. Norwegian University of Science and Technology.

In this study the environmental costs and benefits of smart metering technology systems installed in households in Norway have been assessed. Smart metering technology systems enable mechanisms to manage electricity consumption by shifting loads.

The Bloom Centre for Applied Sustainability. (2011). Environmental Impact Qualification. Mississauga, ON: ENBALA Power Network Technology.

This report describes a framework, developed by BLOOM, that will estimate the environmental and societal impacts that ENBALA's Power Network (EPN) technology may have when implemented in specific jurisdictions. ENBALA's technology will provide Demand-Side Regulation Service to Independent System Operators allowing them to regulate the demand, as well as supply, of electricity. This will free up capacity at generators that were previously providing Regulation Service, and allow that capacity to be redeployed in a more efficient manner.

The Brattle Group. (2007). Quantifying Demand Response Benefits In PJM. Cambridge, MA.

This study uses a simulation-based approach to quantify the market impact of curtailing 3% of load in the BGE, Delmarva, PECO, PEPCO, and PSEG zones during the top twenty 5-hour price blocks in 2005 and under a variety of alternative market conditions. We performed simulations using the Dayzer model developed by Cambridge Energy Solutions (CES), and using data provided by CES, PJM, and public sources.

Turner, J., & Sinclair, J. (1996). Environmental Assessment of Demand-Side Management Programs. Energy Studies Review, 7(3).

Demand side management (DSM) programs provide unique challenges to environmental impact assessment (EA). It is unclear whether traditional EA is warranted, or, what framework such an EA should have. This paper discusses the characteristics of the environmental impacts of DSM programs and decides that an EA is required when programs introduce new technologies or practices, or when positive impacts need to be more clearly defined. The results of a survey of international utilities identified four types of DSM EAs. From this, and the literature, a number of EA approaches are developed and evaluated. A multi-staged DSM EA framework is developed and applied to a DSM program.

UK Energy Research Council. (2012). The Role of Demand Side Participation in Managing Generation Intermittency.

Report of workshop which brought together 46 experts from academia, consultancy and industry to discuss high wind integration in the UK and demand side flexibility (2015-2050) to: a) share experiences on demand side response (from previous deployments and trials); and b) assess how much flexibility might be gained from DSM to help compensate for wind generation variability. Day 1 was structured as a high-level dialogue with interventions to provoke discussion and Day 2 was technically oriented with the focus on strategies for dealing with intermittency 2015-2050.

Yassin, I., & Eisobki, M. S. (Jr). (n.d.). Electric Energy Sustainability through a DSM Priority Selection Technique: An Egyptian Experience, 1–16.

In this paper the design and implementation of a DSM priority selection technique are presented aiming at improving the system overall load factor. The developed priority selection technique uses simple sequential ordering and set theory procedures to simulate particle decision steps of electric utilities when selecting eligible plants for DSM programs. It was applied to 1,690 electric motive power users in Egypt. These users included industrial, large service buildings and commercial users, which are supplied at the low, medium, and high voltage levels with contracted demands exceeding 500 kW.

Tier Two

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