Mitigating GHG Emissions and Delivering Electricity System Benefits

Research Report No 3
Task XVIII of the International Energy Agency Demand Side Management Programme

Final revised version
19 November 2010

Operating Agent:
Dr David Crossley, Energy Futures Australia Pty Ltd, Australia

Undertaken with participation and support from:
Australia (Sustainability Victoria)
France (Agence de l'Environnement et de la Maitrise de l'Énergie)
India (Bureau of Energy Efficiency, Ministry of Power)
Spain (Red Eléctrica de España)

DISCLAIMER

While this document has been prepared to the best of the authors' knowledge and understanding and with the intention that it may be relied on by the client, Energy Futures Australia Pty Ltd and the individual authors of the document make no representation or warranty as to the accuracy or completeness of the material contained in this document and shall not have, and will not accept, any liability for any statements, opinions, information or matters (expressed or implied) arising out of, contained in or derived from this document or any omissions from this document, or any other written or oral communication transmitted or made available to any other party in relation to the subject matter of this document.

Final revised version
19 November 2010

Publisher: Energy Futures Australia Pty Ltd
11 Binya Close
Hornsby Heights NSW 2077
Australia
Telephone: + 61 2 9477 7885
Facsimile: + 61 2 9477 7503
Email: efa@efa.com.au
Website: http://www.efa.com.au

Principal Investigator: Greg Watt
Energy Futures Australia Pty Ltd

Report Editor: Dr David Crossley
Energy Futures Australia Pty Ltd

IEA DSM Secretariat: Anne Bengtson
IEA DSM Executive Secretary
PO Box 47096
S-100 74 Stockholm
Sweden
Telephone: + 46 8 5105 0830
Facsimile: + 46 8 5105 0830
Email: anne.bengtson@telia.com
Website: http://www.ieadsm.org/

CONTENTS

LIST OF FIGURES

LIST OF TABLES

THE IEA DEMAND SIDE MANAGEMENT PROGRAMME

The International Energy Agency (IEA) was established in 1974 as an autonomous agency within the framework of the Economic Cooperation and Development (OECD) to carry out a comprehensive program of energy cooperation among its 25 Member countries and the Commission of the European Communities.

An important part of the Agency's program involves collaboration in the research, development and demonstration of new energy technologies to reduce excessive reliance on imported oil, increase long-term energy security and reduce greenhouse gas emissions. The IEA's R&D activities are headed by the Committee on Energy Research and Technology (CERT) and supported by a small Secretariat staff, headquartered in Paris. In addition, three Working Parties are charged with monitoring the various collaborative energy agreements, identifying new areas for cooperation and advising the CERT on policy matters.

Collaborative programs in the various energy technology areas are conducted under Implementing Agreements, which are signed by contracting parties (government agencies or entities designated by them). There are currently over 40 Implementing Agreements, including the IEA Demand-Side Management Programme. Since 1993, the following 20 member countries have been working to clarify and promote opportunities for DSM.

Australia
Austria
Belgium
Canada
Denmark
European Commission
Finland
France
Greece
Italy
India
Japan (Sponsor)
Republic of Korea
Netherlands
New Zealand
Norway
Spain
Sweden
Switzerland
United Kingdom
United States

A total of 22 Tasks (multi-national collaborative research projects) have been initiated by the IEA DSM Programme, 15 of which have been completed. Each Task is managed by an Operating Agent (Project Director) from one of the participating countries. The Operating Agent is responsible for overall project management including project deliverables, milestones, schedule, budget and communications. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition, a number of special ad hoc activities–conferences and workshops–have been organized.

The actual research work for a Task is carried out by a combination of the Operating Agent and a group of Country Experts, depending on the nature of the work to be carried out. Each country which is participating in a Task nominates one or more persons as its Country Expert. Each Expert is responsible for carrying out any research work within his/her country which is required for the Task All the Experts meet regularly to review and assess the progress of the work completed by the Operating Agent and by the group of Experts. Experts meetings are usually held between two and four times a year.

The IEA DSM Programme has undertaken the following Tasks to date:

Task I*	International Database on Demand-Side Management
Task II*	Communications Technologies for Demand-Side Management
Task III*	Cooperative Procurement of Innovative Technologies for Demand-Side Management
Task IV*	Development of Improved Methods for Integrating Demand-Side Management
Task V*	Investigation of Techniques for Implementation of Demand-Side Management Technology in the Marketplace
Task VI*	Mechanisms for Promoting DSM and Energy Efficiency in Changing Electricity Businesses
Task VII*	International Collaboration on Market Transformation
Task VIII*	Demand Side Bidding in a Competitive Electricity Market
Task IX*	The Role of Municipalities in a Liberalized System
Task X*	Performance Contracting
Task XI*	Time of Use Pricing and Energy Use for Demand Management Delivery
Task XII*	Cooperation on Energy Standards (not proceeded with)
Task XIII*	Demand Response Resources
Task XIV*	Market Mechanisms for White Certificates Trading
Task XV*	Network-Driven Demand Side Management
Task XVI	Competitive Energy Services
Task XVII	Integration of Demand Side Management, Energy Efficiency, Distributed Generation and Renewable Energy Sources
Task XVIII	Demand Side Management and Climate Change
Task XIX	Micro Demand Response and Energy Saving
Task XX	Branding of Energy Efficiency
Task XXI	Standardisation of Energy Savings Calculations
Task XXII	Energy Efficiency Portfolio Standards

* Completed Task

For additional information contact:

Anne Bengtson
IEA DSM Executive Secretary
PO Box 47096
S-100 74 Stockholm
Sweden
Telephone: + 46 8 5105 0830
Facsimile: + 46 8 5105 0830
Email: anne.bengtson@telia.com

Also, visit our web site at: http://www.ieadsm.org/.

FOREWORD

This report is a result of work which was completed within Task XVIII of the International Energy Agency Demand-Side Management Programme. The title of Task XVIII is "DSM and Climate Change." Task XVIII is a multinational collaborative research project which is investigating circumstances in which DSM can contribute to mitigating greenhouse gas emissions and emissions mitigation measures can achieve benefits for electricity systems.

Task XVIII is organised into six subtasks as follows:

- **Subtask 1:** Interactions between DSM and Climate Change;
- **Subtask 2:** Principles for Assessing Emissions Reductions from DSM Measures;
- **Subtask 3:** Mitigating Emissions and Delivering Electricity System Benefits;
- **Subtask 4:** Fungibility of DSM and Emissions Trading;
- **Subtask 5:** TOU Pricing and Emissions Mitigation;
- **Subtask 6:** Communicating Information about DSM and Climate Change.

This report summarises the results from Subtask 3.

The Operating Agent (Project Director) for Task XVIII is Energy Futures Australia Pty Ltd, based in Sydney, Australia.

The work of Task XVIII is supported (through cost and task sharing) by the four participating countries: Australia, France, India and Spain. Participants provided one or more Country Experts who were responsible for contributing to the work of the Task and for reviewing work as it was completed.

Information for this report was collected, and the document was reviewed by, Country Experts and representatives from the organisations listed in the Table on page vi.

The Principal Investigator for, and main author of, this report is Greg Watt of Energy Futures Australia Pty Ltd.

The report was edited and additional material was contributed by Dr David Crossley who also provides Operating Agent services for Task XVIII through his consultancy company Energy Futures Australia.

Any errors and omissions are the responsibility of Mr Watt and Dr Crossley.

Country Experts and Representatives Participating in Task XVIII		
Name	**Organisation**	**Country**
“Ian McNicol	Sustainability Victoria	Australia
*Eric Vidalenc	Agence de l'Environnement et de la Maîtrise de l'Énergie (ADEME)	France
Jean-Marie Bouchereau	Agence de l'Environnement et de la Maîtrise de l'Énergie (ADEME)	France
*Balawant Joshi	ABPS Infrastructure Pvt Ltd	India
*Miguel Ordiales Botija	Red Eléctrica de España	Spain
Javier Argueso Montero	Everis	Spain
* Country Expert		

EXECUTIVE SUMMARY

Amending DSM activities to better mitigate greenhouse gas emissions and modifying emissions reduction measures to achieve benefits for electricity systems are not opposite sides of the same coin. The former involves (mainly) one entity (the electricity distribution business), technically-achievable outcomes and reasonably familiar applications; the latter comprises a plethora of activities, driven by a multitude of stakeholders, usually without a deep appreciation of the technical parameters.

Reconciling the two approaches is largely not a technical issue – it is a matter of alignment of differing business / institutional perspectives for the greatest societal benefit. Usually this involves both market transformation (over the longer-term) and regulatory oversight (in the near-term).

The following table summarises the main proposals of this report from two perspectives – DSM activities better contributing to emission reductions, and emission mitigation measures achieving benefits for electricity systems.

Summary of Proposals	
Demand management activities better contributing to emission reductions	Electricity distribution businesses could move to providing a full range of energy services to reduce barriers to the implementation of some emissions reduction options (such as renewable energy) and provide added impetus to the roll-out of others (such as end-use energy efficiency, electric vehicles).
	Electricity regulators could promote a geographical broadening of existing or planned demand management efforts to increase kilowatt-hour savings (and hence emission reductions) across the network.
	Electricity regulators could appropriately reward load management and other activities designed to improve the operation and integrity of the network (and consequently its ability to incorporate more emissions reduction activity).
	Electricity system operators could adopt grid management practices and systems that improve the handling of distributed generation, and customer participation more generally.
	Electricity transmission and distribution businesses could capitalise on the synergies that exist between technologies and applications already making use of the electricity network – to both allow unhindered development of emissions reduction options (renewable energy and energy efficiency), and to improve operation of the electricity system (via energy storage and load management activity).
Emissions mitigation measures achieving benefits for the electricity system	Governments could adopt planning and design processes that are much more inclusive of electricity distribution businesses when developing emissions reductions strategies, particularly those involving deployment of renewable energy, promotion of cogeneration or support of end-use energy efficiency.
	Governments could pay particular attention to technologies, applications and locations whereby peak demand on the electricity network can also be addressed when developing emissions reductions strategies. This could range from renewable energy options in the short-term to roll-out of electric vehicle technology in the future.

1. INTRODUCTION

1.1 Demand-side Management

In the electricity industry, the term 'demand-side management' (DSM) is used to refer to actions which change the electrical demand on the system.

Task XVIII takes a broad view of demand-side management and includes the following measures within the definition of DSM:

- distributed generation, including standby generation and cogeneration;
- energy efficiency;
- fuel substitution;
- load management, including interruptible loads, direct load control, and demand response;
- power factor correction;
- pricing initiatives, including time of use and demand-based tariffs.

1.2 Purpose of Task XVIII

The purpose of Task XVIII is to investigate the potential contribution to mitigating greenhouse gas (GHG) emissions that can be made by DSM measures and the extent to which emission mitigation measures can achieve benefits for electricity systems.

Currently, DSM and emission mitigation measures are implemented quite independently:

- DSM measures are implemented primarily to assist and improve the operation of electricity systems. Any impacts (positive or negative) of DSM measures on climate change are only a minor consideration, if they are considered at all;
- efforts to mitigate GHG emissions from electricity production have focussed on improving the efficiency of both electricity generation and end-use. However, emission mitigation measures focussed on increasing end-use efficiency have usually not considered any benefits to the electricity system (eg peak load reduction) that might be gained through implementing the measures.

The overall aim of Task XVIII is to reconcile these two different approaches so as to identify circumstances in which DSM can contribute to mitigating GHG emissions and emission mitigation measures can achieve benefits for electricity systems. Task XVIII then determines what is required to maximise the emissions reductions and electricity system benefits from these two types of measures.

1.3 Purpose of this Report

The purpose of this report is to identify circumstances in which demand side management can better contribute to mitigating greenhouse gas emissions and emissions mitigation measures can achieve benefits for electricity systems, recognising that the nature of the electricity generation system itself will also play a significant role in achieving these outcomes.

Consequently, the target audience for this report is somewhat diverse and the assumption has been made that the levels of technical knowledge about specific topics might be high for a specific area of interest but may not be as advanced across all the issues covered. The target audience may include regulatory affairs, business development and network planning personnel in electricity businesses, energy and environmental policy staff in government agencies, and electricity industry regulators.

The report is structured as follows: an overview of GHG emissions reduction strategies is presented in section 2; section 3 discusses DSM as an electricity industry activity and the implications for emissions reduction; section 4 maps the pathway between a customer saving a kilowatt-hour of electricity and the emissions reduction ascribed to the electricity sector; the key emissions reduction measures of relevance to this report are elaborated further in section 5; in section 6 suggestions for delivering value for both electricity systems and emissions mitigation are presented; and section 7 provides a summary and conclusions.

2. EMISSIONS MITIGATION AND THE ELECTRICITY SUPPLY INDUSTRY

2.1 Strategies to Reduce GHG Emissions

The Intergovernmental Panel on Climate Change has concluded:

> *Economic development needs, resource endowments and mitigative and adaptive capacities differ across regions. There is no one-size-fits-all approach to the climate change problem, and solutions need to be regionally differentiated to reflect different socio-economic conditions and, to a lesser extent, geographical differences........ The conundrum for many governments has become how best to meet the ever growing demand for reliable energy services while limiting the economic costs to their constituents, ensuring energy security, reducing dependence on imported energy sources and minimizing emissions of the associated greenhouse gases and other pollutants. Selection of energy supply systems for each region of the world will depend on their development, existing infrastructure and the local comparative costs of the available energy resources*[1].

Clearly, the approach to reducing GHG emissions varies from country to country. It is beyond the scope of this report to detail emissions reduction strategies across a broad range of countries. However, while there can appear to be significant differences in the framing of initiatives, national emissions reduction strategies are quite similar worldwide. A typical model might include the following elements:

- a national emissions reduction target set for some point in the future;
- a methodology for allocating a price to carbon emissions (either implemented or under consideration);
- a national strategy for achieving emissions reductions over time; and
- a variety of measures, often at a local level, for delivering prescribed results.

---

[1] Intergovernmental Panel on Climate Change (2007). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Technical Summary*. Cambridge, Cambridge University Press.

It is the final element that is significant for this study. Different measures may be the responsibility of different stakeholders, each with their own perception of the potential impacts of their activity on the electricity system. In practical terms these differing perceptions are likely to provide a strong influence on the ability to deliver emissions mitigation measures that also achieve benefits for electricity systems.

2.2 Emissions Reductions in the Electricity Supply Industry

Worldwide, the electricity industry accounts for roughly 40% of energy-related GHG emissions, with projections suggesting that sector emissions might double by 2030[2]. This figure varies from country to country depending on various factors, including the fuels used in generation and local climatic conditions.

The electricity industry has, and always will, attract attention with respect to GHG emissions reductions – not simply because of the magnitude of the emissions but also because it is either publicly owned or closely regulated, and it is a much easier political target than individual consumers. Further, emission reductions in terms of coal not combusted are a lot easier to deal with than the vagaries of customer behaviour and institutional culture. An additional important factor for the global electricity sector is the need for massive investment in capital replacement and additional infrastructure – upwards of 11 trillion USD by 2030[3].

During recent public debate about the desirability or otherwise of putting a price on carbon, economists have tended to argue that implementing regulation – the command and control approach – is inflexible and suboptimal in relation to both environmental and economic efficiencies. In contrast, the use of markets to solve environmental problems clearly allocates the costs associated with environmental damage to those responsible and allows the responsible entity the flexibility to select the best (cheapest) means to meet their responsibility.

Beyond a simple carbon tax, permits can be used to set a carbon emissions quota, and trading of these allows compliance costs to be minimized across the permit market. Energy efficiency can also be ‘traded’. White certificate schemes allow energy retailers to make a profit from energy efficiency as yet another commodity to be sold and marketed to customers[4]. However, when considering approaches to achieving emissions reductions, it would be prudent to design policy instruments for real world conditions rather than try to make the world conform to a particular policy model[5].

---

[2] World Business Council for Sustainable Development (2008). *Power to Change – A Business Contribution to a Low-carbon Electricity Future*. Geneva, WBCSD.

[3] World Business Council for Sustainable Development (2008). *Op. cit.*

[4] Crossley, D. J. (2009). *Preliminary Study of Emissions Trading Schemes in the United Kingdom and Australia*. International Energy Agency Demand Side Management Programme, Task XVIII Working Paper No 2. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

[5] Rayner, S. and Malone, E. L. (1998). *Human Choice and Climate Change: Ten Suggestions for Policymakers. Guidelines from an International Social Science Assessment of Human Choice and Climate Change*. Columbus, Ohio, Battelle Press.

Achieving actual GHG emissions reductions from the electricity sector in any economy is quite straightforward. Reducing the net amount of emissions requires adopting one or more of the following broad strategies:

- improving the operating efficiency of supply-side elements, such as power stations;
- carrying out fuel switching from higher to lower greenhouse gas intensive fuels;
- achieving savings in energy end-use;
- implementing complementary options including cross-sectoral opportunities (transport, agriculture) and forms of carbon sequestration.

At the implementation level, the following specific measures feature prominently in electricity supply industry proposals, plans and activities worldwide to reduce GHG emissions:

- **improved coal fired generating plant efficiencies** – typically a 1% improvement in thermal efficiency (say from 34% to 35%) corresponds to a 3% decrease in GHG emissions for equivalent energy production;
- **increased use of combined cycle gas turbines for electricity generation** – gas turbine fuels (oil and natural gas) produce lower emissions than coal for given energy production, and combined cycle plants also have higher thermal efficiencies because they make use of the heat in the exhaust gases. A combined cycle plant produces about one half of the GHG emissions of a comparable coal-fired steam plant;
- **increased use of cogeneration** (also known as combined heat and power) – typically may involve the use of combined cycle gas turbines, gas engines or fuel cells. Some of these plants may operate at overall energy efficiencies of 70% to 90% and are suited to on-site generation for a wide range of industrial and commercial customers requiring both heat and power;
- **increased use of nuclear power generation** – despite other drawbacks nuclear power does provide a means of large-scale electricity production without emitting greenhouse gases;
- **increased deployment of renewable energy** – hydro-electric schemes, wind energy, solar photovoltaic (PV) and solar thermal power, biomass energy, and to a lesser extent wave, tidal, geothermal and ocean thermal energy conversion are viable energy sources with minor carbon footprints and a huge potential (and, in some cases, existing positive experience) worldwide. Their costs vary greatly as does the resource availability from country to country. Impacts on electricity networks from dispersed and intermittent power sources are discussed elsewhere in this report;
- **improvements in end-use energy efficiency** – especially amongst commercial and residential customers whose energy use is dominated by electricity (eg lighting, air conditioning applications, refrigeration, water and space heating). While the energy consumption of many industrial customers is dominated by direct fossil fuel use and electricity efficiency improvements are often already pursued for business reasons, the scale of electricity demand by industry makes this sector of interest to electricity network system operators for load reduction activity;

- **carbon capture and storage (CCS)** – while it is technically feasible to absorb CO_2 from power station exhaust gas, a major reason that it is not widely carried out now is that it causes a significant drop in the power generation efficiency and an associated jump in the cost of generation. The disposal or reuse of the captured CO_2 may be the weakest link in the control chain. Options include storage in depleted oil and gas wells, in excavated salt caverns or, most promisingly, deep ocean storage;
- **carbon sequestration through tree planting schemes** – a number of examples exist worldwide of power companies sponsoring plantations in their own or other countries and claiming credit for the carbon that is absorbed by the growing trees;
- **electrification of urban transport** – the use of electricity for transport offers the advantage of a clean fuel at the point of use and, particularly in congested urban traffic conditions, the overall conversion efficiency of primary energy may be higher than for conventionally fuelled vehicles. The potential for off-peak charging of batteries (for urban bus fleets for example) is attractive to electricity utilities. Other charging regimes, for example for private motorists, may have positive or negative impacts on electricity system load curves;
- **capture of methane gas for power generation** – molecule for molecule methane is a much more potent greenhouse gas than carbon dioxide and hence there is a considerable advantage in preventing its escape to the atmosphere. Methane can be drained from coal seams and captured in landfills and subsequently be used as fuel in gas turbines and gas engines. From an emissions perspective there is a double benefit – methane is prevented from reaching the atmosphere and other power generation (eg coal fired plants) can be displaced.

The finer details behind the strategies discussed above vary between countries but in the context of this study – how emission mitigation measures can better achieve benefits for electricity systems – the following matters are of particular interest:

- who is driving the measure, and why?; and
- how is the measure implemented, and what is the scope for some adjustments?

3. DSM PROGRAMS AS POTENTIAL SOURCES OF EMISSIONS REDUCTIONS

3.1 A Brief History of DSM

Demand-side management as we now know it arose out of society's heightened interest in energy efficiency following the oil shocks of the 1970s. Until the early 1990s, DSM was implemented mainly in the United States and was seen by electricity industry regulators mainly as a way to force electricity utilities to deliver energy efficiency. In the early 1990s, this view changed somewhat and DSM began to be seen as an environmental and social tool. However, later in this decade the interest of the regulators and the electricity industry itself began to wane as a preoccupation with restructuring and competitive markets swept through the industry (see Figure 1, page 6).

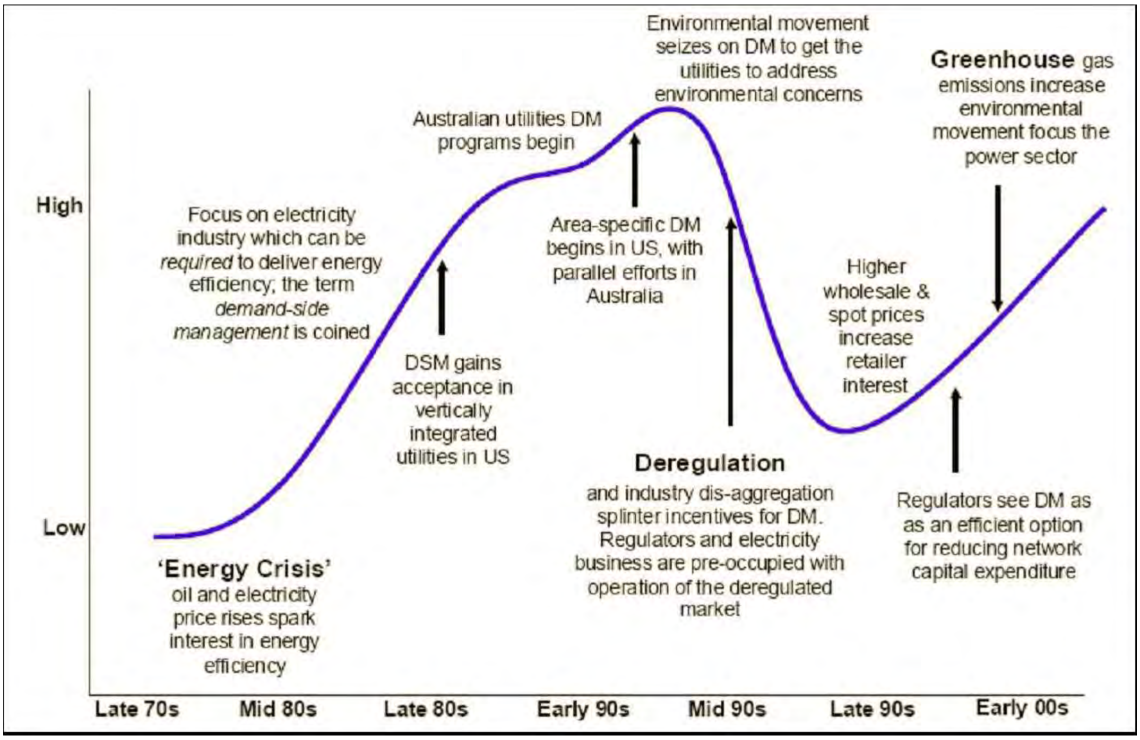

Figure 1. A Brief History of Demand Side Management[6]

Almost perversely, the price rises in electricity markets (the opposite of what was promised to occur as a consequence of electricity reforms) have raised interest in DSM as a tool to manage wholesale electricity purchases. Meanwhile, the paucity of investments flowing into aging electricity networks has lead regulators to see DSM as an alternative to capital expenditure. Most recently, the 'demand side' has attained the moral high ground with the heightened political and social interest in discussions concerning climate change mitigation.

3.2 Types of DSM Programs

DSM programs can be broadly characterised according to the underlying purpose of the program[7]:

- **Environmentally-driven DSM** achieves environmental goals by reducing energy use, eg leading to reduced greenhouse gas emissions;
- **Network-driven DSM** deals with problems in the electricity network by reducing demand to maintain system integrity in the immediate term and to defer expenditure on the network in the longer term;

---

[6] Smith, R. (2007). Shifting the Spare Tire: Values and Incentives for Electricity Demand Management Following Market Reform – The Australian Experience. *International Association of Energy Economics International Conference*, Wellington, New Zealand.

[7] Independent Pricing and Regulatory Tribunal of New South Wales (2002). *Inquiry into the Role of Demand Management and Other Options in the Provision of Energy Services. Final Report.* Sydney, The Tribunal.

- **Market-driven DSM** provides short-term responses to adverse electricity market conditions such as high market prices at times of peak load.

In addition to the categories of DSM outlined above, it is useful to further consider DSM programs according to the following parameters[8]:

- **timing** – DSM programs may be designed to achieve specific outcomes at particular times of the day;
- **pre- or post-contingency** – DSM programs may be designed to achieve specific outcomes either prior to a contingency or in response to a particular event;
- **geographical locations** – DSM programs may be targeted to specific locations, eg whole network, network regions or network element;
- **market segments** – DSM programs may be targeted to specific segments, eg residential, commercial or industrial customer classes.

These features are significant because, as discussed later in the report, changing the parameters of a DSM program may provide the simplest approach to increasing the program's wider societal benefit (ie benefits to the electricity system plus emissions reductions).

3.3 Emissions Reduction Potential of DSM Measures

There are a range of measures that change the demand on the electricity system and therefore can be regarded as demand-side management. DSM measures are usually implemented without any consideration about their potential to reduce GHG emissions. However, as shown in Table 1 (page 8), most types of DSM measures do have the potential to change the level of GHG emissions in addition to providing benefits to the electricity system.

As shown in Table 1, some types of DSM measures, such as energy efficiency and power factor correction, always result in emissions reductions. However, this may not be the case with other types of DSM measures. A separate Task XVIII report[9], showed that the magnitude of the change in GHG emissions achieved by a DSM measure and, in many cases, whether a DSM project actually achieves emissions reductions, depends on the power station that is marginal on the electricity grid at the time the DSM measure is operating. The marginal power station is the one that would be backed off in response to a load reduction resulting from a DSM project. If the marginal power station is a low emission generator (eg hydro or gas–fuelled) and the DSM project results in electricity consumption being transferred to a time period when a high emission power station is marginal, it is possible that a DSM project may result in an increase, rather than a reduction, in GHG emissions.

---

[8] Crossley D (2008a). International perspectives on demand (side) management. *Australian Institute of Energy Symposium Energy in NSW 2008 - Supply and Demand-side Prospects*. Sydney, 29 July.

[9] Crossley, D. J. and Pujari, A. (2010). *Principles for Assessing Emissions Reductions from DSM Measures.* International Energy Agency Demand Side Management Programme, Task XVIII Research Report No 2. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

The implications for emissions reduction can vary significantly between countries depending on the type of electricity generation system in place. Essentially the electricity generation system comprises base-load plants that operate almost continuously and are the source of most of the country's electrical energy, and the load-following plants (intermediate and peaking plants), including the marginal power stations mentioned above, that are used to respond to shorter-term fluctuations in demand. DSM activity will generally target the demand peaks, often reducing the requirement for the load-following generation and increasing the base-load contribution. It would be expected that countries such as Australia and India, largely using coal-fired plant for base-load generation and lower emission gas-fired and zero emission hydro plant for peak periods, could see an increase in emissions (although even the hydro component is not straightforward if it is derived from pumped storage). Italy presents a similar but varying situation with largely gas-fired and some coal-fired base-load plant, and a mixture of hydro and oil-fired plants making up a large portion of the remainder of generation. A country such as France with largely zero emission nuclear base-load generation would be likely to experience a decrease in emissions to the extent that load is shifted away from any gas-fired peaking plant. The situation becomes much more complex in countries such as Germany, the US, Spain and the UK where the base-load plant comprises a mixture of coal-fired, nuclear and even in some cases gas-fired plant, and the load following generation could be hydro, gas-fired or even oil-fired. Another layer of complication is introduced in those countries where must-run zero emission renewable energy generation is approaching or has already exceeded 10% of generated electricity.

Table 1. Emissions Reduction Potentials of Different Types of DSM Measures

DSM Measure	Benefits to the Electricity System	Emissions Reduction Potential
Energy efficiency	Measures carried out on the customer side (demand side) of the electricity meter so as to reduce the customer's load	Emissions reduction
Interruptibility contracts, curtailable tariffs, direct load control and demand response	Arrangements for reducing customers' loads on request (for example when system stability is at risk)	Emissions reduction or increase (depending on the marginal power station on the electricity grid)
Fuel substitution	Substitution of electricity by another fuel or energy source to transfer customers' loads off the electricity system	Emissions reduction or increase (depending on emissions from substituted fuel)
Distributed generation	On-site generation to reduce the customer's load on the electricity system	Emissions reduction or increase (depending on fuelling of distributed generator)

DSM Measure	Benefits to the Electricity System	Emissions Reduction Potential
Pricing initiatives	Time of use and demand-based tariffs designed to encourage customers to reduce their demand on the electricity system, particularly at peak times	Emissions reduction or increase (depending on the marginal power station on the electricity grid)
Power factor correction	Reduction of the amount of reactive power in a circuit, thereby reducing the customer's load	Emissions reduction

4. LINKING CUSTOMER DEMAND AND EMISSIONS REDUCTIONS

The primary objective of the electricity supply industry is to match customer demand with electricity supply. However, within this overarching objective, there is some scope for also delivering emissions reductions. This section of the report provides an outline of the journey from customer load to dispatch of generators, and seeks to identify the relevant issues for implementing DSM and emissions reductions projects along the way.

4.1 Operation of the Electricity Supply System

The principles behind the operation of the electricity supply system are quite straightforward. However, the design of electricity markets and the technical specialisation of the various players introduce considerable complexity. To develop policies, regulations and business strategies that encourage improvement of electricity supply system operations while achieving substantial emission reductions from the sector, it is necessary to have a firm grasp of the principles and some understanding of the market and its operation.

The supply of electricity is analogous to the flow of water in a pipe, driven by a water pump at one end and ending in a tap at the other. The pump (the electricity generator) provides pressure (voltage), but for the water to flow (current) the tap needs to be opened – the customer load. If the tap is opened further (or more open taps are added) the pump must compensate by spinning its impeller faster and forcing more water into the pipe, and vice versa. The pressure can be in the water pipe all the time but water only flows when the tap is opened. The instantaneous rate at which the water flows from the tap is analogous to power (for example a kilowatt); the amount of water that is collected over time is analogous to energy (for example a kilowatt-hour). This very simple analogy (minus much salient detail such as frequency control, return flows, harmonics etc) can be useful to help visualize the operation of the electricity supply system.

4.2 Matching Supply and Demand

The primary focus of the entire electricity value chain is to reliably and safely meet society's demand for electrical energy. On both operational and planning levels this means being able to supply the quantity and quality of electricity required by each and every customer, at all times. Matching the electrical load with an adequate high quality supply can involve both generating and transporting the required amount of electricity (the supply side) and, when necessary, managing the load itself (the demand side).

Historically, a major focus on the supply side has resulted worldwide in a large amount of installed generation capacity and network infrastructure to cater for peak demand on a small number of occasions per year. It is not unusual amongst electricity distribution businesses to have 10% of the network capacity required to meet a peak load occurring for less than 1% of the time.

Whereas the point of maximum demand (or peak load) is an obvious parameter of interest, the entire load curve over time provides the information that can allow demand side management activities and greenhouse gas emission reductions to be better integrated. Load curves can be constructed at different levels within the electricity supply system, for example at the point of supply between transmission and the distribution network utility, at the distribution substation level, on a particular distribution feeder or transformer, and even for various appliances within a customer's premises.

Figures 2, 3 and 4 (page 11) show indicative load curves at levels from a whole city to an individual household appliance. Such curves can be used to illustrate variations in demand on the electricity system over a day, differences between a weekday and weekend, and seasonal and annual variations in demand. For example, it is generally expected that, for domestic loads, mean daytime consumption during weekdays is typically lower than that at weekends, and weekday evening consumption is relatively higher compared to weekend evenings, as a consequence of the combined effects of customer availability and customer activity.

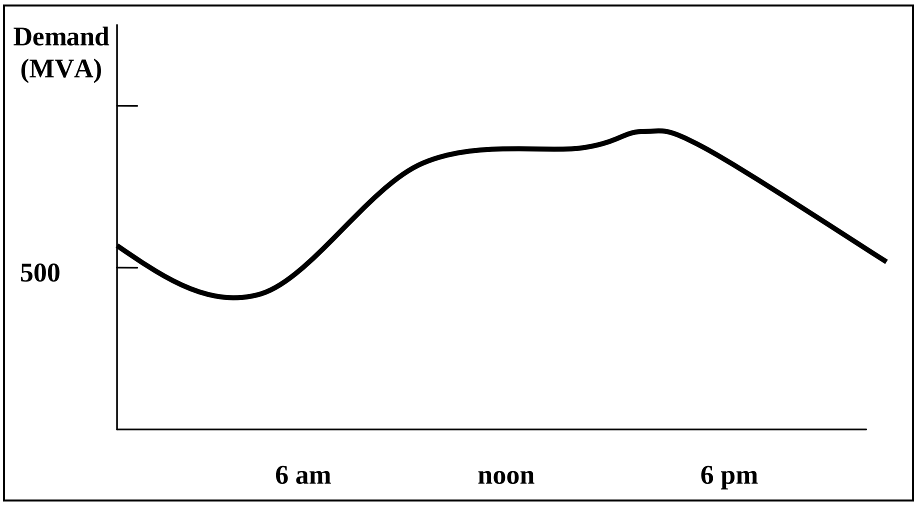

Figure 2. Indicative Load Curve at the Level of a City

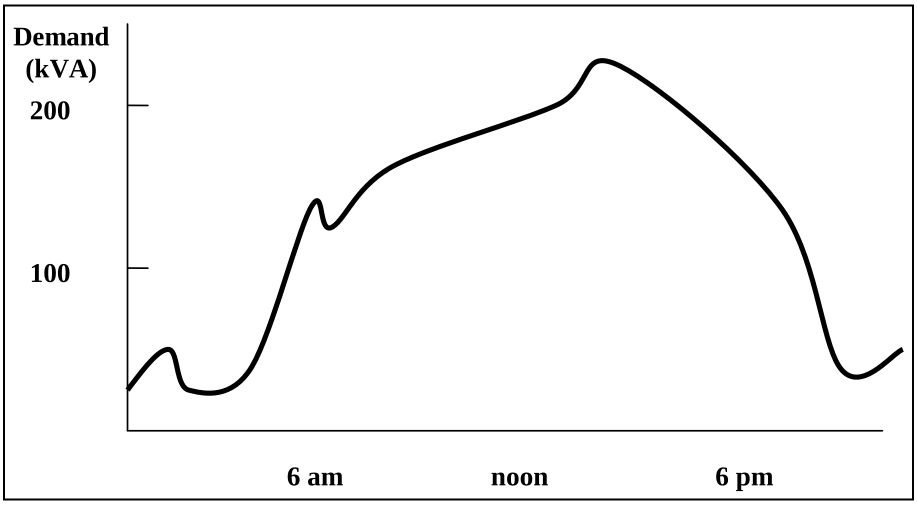

Figure 3. Indicative Load Curve at the Level of a Commercial Office Building

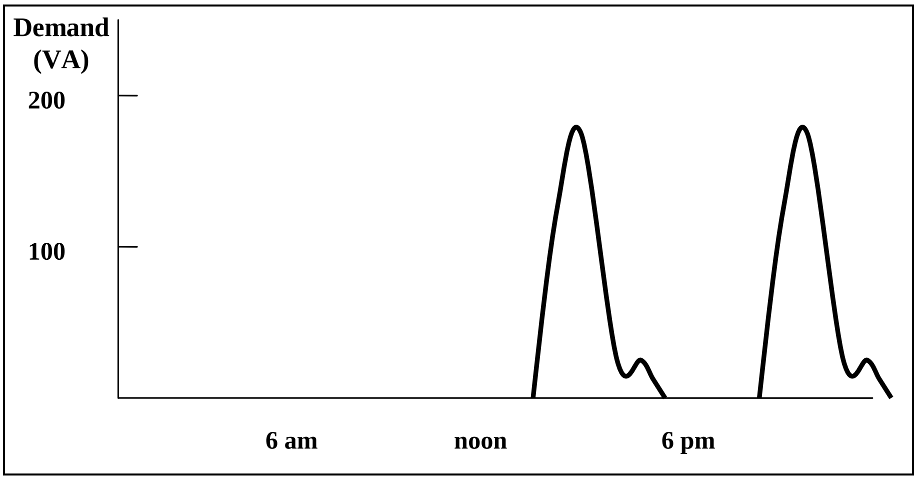

Figure 4. Indicative Load Curve at the Level of a Household Appliance (Dishwasher)

A Portuguese study[10] clearly shows the differences, for groups of customers, between the electricity consumption patterns on weekdays and weekends, the differing load profiles of appliances such as water heaters, refrigerators, lighting and washing machines (and their variation between weekdays and weekends), and the effects on load profiles on different days at the distribution substation level.

Typically, electricity utilities do not have detailed load data at the appliance level but this can be produced using simulation models. The load curves of individual households vary greatly. As the number of households included in a load curve increases, the curve becomes smoother, and approaches a mean consumption curve. However, some variation remains between mean daily electricity consumption data, partly as a result of the strong correlation between some loads (eg air conditioning) and temperature, and also partly due to social responses to external events. High-rating television programs and associated commercial breaks can cause observable load variations (as viewers make coffee, snacks etc). An anecdote was relayed to this writer about the financial benefits that flowed to a particular pumped storage plant in Wales from the load peaks that occurred during commercial breaks in a critical football match.

Paatero and Lund state that load curves are:

> *...crucial for planning electricity distribution networks and optimal production capacity. Accurate knowledge of the household consumer loads is important when small scale distributed energy technologies are optimally sized into the local network or local demand side management (DSM) measures are planned. This knowledge is also useful for planning medium and low voltage networks in residential areas*[11].

4.3 Approaches to Managing Load

Different electricity utilities worldwide, and within countries, manage load for a range of different reasons. These differences can be due to physical features such as climate, area covered and customer density, and socio-economic factors including industry structure, depth of competition and regulatory oversight.

Managing load is typically driven by system planning within electricity distribution businesses. The California Energy Commission has described how electricity distribution planning is typically carried out[12]:

> *Distribution planners are typically assigned to a particular planning area within a utility's system. They are responsible for understanding that area's capacity, potential load growth, operation, and reliability. Planners model their portion of the system including inherent equipment, protection*

---

[10] Figueiredo V., Rodrigues, D. and Vale, Z. (2005). Simulating DSM Impact in the New Liberalized Electricity Market. *9th Spanish Portuguese Congress on Electrical Engineering (9CHLIE)*. Marbella, Spain, 30 June to 2 July.

[11] Paatero J and Lund P (2006), A model for generating household electricity load profiles, *International Journal of Energy Research*, Vol. 30, No. 5, pp. 273-290.

[12] California Energy Commission (2005). *Implementing California's Loading Order for Electricity Resources*. CEC-400-2005-043. Sacramento, CA, CEC, p 120.

> *schemes, connectivity to other parts of the utility system, and tie points within that part of a distribution system.*

Load forecasting is an essential tool that enables effective load management. Load forecasting for forward planning over typically 10 years is carried out on a fairly similar basis amongst distribution utilities. It requires a defined area, load research (looking at customer classes, rates of growth and changes in end-uses of electricity), normalizing for weather conditions, an accurate knowledge of how much and where load can be shed if required and incorporation of relevant planning and approvals criteria.

As previously mentioned, electricity utilities typically do not have access to load data at the end-user appliance level, though this can be simulated using modelling techniques. Therefore, load management may involve modelling of the physical properties of the network, allowances for known load behaviour, incorporation of expected weather conditions plus operational regimes relating to load shedding and maintenance. The models can be extremely sophisticated using fuzzy logic, genetic algorithms and neural networks or of the more conventional econometric type. There are also end-use models available which represent a bottom-up approach to load forecasting.

Load duration curves show the proportion of time over which different loads occur. Figure 5 shows an indicative load duration curve. Such curves are important planning tools in electricity distribution businesses and are used to analyse exposure to marginal costs (at the system level) and the degree to which different parts of the network exhibit 'peakiness' of demand.

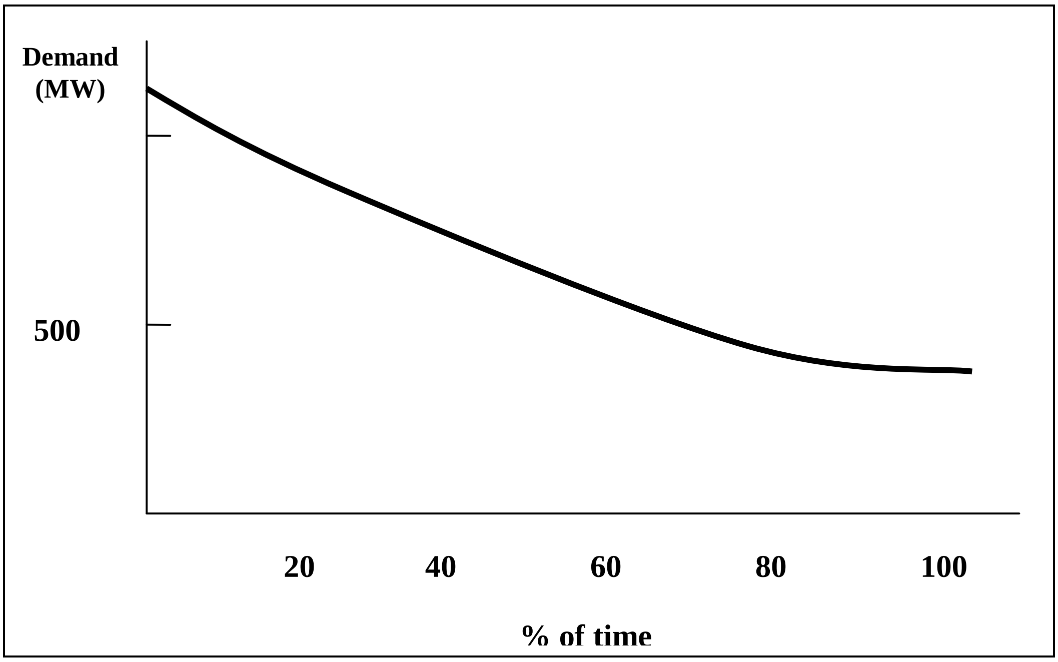

Figure 5. Indicative Load Duration Curve

4.4 Role of the Customer

The customer has two roles in the electricity supply system – the traditional role as the passive consumer of electricity (the load), and now increasingly (as a result of technological advances, market designs and government policies) as an active participant in activities that impact both positively and negatively on the operation of the electricity supply system.

The International Energy Agency DSM Programme[13] (eg Task XI) has identified how customer behaviour can be modified by feedback and information. For example, when customers are presented with a breakdown of their individual end-uses of electricity, its costs and environmental impacts, they can be motivated to make energy savings. Similarly, different prices for electricity at different times of the day can influence customers to shift their patterns of consumption. The price differences can be as simple as differences for day and night hours, a more sophisticated representation of the system peaks or even real-time pricing reflecting the changing prices of generation. Some customers (typically larger in size) can be contracted (at an attractive rate) by the electricity utility to provide automatic load control, instantaneous interruptible load and similar at times of system stress[14].

Customers can also actively participate in the electricity trading market, by offering specific demand changes in response to requests by the electricity utility, a type of DSM called "demand response". Dynamic time-of-use pricing, where advance notice of price changes is provided, is a valuable motivator of demand side bidding of load reductions by customers.

Customers can also actively participate in the electricity supply system by becoming a generator of electricity, able to supply power, often intermittently and to a degree unpredictably, back into the grid. This use of distributed generation by customers is particularly significant for this study because fuel switching and promotion of renewable energy are being strongly promoted by governments worldwide as key greenhouse gas emission reductions strategies[15]. The potential impact on current electricity systems of such distributed generation can be significant. Examples of distributed generation include:

- on-site, small-scale cogeneration (the combined production of electricity and heat, or cooling), using a gas engine for example and providing the customer with lower overall energy costs while (for society) providing a more efficient use of primary energy and reduced emissions. Typical applications are those with a specific requirement for heat and electricity, including hospitals, hotels and large commercial buildings;

---

[13] See the IEA DSM Programme website at: http://www.ieadsm.org/.

[14] Crossley, D.J. (2008b). *The Role of Advanced Metering and Load Control in Supporting Electricity Networks*. International Energy Agency Demand Side Management Programme, Task XV Research Report No 5. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

[15] For example, witness the plethora of politically-appealing “20% renewables by 2020” targets worldwide.

- solar PV electricity systems, often on rooftops or integrated into the building design and, depending on the particular government support program, exporting directly to the electricity grid and/or meeting some of the customer's load.

4.5 Role of the Electricity System Operator

The next level above customers in the electricity supply chain varies from country to country and what follows is a general outline.

Most customers purchase electricity from an electricity retailer, via the electricity transmission and distribution network. The electricity retailer may be integrated with, or separate from, the distribution network operator. The distribution network operator may be a separate entity or may be integrated with the transmission system operator.

Traditional distribution system operators are not concerned with marketing, sales, energy prices and so on – they are focused on keeping the electricity network stable or, to use the earlier analogy, ensuring that the water flowing from the taps (the system load) is balanced by the water flow ultimately provided by the pump (the generators). Therefore, until recently, the role of distribution operators was simply to manage the flow of electricity between generators and customers.

However, as described by Kärkkäinen, it is now recognized that:

> *...with increased levels of distributed generation and active demand-side penetration, the distribution network can no longer act as a passive appendage to the transmission network. The entire system has to be designed and operated as an integrated unit. In addition, this more complex operation must be undertaken by a system where ownership, decision-making and operation are also dispersed*[16].

Distributed generation is usually operated at the owner's discretion, and may not meet the utility's preferences. Energy efficiency is often initiated by the end user, rather than as part of a utility DSM program. Customers' demand response decisions are affected by a variety of motivations beyond what the grid operator wants and needs. As customers decide to install more distributed renewable generation, it changes the topology of the distribution grid as well as the load patterns perceived on the utility side of the meter. The resulting electricity grid is significantly more complex and uncertain and requires a more complex, interactive means of operation and coordination.

Consequently, load management is a subject that is continually on the minds of the system operators. Sometimes the load on a system can approach the maximum generating capacity or the maximum distribution network capacity or the rate at which the load is increasing can increase faster than the rate at which generating output can be increased. At such times, and depending on the issue at hand, the system operators must either find more electricity or curtail the load. The consequences of inaction may be an unstable network and, ultimately, politically-unpalatable blackouts.

---

[16] Kärkkäinen, S. (undated). *Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages – State of the Art Report. Volume 1: Main Report.* International Energy Agency Demand Side Management Programme, Task XVII,. Espoo, Finland, VTT Technical Research Centre of Finland, p 4.

4.6 Role of Electricity Generation and Dispatch

System operation dispatch is located further along the electricity supply chain and essentially ensures that the water flowing from the pump (the generators) meets the requirement of the system operator for the open taps (the load). Usually there are a number of the large, centralized generators that not distributed or embedded within the network. These may include coal-fired plants, open cycle or combined cycle gas turbines, hydro plants and nuclear power stations with different costs and capabilities.

The operation of a competitive electricity market was described by the National Grid Management Council which developed the initial design for the Australian National Electricity Market:

> *Generators declare a price to the system operation function. The system operation function determines which generators will operate in a particular period and what level of output they will produce. The level of output will take into account the merit order loading, the physical capability of the network and a requirement to maintain a secure power system at minimum overall cost of inputs*[17].

The merit order loading is determined mainly by the relative cost of generation, with the most expensive power stations being dispatched last. The merit order determines the power station that is operating at the margin and which therefore will reduce output (and emissions) when system load falls. Depending on the marginal power station, a load reduction resulting from a DSM project may lead to a larger or smaller reduction in GHG emissions, or may even result in an increase in emissions. Various methods are available to identify marginal power stations and estimate the emissions reductions from specific DSM projects. A separate Task XVIII report discusses these methods in detail[18].

From the perspective of system operation dispatch, the impact of small-scale distributed generation is seen as a decrease in load. Some power plants, such as small-scale distributed generators and large-scale wind farms, are not dispatched but are treated as "must-run" generation and their output is accepted whenever available. At the extreme this can require the system dispatch operator to make difficult decisions. For example, in Denmark on a cold, windy night thousands of wind turbines are operating close to their maximum rated power, combined heat and power plants are generating heat but also a lot of electricity that must be supplied to the grid, and the system load has decreased overnight. Surplus generated power may be exported through system interconnections with neighbouring countries, but eventually some generation by Danish wind farms may have to be backed off. This situation demonstrates how the traditional electricity supply industry boundaries between generation, transmission and distribution are becoming blurred.

---

[17] National Grid Management Council (1993). Transition to a National Electricity Market. Melbourne, NGMC.

[18] Crossley and Pujari (2010). *Op.cit.*

In addition to the emissions reductions achieved by renewable energy and cogeneration, the combination of the merit order loading and the requirement to accept certain sources of energy whenever generated (or a load reduction for that matter), leads to an economic benefit referred to as the "merit order effect". Where the market price of electricity (spot price) is determined by the most expensive power station still required to be dispatched to meet the load, any activity that reduces the need for those most expensive power plants causes a fall in prices. Studies commissioned by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety suggest that renewable energy supported over three years under Germany's Renewable Energy Act and feed-in tariffs reduced the cost of electricity purchased by electricity suppliers via the spot market by between 2.5 EUR/MWh and 7.5 EUR/MWh[19]. The retail electricity price in Germany is about 220 EUR/MWh).

Similar to the merit order effect, it is possible that emissions reductions from energy efficiency and renewable energy could be devalued under cap and trade emissions trading schemes that allocate emissions allowances to incumbent high-emission generators[20]. If total emissions are capped, emission reductions from DSM and energy efficiency programs and new zero-emission generation will contribute to meeting the cap, reducing the requirement for incumbent generators to reduce emissions. The incumbent generators can then simply sell excess allowances and the market price of emission reductions decreases because the demand for allowances has eased.

5. ACHIEVING ENHANCED EMISSIONS MITIGATION OUTCOMES

Two key measures are particularly relevant in terms of potential negative or positive impacts on the electricity system. Renewable energy generation (as an emissions mitigation measure) and end-use energy efficiency (as either an emissions mitigation measure or a DSM measure) are discussed in this section of the report. In addition, certain cross-sectoral activities, such as transport electrification, can also be significant for the nexus between emissions reductions and electricity system impacts. These cross-sectoral activities are discussed in section 6 (page 22).

5.1 Renewable Energy Generation

The emissions reduction measure that is particularly relevant to this report is the promotion of renewable energy. The deployment of renewables is an emissions mitigation measure that is already causing impacts on electricity systems worldwide.

Widespread deployment of renewable energy is a key greenhouse gas emissions reduction strategy that can have both positive and negative impacts on electricity networks. Positives can include the potential to defer expenditure on network

---

[19] German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, (BMU) (2009). *Renewable Energy Sources in Figures – National and International Development*. Berlin, BMU.

[20] Keith, G. and Biewald, B. (2005). *Methods for Estimating Emissions Avoided by Renewable Energy and Energy Efficiency.* Cambridge, Massachusetts, Synapse Energy Economics Inc.

augmentation, reduce network losses and improve outcomes for the environment, voltage control and/or availability and quality of supply. Negatives can include concerns about safety and protection, increased capital expenditure, and worse outcomes for voltage control and/or availability and quality of supply.

Problems arise when high levels of output from renewable electricity generators, such as wind farms and photovoltaic (PV) arrays, are fed into electricity systems that do not require the additional power[21]. For example, consider what can occur when too many PV systems are allowed to supply power to a lightly loaded part of the network, in the absence of ameliorating measures. In simple terms, if the taps cannot be opened further (adding more load) the pressure builds up (an ‘overvoltage’ situation). Both overvoltage and undervoltage impact negatively on the stable operation of generators and transformers. In addition, overvoltage may shorten the lifetime of end-use appliances and undervoltage can restrict the performance of electrical equipment. The voltage must be kept in a certain range, as specified in laws, standards or guidelines that vary from country to country, and electricity utilities apply various measures to achieve this.

As a consequence of overvoltage, the benefits of the PV electricity can be wasted. A study by the Tokyo Institute of Technology[22] looked at the performance of the 553 clustered PV systems at Ota City in Japan. They found that, while only a few systems experienced a significant amount of output reduction due to the high grid voltage caused by the clustered PV systems, individually this could be as high as 73% of the energy produced (and, consequently, a significant wasted emissions reduction opportunity). Simulations suggested wastage of output energy of around 8% overall, still a significant amount. The study noted that reactive power control in the network can be effective in dropping the voltage, and battery integration can also solve the problem – but the issue then becomes one of cost allocation and social equity. This clearly illustrates the need for an emissions reduction strategy (such as increasing the deployment of renewable energy) to be developed in concert with electricity network strategies.

Another important issue for the operation of the electricity supply system at different scales of renewables deployment concerns the intermittency of the resource, particularly with respect to wind power generation on the transmission system and high levels of PV penetration on distribution feeders. Technological solutions to deal with large scale wind power intermittency already exist and studies suggest that the cost of compensating for intermittency is expected to be low even at much higher levels of penetration than currently found. This is particularly true for large diverse electricity grids; smaller grids are more problematic. At large penetrations of wind power, the aggregate of all the sources spread over a large area actually increases the reliability and, while the total output can change as a result of the weather, this is quite predictable.

---

[21] Renewable generators are often underpinned by a government mandate that their output must be accepted by an electricity utility whenever the generator is operating.

[22] Ueda. Y., Ogimoto, K. and Oozeki, T. (2009). The Japanese experience with large concentrations of PV in communities. Presentation to *International Energy Agency Photovoltaic Power Systems Programme Workshop*, Hamburg, Germany, 22 September.

The California Energy Commission concluded[23]:

> *Integrating modest amounts of as-available or intermittent resources into the system can be accommodated with minor adjustments to the system. However, experience in Europe shows that high levels of wind (for example 20% or greater), relative to other resources on the electricity grid, can require changes in operation and equipment requirements of the transmission system. The fit between renewable energy product characteristics and the load serving entity's supply needs can be improved through changes in system operations, the use of energy storage, the use of hybrid generating facilities, and strategic placement of generation where possible.*

Changes in system operations include improved day-ahead planning (incorporating wind forecasting), increasing the solar resources in the renewable mix and procuring controllable resources able to match the dynamics of system load. Coordinated storage deployment and price signals to end-use customers to encourage load shifting are also important.

As distributed generation resources, often connected to the distribution network, renewable energy generators are already changing the way the distribution network is viewed – and it appears that optimisation of distribution networks is one key way to get more benefit from renewable energy as an important emissions reduction strategy.

Renewable energy is also interesting because of the variety of support measures that are being used to support its deployment and the variety of stakeholders that can be involved with program design and implementation. Consequently, it may be difficult to modify these measures to take account of the operation of the electricity supply system.

Table 2 (page 20) lists various support measures that are applied to renewable energy worldwide; in many countries, several of these operate concurrently. Implementing parties for these measures include national and state government agencies covering energy, environment, finance, taxation and industry development, local government planning and building offices, electricity industry regulators, electricity retail businesses, electricity distribution businesses and the finance sector.

---

[23] California Energy Commission (2005). *Op. cit.*, p 91.

Table 2. Typical Support Measures for Deployment of Renewable Energy

Measure	Description
Capital subsidies	Direct financial subsidies aimed at tackling the up-front cost barrier
Green electricity schemes	Enable customers to purchase green electricity based on renewable energy from the electricity utility, usually at a premium price
Renewable portfolio standards (RPS)	A mandated requirement that the electricity utility (often the electricity retailer) source a portion of their electricity supplies from renewable energies
Investment funds for renewables	Share offerings in private renewable energy investment funds plus other schemes that focus on wealth creation and business success using renewables as a vehicle to achieve these objectives
Income tax credits	Enable some or all expenses associated with a renewable energy installation to be deducted from taxable income streams.
Enhanced feed-in tariffs	An explicit monetary reward is provided for producing renewable electricity; paid (usually by the electricity utility) at a rate per kWh somewhat higher than the retail electricity rates being paid by the customer
Net metering	Owners of renewable energy systems receive retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
Net billing	Electricity taken from the grid and electricity fed into the grid are tracked separately, and owners of renewable energy systems receive a set price for electricity fed into the grid
Commercial bank activities	Includes activities such as preferential home mortgage terms for houses including renewable energy systems and preferential green loans for the installation of renewable energy systems
Electricity utility activities	Includes 'green power' schemes allowing customers to purchase green electricity, large-scale utility renewable energy plants, various renewable energy ownership and financing options with select customers and renewable electricity power purchase models
Sustainable building requirements	Includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where renewable energy may be included as one option for reducing the building's energy foot print or may be specifically mandated as an inclusion in the building development

5.2 End-use Energy Efficiency

End-use energy efficiency programs can be implemented either by governments as an emissions mitigation strategy or by electricity utilities as a DSM measure. Of course, individual energy efficiency projects may also be implemented by private entities, largely with the objective of saving money.

When energy efficiency programs are designed and implemented by government agencies they are seen as a true 'no regrets' emission reduction strategy – reducing kilowatt-hours with relatively short payback periods, reducing end-users' operating costs and (generally) not substituting one environmental issue for another. The range of possible activities is extremely broad but typically could include: energy efficiency labelling of appliances, minimum energy performance standards and codes for buildings and technologies, energy auditing services, demonstration of best practice efficient technologies, improved access to information, commercialisation of energy efficiency technologies and energy management training support programs.

DSM activities undertaken by electricity utilities can include end-use energy efficiency improvements, particularly where the appliances or equipment typically operate at the times of peak demand. Governments may also impose obligations on electricity utilities to carry out energy efficiency activities, usually to achieve GHG emissions reductions[24]. In these cases, providing benefits to the electricity system is usually a secondary objective, even though the energy efficiency programs are actually implemented, or supported by, electricity utilities. However, in Australia, mandatory appliance labelling and minimum energy performance standards (MEPS) are also being refined to highlight the electricity system benefits. Under consideration are the requirement for air conditioner labels to include information on demand response capabilities, and mandatory requirements for air conditioners to include demand response enabling devices (DREDs). This approach may also be extended to other devices contributing to summer peak demands. In addition, building standards incorporating minimum energy performance ratings and promoting increased use of shading can help to reduce the air conditioner load on summer afternoons.

While energy efficiency is widely accepted to be the emissions mitigation strategy of first choice and of the utmost priority for any country, mention should also be made of the difficulties facing quantification of the resulting emissions reductions. The California Energy Commission[25] lists the following uncertainties and risks in evaluating the reality of energy savings from utility-implemented energy efficiency programs: insufficient staff levels for monitoring, a cumbersome and expensive evaluation process, complex and time consuming data reporting protocols, unreliable underlying metrics, short supply of qualified consultants, difficulties in obtaining commercially sensitive electricity utility data, and shifts in political support.

---

[24] Crossley, D. J. (2009). *Preliminary Study of Emissions Trading Schemes in the United Kingdom and Australia*. International Energy Agency Demand Side Management Programme, Task XVIII Working Paper No 2. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

[25] California Energy Commission (2005). *Op. cit*., pp 51 - 52.

There are numerous examples worldwide of energy efficiency DSM programs delivering specific energy savings (kWh) over time and providing demand reduction (kW) benefits to the network. Such programs can also produce GHG emissions reductions. Indeed, describing demand response measures the California Energy Commission[26] points out that "reduced energy consumption also reduces the environmental costs of generation, including greenhouse gas emissions".

However, in situations where DSM programs that include energy efficiency measures are implemented primarily to achieve electricity system benefits, and the programs also have emissions mitigation as a second objective, the following issues may arise:

- is the shape of the load curve being 'managed' affecting the emissions reductions achieved? – reducing a very spiky peak by one kW will not generate the same amount of kWh savings (and hence emissions reductions) as the same load reduction to a much flatter peak;
- are changes in customer behaviour to achieve kW and kWh electricity savings leading to increases in GHG emissions from other end-uses?
- does a customer load reduction move upstream and directly result in emissions reductions from electricity generating plant?

The first two of these points are dealt with later in this report.

In relation to the final point, it appears likely that any changes in load (for example a customer demand reduction as a consequence of an energy efficiency DSM measure) will simply pass through the hands of the system operators to the next level of the electricity supply chain. However, with the emergence of the more complex electricity grid in the future, this proposition may no longer be applicable. Put simply, the system operator may become technically able and financially motivated to bank saved energy in storage options and make use of it at high value times.

6. IMPROVING INTEGRATION OF ELECTRICITY SYSTEM OBJECTIVES WITH EMISSIONS MITIGATION OUTCOMES

It may be simplistic to talk of 'circumstances in which DSM can better contribute to mitigating greenhouse gas emissions' and 'emissions mitigation measures achieving benefits for electricity systems' because, in practice, both emissions mitigation and demand management are diverse, dynamic and complex. Further, it is likely that the intricacies of load management will no more be on the minds of (the many) GHG emissions policy makers than emissions reductions occupy the thoughts of electricity network operators and planners. In this section we explore how this dichotomy can be changed – practically, smoothly and with societal benefit as the main driver.

---

[26] California Energy Commission (2005). *Op. cit.*, p 56.

6.1 Relationship Between Emissions Mitigation and DSM

It is useful to map the relationship between emission mitigation and DSM to make clear where some of the challenges and opportunities arise. Table 3 lists the main emissions mitigation strategies and measures in the left-hand column; key DSM objectives are presented in the first row. How each of these interacts is indicated by the colour of the square – blue suggests that they are complementary; red suggests that they could be complementary or conflicting; and white suggests that they are of little consequence to each other. The text in each square gives an example of a specific activity that may be relevant.

Table 3. Relationship Between Emissions Mitigation and DSM

DSM Emissions mitigation strategies	**Primary objectives**			**Secondary objectives**	
	System operational improvement	Network augmentation	Network investment deferral	New business opportunities	Reduced wholesale purchase costs for distributors
Renewable energy generation/ distributed generation	🟥 Cogeneration applications	🟥 Distributed generation	🟥 Promotion of PV	🟦 Sales and financing of technologies	🟥 Solar water heating
Supply-side efficiency gains					🟦 Line loss reductions
End-use efficiency gains		🟦 Efficient lighting and refrigeration	🟦 Cooling strategies	🟦 Sales and financing	🟦 Heat pump water heating
Customer behavioural change, cross-sectoral measures	🟥 Electric vehicle batteries	🟥 ToU pricing	🟥 Critical peak pricing	🟦 Financing	🟥 Electric vehicle batteries

Table 3 indicates the following:

- there is a high degree of overlap between many strategies for GHG emission reductions and DSM objectives and measures;
- there is a large potential for conflict between some aspects of emissions mitigation and DSM, as would be expected given their differing backgrounds and rationales. However this may be resolvable with appropriate regulatory, technical or institutional intervention;

- there is also a large potential for complementary approaches that could be strengthened with appropriate intervention.

6.2 New Developments in Electricity Networks

Currently, there are many advances in both new technology and new ways of using existing technology that are causing evolutionary changes in electricity networks. These changes have been characterised as developing "smart" grids, though there is no commonly-accepted definition of what a smart grid comprises. Most advances are taking place in three main areas:

- the development of advanced meters that record customer consumption (and possibly other parameters) hourly or more frequently and that provides for daily or more frequent transmittal of measurements over a communication network to a central collection point[27];
- the ability to remotely control and automate the operation of electrical appliances and equipment, enabling electricity utilities to directly control customer loads[28];
- the development of new technology for, and new ways of using, systems for storing electricity.

The US Federal Energy Regulatory Commission estimates that by 2019 there could be up to 140 million advanced meters deployed across the United States that would provide the technology necessary to implement dynamic pricing initiatives[29]. It is believed that demand response programs enabled by advanced metering technology could reduce the peak load across the country by as much as 150 GW.

When utilities, or customers themselves, implement remote control and automation of domestic appliances, residential customers experience increased interaction with their electricity distributor. Appliances such as air conditioners, water heaters, dryers and heat pumps can be controlled via in-home devices, home energy management systems and wireless networks to provide demand reductions. By having many such appliances in the pool, distribution utilities can use direct load control to shape load curves without the homeowner noticing much difference in performance.

However this evolutionary change in electricity networks will not occur without challenges. There are already concerns being expressed that vulnerable customer segments could be adversely affected because they are unable to take advantage of smart meters, time-of-use tariffs and direct load control to shift or moderate their energy usage. These matters will need to be addressed by electricity industry regulators or could be tackled technically by the electricity businesses.

Many established energy storage systems are being integrated at different levels of the electricity supply system, enabling electricity to be delivered when it is needed or has a high value. Depending on the technology used, these storage systems can operate as a

---

[27] Federal Energy Regulatory Commission (2006). *Assessment of Demand Response and Advanced Metering*. Washington DC, FERC.

[28] Crossley, D.J. (2008b). *Op. cit.*

[29] Federal Energy Regulatory Commission (2009). *2009 Assessment of Demand Response and Advanced Metering*. Staff Report. Washington, DC, FERC.

dispatchable source of peak power at times of high market demand – currently, this is quite common and financially successful. Storage systems can also be used as embedded elements in a distribution network, providing technical support when required by the system operator – this is less common.

Meeting the ambitious renewable energy targets being promulgated worldwide will require not only massive investment in new transmission and distribution infrastructure but also a lot of energy storage. In California alone, 4 GW of storage capacity by 2020 to support the renewable energy aspirations is being discussed. To facilitate this development, a bill has been introduced into the Californian legislature that requires electricity utilities to incorporate energy storage capacity amounting to 2.25% of peak system demand by 2014, rising to 5% of peak demand by 2020[30].

Energy storage systems under development or already implemented include[31]:

- pumped storage hydroelectric systems – Californian projects are used to effectively make utility wind energy projects dispatchable to provide spinning reserve for high load periods;
- compressed air energy storage – the Texas State Energy Conservation Office has investigated compressed air energy storage together with wind energy to address transmission constraints; and
- battery and flywheel technologies – Fairbanks, Alaska, has a 40 MW, 15-minute nickel-cadmium battery energy storage system, together with a new transmission line parallel to the existing line, to improve reliability of the transmission of electricity from over 600 km away.

Many other energy storage systems are reported worldwide, providing a range of services including system reliability and balance, meeting peak demand, reduced line losses, postponed transmission upgrades, renewable energy storage, load levelling, emergency power supply and power quality protection.

Increased ‘smartness’ of the electricity supply chain, the widespread deployment of emerging electricity storage technologies and new markets for electricity such as charging of electric vehicles will provide benefits, opportunities and challenges for the management of electricity networks.

Worldwide there is currently much government, electricity utility and other industry focus on smart grids. In particular, the potential group of (financial) beneficiaries from increased “smartness” in electricity networks has broadened and the information, communication and computing functions necessary to implement smart grids are (apparently) on the verge of being able to be commercially applied.

Although a considerable number of smart grid trials are underway worldwide it is accepted that both demonstration of the benefits and resolution of many of the barriers are required. Issues that still require clarification include technical maturity of key components, costs and benefits at different levels of the value chain, and supporting regulation and standards.

---

[30] State of California (2010). *California Legislature Assembly Bill No 2514*.

[31] California Energy Commission (2005). *Op. cit*.

Some see these developments as providing answers to every conceivable electricity industry issue; others see smart grids as simply a new term for demand side management. It is useful to try to clarify this relationship – the key parameters of DSM and smart grids are compared in Table 4.

Table 4. Comparison of Demand Side Management and Smart Grids

Parameter	Demand Side Management	Smart Grids
Scope	Actions to alter the demand on the electricity system	Use of information and communications to improve the efficiency and effectiveness of power generation, transmission, distribution and usage, primarily focusing on the distribution and retail elements
Advocate	Electricity utilities (third parties to a lesser extent)	Information collection and processing businesses, distribution and transmission network businesses and end-use customers (to a lesser degree)
Target group	End-use customers	Distribution network businesses, end-use customers (to a lesser degree)
High-level outcome	Influence / change customer behaviour and investment decision making	Achieve direct financial savings, improve system reliability, enhance environmental protection (eg emissions reductions) and promote customer empowerment
Methodology	Energy efficiency measures, interruptibility contracts, direct load control, demand response, fuel substitution, distributed generation, pricing initiatives	Information provided by website or in-home display; automated controls for appliances; programmable thermostats with communications; pricing initiatives; advanced metering infrastructure; integrated Volt-VAR control (including conservation voltage reduction); fault detection, isolation and restoration (FDIR); substation and feeder monitoring and diagnostics; wide-area measurement; distributed storage (which may include electrical vehicle elements); distributed generation enablement; electric vehicle support; data collection, processing and back-office
Measurable results	Relieve constraints on distribution and/or transmission networks; provide operational support services for electricity networks; defer investments on network infrastructure; reduce energy use (and environmental impacts); save on electricity purchase costs at times of high prices	Operating and capital cost savings; increased network reliability (including fewer outages and injuries and improved power quality); assisting customers to implement energy efficiency and increased use of renewable energy; greater transparency and choice for customers

Table 4 shows that there are many similarities between DSM and smart grids. When considering an integrated approach to both improved DSM and emissions reduction outcomes, the following attributes of smart grid development and their availability are particularly relevant:

- **emerging customer applications and supporting infrastructure and systems**, such as smart appliances and thermostats, in-home displays, smart meters, communication and pricing options;
- **support for distributed generation**, such as rooftop PV, with respect to protection and control features that allow a high level of penetration of these technologies in the electricity network, attractive pricing options and innovative business models;
- **distributed storage**, able to provide power quality, reliability and security for some customers, reduce demand during critical peak times, and support distributed generation's integration with the electricity supply system;
- **support for electric vehicles**, including management of the load created by charging of batteries, and distributed storage opportunities created by the vehicle batteries themselves.

6.3 Implications of the Large-scale Introduction of Electric Vehicles

Vehicles powered by electricity from the grid are enjoying a strong resurgence in public interest worldwide, mainly due to recent spikes in oil prices and the pain felt by motorists filling their fuel tanks. Electric vehicles have the potential to reduce emissions from the transport sector which is a very large source of greenhouse gas emissions. Road transport currently accounts for about three quarters of total transport GHG emissions and the contribution of transport to total energy-related global greenhouse gas emissions was about 23% in 2004[32].

The transport sector is a notoriously difficult emission source for politicians to address. Electric vehicles seem too good to be true – and some suggest that they are. From a total emissions reduction perspective, the question is whether the reduction in vehicle fuel emissions is exceeded by the additional emissions associated with the required electricity generation.

A 2007 study by the US National Renewable Energy Laboratory[33] in the service territory of the electricity utility Xcel Energy Colorado looked at the potential impact on the electricity system and net emissions (from the vehicles, electricity generation and refinery operations) arising from the introduction of plug-in hybrid electric vehicles (PHEVs)[34].

---

[32] Intergovernmental Panel on Climate Change (2007). *Op. cit.*

[33] Parks, K., Denholm, P., and Markel, T. (2007). *Costs and Emissions Associated with Plug-in Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory.* Technical Report NREL/TP-640-41410. Golden, CO, National Renewable Energy Laboratory.

[34] PHEVs feature a larger battery than conventional hybrid vehicles, and may achieve significant mileage from electricity sourced from the grid without the range restrictions of pure battery electric vehicles.

The NREL study considered a PHEV-20 option which means that the vehicles are capable of driving 20 miles powered by the battery before switching to conventional fuel. The electricity generation mix in the area studied by NREL was heavily fossil fuel based, with 71% of the electrical energy arising from coal fired generation, 24% from natural gas fired generation and the remaining 5% coming from hydro and renewables. The study found that a PHEV would achieve a reduction in net GHG emissions of between 40% and 45% compared to a gasoline fuelled vehicle, with some small variations depending on the battery charging regime employed.

Results from Denmark (with a different electricity generation mix) showed similar results. A study by the Danish Energy Association estimated that the net GHG emissions produced by electric vehicles would be about 44% of those for new petrol- or diesel-fuelled passenger cars[35]. Replacing 30% of cars with PHEV-20 vehicles (achieving 39% of their mileage from electricity) would increase the total electricity system load by less than 3%. Furthermore, the normal system peaks in both summer and winter would not be significantly impacted by the times of day when significant charging would be expected to occur. While a very large penetration of vehicles with completely uncontrolled charging would increase pressure on peaking plant, it was found that simple time-of-day charge pricing could transfer charging load to off-peak periods.

Electric vehicles can reduce net emissions and their charging can offer some load management benefits to an electricity utility by improving the shape of the load duration curve (ie filling the valleys in the load profiles). Furthermore, charged vehicles can even provide power back to the grid as an active peak load management option called V2G (vehicle to grid). In addition to addressing peak demand, it may also be possible to use power from electric vehicles to meet network ancillary services requirements.

The ultimate emissions reduction benefit will be achieved if electric vehicles can be charged by power derived from renewables. The Danish Energy Association note that in western Denmark wind turbines will be providing a surplus of power to the electricity system about 20% of the time by 2025. The recharging of batteries in plug-in electric and hybrid vehicles may provide an ideal option to maximize the value of this excess wind energy generation. Also in Denmark, the utility Dong Energy, IBM, Siemens and others are undertaking a research project on Bornholm, a Danish island with 40,000 residents, to integrate wind power and electric vehicle charging. In Spain, it is expected that by 2016 there will be about 1.7 million electric vehicles. It is also anticipated that by this time around 1000 GWh to 2000 GWh of renewable electricity may be lost annually because the electricity network is not able to accommodate it. The potential lost renewable energy opportunity represents about 0.32% to 0.71% of demand, equivalent to the charging requirements of 350,000 to 700,000 electric vehicles, and it is considered that dedicated electric vehicle battery charging may reduce the amount of otherwise-lost renewable energy by 25%.

The type of battery charging infrastructure that is deployed for electric vehicles will have the potential to impact positively, less positively or negatively on the electricity system. In particular, charging stations could be operated by private companies (such as those recently opened in Hong Kong), public agencies or individual property owners.

---

[35] Danish Energy Association (2007). *Energy Agenda 6*, Copenhagen, DEA.

6.4 Delivering Results for Electricity Networks and Emissions Mitigation

It is possible to deliver significant emissions reductions while also improving electricity networks. The best outcomes would come from a combination of measures directed towards updating business models for electricity network businesses and enabling investments in new and innovative technological solutions. Table 5 summarises possible approaches. Some of these approaches are discussed further following the Table.

Table 5. Approaches to Achieving Results for Electricity Networks and Emissions Mitigation

Type of Approach	Key Parties	Scope	Outcomes
Institutional/ organisational	Government bodies responsible for emissions reduction policies and energy program delivery. Electricity distribution businesses.	Adopt a more holistic and inclusive planning approach to the design of emissions reduction activities to better identify (and resolve) electricity network bottlenecks and perverse outcomes.	Greenhouse gas emissions reduction activities made more effective by integrating electricity network function in the program design process. A potential benefit for electricity networks from emission reduction activities – or, at least, no new problems introduced inadvertently.
Institutional/ organisational	Electricity distribution businesses. Responsible regulatory and industry policy bodies.	Move electricity distributors to become energy services providers, underpinned by opportunity for business growth in the changing electricity market. Encourage business models that incorporate provision and financing of DSM activity and targeted distributed generation (such as on-site renewables) for customers.	A much more effective delivery mechanism for emissions reduction activities because of the alignment with the electricity distributor's ongoing DSM focus and its new business interests.
Institutional/ organisational	Government bodies responsible for emissions reduction policies and energy program delivery.	Develop appropriate support measures for emissions reduction technologies that are also able to provide a quantifiable degree of peak load reduction.	Identified emissions reduction activities also achieving benefits for electricity systems.

Type of Approach	Key Parties	Scope	Outcomes
Market/ regulatory	Electricity network regulator	Promote a geographical broadening of planned DSM activities beyond the 'feeder of interest'.	DSM by the electricity distributor contributes to enhanced kWh (and emissions) savings because of its wider geographical application.
Market/ regulatory	Electricity network regulator	Use financial instruments – penalties and rewards – to influence network operation and investment behaviour, particularly to avoid losses and congestion.	Creation of more robust networks better able to incorporate many greenhouse gas emissions reduction initiatives.
Technical solutions	Electricity industry system operators	Adopt state-of-the-art grid management systems that encourage customer-based activities.	More incentive for interested parties to implement a range of emissions reduction activities.
Technical solutions	Communications technology businesses, distribution and transmission network businesses	Better integrate the promotion of DSM plus energy storage opportunities, and renewable energy generation, within electricity networks.	Increased renewable energy penetration in networks and consequent reductions in GHG emissions.

6.4.1 Planning and Integrating Emissions Reduction Activities

The intent of this suggestion is to better involve key stakeholders in the design of emissions reduction measures from the outset.

Consider two simple hypothetical examples of emissions reductions activities commonly being advanced by governments: 1,000 kW of PV to be connected to the network of a rural electricity distributor, and an increased use of natural gas for power generation.

In the first case, the government might mandate a feed-in tariff for all PV electricity to be supplied to the grid, and require connection by the distributor of all interested PV installations. The likely result could be 1,000 PV systems, anywhere on the distributor's system, including locations such as isolated weak rural feeders where problems may arise from the supply of so much PV electricity to the grid[36]. Alternatively, the distributor could be required and supported (via a Renewable Portfolio Standard, for example) to install 1,000 kW of PV where, when and how they choose. The likely outcome could include some large projects on public buildings where the network is more robust, a

---

[36] The government could also design a feed-in tariff more sensitive to the local conditions, such as the amendment to the very popular German feed-in tariff to provide additional incentive for own or neighbourhood consumption of the PV electricity.

range of different financing (new business) and support mechanisms appropriate to the variety of PV customers and, in the case of interested parties on the weak feeders, a special program encouraging own consumption of their PV electricity. The emissions reductions are the same (and, in practice, more likely to be achieved) and benefits rather than problems are delivered to the electricity network.

In the second case, a low capital cost open-cycle gas turbine, fuelled by natural gas or fuel oil, might be developed outside the city providing high priced power to the electricity market at times of high demand. Alternatively, the urban electricity distributor, facing demand constraints within the city, could promote (own, finance etc) a natural gas-fired cogeneration unit at the local hospital, providing heat and electricity for the hospital plus power for the network at critical times. Whereas the initial cost of this alternative is likely to be higher, the emissions reductions achievable will also be greater.

6.4.2 Moving Electricity Distributors to Become Energy Services Providers

Currently, the business model adopted by most electricity distribution businesses consists simply of building and maintaining the poles and wires comprising the electricity distribution network, plus (where the distributor is also an electricity retailer) selling power to end-users. However this may not be the optimal business model for the future. A different role for the electricity distribution business, and some ideas on how to progress this idea, are outlined below.

The aim is to change the electricity distribution business from being simply a manager of the network to becoming a provider of a full range of energy services for an increasingly sophisticated customer base, while also satisfying growing stakeholder demands and meeting the growing technical complexities of the network. It is important to note that this does not involve electricity distribution businesses simply moving back to the pre-unbundling model of joint distributor/retailer, but could develop as a response to an increasingly sophisticated and complex relationship between the end-use consumer and the electricity network in the future. The most likely drivers of this sort of change are those executives in the distribution business concerned on a daily basis with shortcomings in the current system and exposure to the issues arising from more engaged customers, distributed generation sources and new and untested possibilities for increased DSM.

An all-or-nothing approach to changing the focus of an electricity distribution business is not necessary, nor would it be desirable. A pragmatic strategy could aim to reduce the magnitude of the project risks through small-scale demonstration, experience and capacity building, with further developments promoted as the benefit to risk ratio continues to increase. Given that a progressive approach building on small successes and existing frameworks is likely to prove the most acceptable sustainable energy business model, the ‘outcomes-based’ approach summarised in Table 6 (page 32) is suggested for the short-term, operating within the existing corporate structure and driven by the relevant business plans of a generic electricity distribution business.

Table 6. Possible Approach to an Electricity Distributor Providing Energy Services

Short-term tangible net benefits to the network	Investments would result in identifiable deferred network investments or loss savings
	Could be included in operational plans for return on network assets and asset utilization
	Funded by Networks division and geared to cost / benefit targets
	Performance indicators to relate to asset utilization and return on assets
Investment opportunities	Investments would result in cash flow, and could include equity participation in customer projects, provision of financial services
	Could be included within Finance and Business Development business plans
	Funded by Finance division and geared to RoR criteria
	Performance indicators would relate to income
Ancillary business development	Investments would broaden the base of operations, and could include development of financial and project management services, development of strategic alliances with service providers and potential sustainable competitors
	Could be included in the Corporate Plan and Business Development plan
	Corporate resource allocation
	Performance indicators based on benchmarking in the competitive market
Increased customer focus	Investments would lock-in plum customers and win business outside the distributor's area, and could include project support and in-kind contributions for customers interested in sustainable investments
	Could be incorporated in the business plans of customer account managers (Retail division) and the Business Development plan
	Resources mainly in the form of manpower
	Performance indicators would relate to measures of customer satisfaction, growth in customer numbers and customer uptake of sustainable energy
Sustainable energy technology demonstration	Investments primarily aimed at raising corporate profile while drawing significantly on Government and international RD&D funds or other sources of money – these projects are not likely to be commercial in their own right
	Could be included in the Corporate Plan and Publicity / Promotions Business Plans
	Ideally projects should fall into one of the other investment categories but, at least initially, this provides another option where this is not possible
	Performance indicators could relate to degree of funding matching, and media response
Network R&D	Competitive advantage is increasingly dependent on intellectual property, or at least awareness
	Activities would include participation in targeted sustainable energy national and international programs, and in-kind support for university and Government research projects
	Could be included in a business plan incorporating Network Technology
	Funding requirements should be minimal
	Performance indicators could relate to any new business opportunities arising from sustainable energy RD&D involvement

6.4.3 Using Emission Reduction Technologies to Manage Peak Loads

The nature of peak demand depends on a number of factors, including network location, predominant customer class, geography, and the day of the week. For example, a common demand peak in many warmer climates occurs on summer weekday afternoons, driven predominantly by air conditioning. When governments are designing emission reduction strategies in such climates, it makes sense to allocate resources to a program such as 'PV in schools' that can both mitigate emissions and address the summer afternoon peak demand. Electricity distributors are likely to support such a program because, as well as reducing emissions, it will also help reduce problems on the distribution network. Furthermore, the end-use customers (in this case schools) may be paying more for their grid electricity over the peak period and their costs would be reduced by on-site PV generation, thereby creating an opportunity for a win-win-win situation.

6.4.4 Broadening the Geographical Footprint of DSM Activities

Undertaking DSM activities to achieve a target demand (kW) reduction on a single feeder or substation is a common practice for an electricity distribution business. Although not the focus of the DSM, a kilowatt-hour saving and GHG emissions reduction will also be achieved. Once the program design has been carried out and the required administrative procedures have been developed for use on the relevant network element, it would be relatively straightforward to replicate the exercise on a number of other similar elements that were yet to be identified for a load reduction effort. The initial kilowatt-hour savings (and emission reductions) would be multiplied for minimal extra effort. To enable the distributor to carry out the additional activities, it is important that any extra costs borne by the distributor should be able to be recovered through pricing regulation or by direct payment from government funds allocated to achieving emissions reductions.

6.4.5 Regulating to Achieve Robust Electricity Networks

Electricity network businesses are regarded as natural monopolies that cannot be subjected to competitive markets. Consequently, network businesses are subject to regulation and the role of the regulator (whether regional, national or intra-national) is assuming greater importance. Regulators can influence network operation and investment behaviour, particularly to avoid losses and congestion and therefore achieve both kilowatt-hour savings and emissions reductions.

In general, transmission and distribution grids lose the equivalent of between 7% and 10% of generated electricity each year[37] – and in many countries this figure has been growing over the decades. Losses from distribution grids arise from a variety of sources, including transformer inefficiencies, fluctuating voltages and reactive power. Considerable savings can be achieved particularly through reducing voltage. Keeping the voltage steady is challenging but improved monitoring and communications can help. Transmission networks need to avoid congested, high-loss corridors and use advanced lower-loss conductors amongst other loss reduction measures.

---

[37] This figure is considerably higher in some developing countries.

Price regulation can allow pass-through of costs associated with investments in network loss reduction: congestion pricing can improve the operation of the network and providing financial incentives for appropriate load management programs can underpin both loss and congestion reduction. Electricity industry regulators need to be completely behind the planning, pricing and funding of the required investments in network loss reduction.

6.4.6 Implementing State-of-the Art Grid Management Systems

It is now possible for an electricity distribution business to operate a commercially available energy optimization platform to bundle their distributed resources such as cogeneration, renewables, energy storage systems and controllable loads as a single, virtual generator or distributed energy resources portfolio, optimized and ready for dispatch in the wholesale energy market. Such software can also interface with distributors' SCADA systems. This provides an economical and environmentally sound way of operating distributed generation, while meeting the specific needs of the electricity distributor and supporting both increased emissions reductions and improved system operation.

In reality, the actual trading and optimization of such a portfolio in the competitive and disaggregated electricity markets is still quite an undertaking and the subject of ongoing interest and research.

In Japan, the Central Research Institute of the Electric Power Industry (CRIEPI) is investigating the Autonomous Demand Area Power System. This essentially involves development of a grid system that can:

- flexibly incorporate various distributed power generation options and customer load profiles (using the existing electricity infrastructure);
- easily adapt to future advanced information and communication technologies, and end-use customers' participation in the market;
- and proactively contribute to grid efficiency by minimising negative impacts and enhancing load levelling.

In western Denmark, Energinet.dk's Cell Project divides the electricity system control into virtual autonomous grid areas to provide more flexible and improved control and monitoring options. The vision for the near future is that the entire cell area will be transformed from a classical passive distribution grid to an intelligent active distribution system, which ultimately can be considered as one virtual generator of a varying size determined by the sum of wind turbines, local CHP plants and other types of distributed power generating units in operation at any given time. It is expected that the number of active power generation units in the existing power markets will increase and that it will be possible to establish new markets for reactive power, active voltage control and spinning reserves.

6.4.7 Integrating DSM, Energy Storage and Renewable Energy Generation

Currently, emissions reduction efforts plus retail electricity price increases are focusing customers' interests on distributed generation and energy efficiency opportunities. These interests also provide electricity distributors with leverage to pursue much-needed load management activity in aging networks. The key to achieving optimal outcomes in relation to both emissions reductions and the electricity system is mainly a matter of integration.

The California Energy Commission[38] notes that expanding that state's energy storage options could both resolve the integration issues associated with intermittent resources such as renewable energy and also increase the operational flexibility of the state's transmission and distribution systems. The Sacramento Municipal Utility District (SMUD) is currently investigating the potential value of integrating distributed energy resources (such as PV) and storage systems to mitigate their system's major peak load from 4pm to 7pm, especially from 5pm onwards when the PV output has decreased significantly.

Research has shown that distributed generation, demand response and localized reactive power sources in the right locations and with the right characteristics and operating profiles can improve network performance by reducing real power losses, VAR flow and consumption, distribution system voltage variability, and system stress[39]. Importantly, it was found that most projects would not need to vary power output to provide network benefits, meaning that an expensive communications and controls infrastructure for these resources is probably not needed for now, and that smaller projects can provide relatively larger network benefits.

7. CONCLUSION

Amending DSM activities to better mitigate greenhouse gas emissions and modifying emissions reduction measures to achieve benefits for electricity systems are not opposite sides of the same coin. The former involves (mainly) one entity (the electricity distribution business), technically-achievable outcomes and reasonably familiar applications; the latter comprises a plethora of activities, driven by a multitude of stakeholders, usually without a deep appreciation of the technical parameters.

Problems (and opportunities) arise because, on the one hand, the potential of both distribution businesses and the electricity network to operate in a more complex environment is mostly not realised, and certainly not supported to the degree required. On the other hand, while those responsible for developing emissions reductions measures do not actively ignore the realities of the electricity network, there does not seem to be a strong appreciation that emissions reductions from electricity supply are predicated on the grid's ability to deliver them.

---

[38] California Energy Commission (2005). *Op. cit*.

[39] *Ibid*.

Reconciling the two approaches is largely not a technical issue – it is a matter of alignment of differing business / institutional perspectives for the greatest societal benefit. Usually this involves both market transformation (over the longer-term) and regulatory oversight (in the near-term).

Table 7 summarises the main proposals of this report from two perspectives – DSM activities better contributing to emission reductions, and emission mitigation measures achieving benefits for electricity systems.

Table 7. Summary of Proposals

Demand management activities better contributing to emission reductions	Electricity distribution businesses could move to providing a full range of energy services to reduce barriers to the implementation of some emissions reduction options (such as renewable energy) and provide added impetus to the roll-out of others (such as end-use energy efficiency, electric vehicles).
	Electricity regulators could promote a geographical broadening of existing or planned demand management efforts to increase kilowatt-hour savings (and hence emission reductions) across the network.
	Electricity regulators could appropriately reward load management and other activities designed to improve the operation and integrity of the network (and consequently its ability to incorporate more emissions reduction activity).
	Electricity system operators could adopt grid management practices and systems that improve the handling of distributed generation, and customer participation more generally.
	Electricity transmission and distribution businesses could capitalise on the synergies that exist between technologies and applications already making use of the electricity network – to both allow unhindered development of emissions reduction options (renewable energy and energy efficiency), and to improve operation of the electricity system (via energy storage and load management activity).
Emissions mitigation measures achieving benefits for the electricity system	Governments could adopt planning and design processes that are much more inclusive of electricity distribution businesses when developing emissions reductions strategies, particularly those involving deployment of renewable energy, promotion of cogeneration or support of end-use energy efficiency.
	Governments could pay particular attention to technologies, applications and locations whereby peak demand on the electricity network can also be addressed when developing emissions reductions strategies. This could range from renewable energy options in the short-term to roll-out of electric vehicle technology in the future.

REFERENCES

California Energy Commission (2005). *Implementing California's Loading Order for Electricity Resources*. CEC-400-2005-043. Sacramento, CA, CEC. Available at: http://www.energy.ca.gov/2005publications/CEC-400-2005-043/CEC-400-2005-043.PDF

Crossley D (2008a). International perspectives on demand (side) management. *Australian Institute of Energy Symposium Energy in NSW 2008 - Supply and Demand-side Prospects*. Sydney, 29 July. Available at: http://www.efa.com.au/Library/David/Conference%20Papers/2008/InternationalPerspectivesonDSM.pdf

Crossley, D.J. (2008b). *The Role of Advanced Metering and Load Control in Supporting Electricity Networks*. International Energy Agency Demand Side Management Programme, Task XV Research Report No 5. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

Crossley, D. J. (2009). *Preliminary Study of Emissions Trading Schemes in the United Kingdom and Australia*. International Energy Agency Demand Side Management Programme, Task XVIII Working Paper No 2. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

Crossley, D. J. and Pujari, A. (2010). *Principles for Assessing Emissions Reductions from DSM Measures*. International Energy Agency Demand Side Management Programme, Task XVIII Research Report No 2. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

Danish Energy Association (2007). *Energy Agenda 6*, Copenhagen, DEA.

Federal Energy Regulatory Commission (2006). *Assessment of Demand Response and Advanced Metering*. Washington DC, FERC. Available at: www.ferc.gov/legal/staff-reports/demand-response.pdf

Federal Energy Regulatory Commission (2009). *2009 Assessment of Demand Response and Advanced Metering*. Staff Report. Washington, DC, FERC. Available at: http://www.ferc.gov/legal/staff-reports/sep-09-demand-response.pdf

Figueiredo V., Rodrigues, D. and Vale, Z. (2005). Simulating DSM Impact in the New Liberalized Electricity Market. *9th Spanish Portuguese Congress on Electrical Engineering (9CHLIE)*. Marbella, Spain, 30 June to 2 July. Available at: http://www.aedie.org/9CHLIE-paper-send/206-figueiredo.pdf

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, (BMU) (2009). *Renewable Energy Sources in Figures – National and International Development*. Berlin, BMU. Available at: http://www.bmu.de/files/english/renewable_energy/downloads/application/pdf/broschuere_ee_zahlen_en_bf.pdf

Independent Pricing and Regulatory Tribunal of New South Wales (2002). *Inquiry into the Role of Demand Management and Other Options in the Provision of Energy Services. Final Report.* Sydney, The Tribunal. Available at: http://www.ipart.nsw.gov.au/files/Final%20Report%20-%20Inquiry%20into%20the%20Role%20of%20Demand%20Management%20and%20Other%20Options%20in%20the%20Provision%20of%20Energy%20Services%20-%20October%202002.PDF

Intergovernmental Panel on Climate Change (2007). *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Technical Summary*. Cambridge, Cambridge University Press. Available at: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg3_report_mitigation_of_climate_change.htm

Kärkkäinen, S. (undated). *Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages – State of the Art Report. Volume 1: Main Report.* International Energy Agency Demand Side Management Programme, Task XVII,. Espoo, Finland, VTT Technical Research Centre of Finland. Available at: http://www.ieadsm.org/ViewTask.aspx?ID=16&Task=17&Sort=0#ancPublications3

Keith, G. and Biewald, B. (2005). *Methods for Estimating Emissions Avoided by Renewable Energy and Energy Efficiency*. Cambridge, Massachusetts, Synapse Energy Economics Inc. Available at: http://www.synapse-energy.com/Downloads/SynapseReport.2005-07.PQA-EPA.Displaced-Emissions-Renewables-and-Efficiency-EPA.04-55.pdf

Marnay, C., Fisher, D., Murtishaw, S., Phadke, A., Price, L., Sathaye, J. (2002). *Estimating Carbon Dioxide Emissions Factors for the California Electric Power Sector*. Berkeley, California, LBNL. Available at: http://ies.lbl.gov/iespubs/49945.pdf

National Grid Management Council (1993). *Transition to a National Electricity Market*. Melbourne, NGMC.

Paatero, J. and Lund, P. (2006). A model for generating household electricity load profiles. *International Journal of Energy Research*, Vol. 30, No. 5, pp. 273-290. doi: 10.1002/er.1136.

Parks, K., Denholm, P., and Markel, T. (2007). *Costs and Emissions Associated with Plug-in Hybrid Electric Vehicle Charging in the Xcel Energy Colorado Service Territory*. Technical Report NREL/TP-640-41410. Golden, CO, National Renewable Energy Laboratory. Available at: http://www.nrel.gov/docs/fy07osti/41410.pdf

Rayner, S. and Malone, E. L. (1998). *Human Choice and Climate Change: Ten Suggestions for Policymakers. Guidelines from an International Social Science Assessment of Human Choice and Climate Change*. Columbus, Ohio, Battelle Press.

Smith, R. (2007). Shifting the Spare Tire: Values and Incentives for Electricity Demand Management Following Market Reform – The Australian Experience. *International Association of Energy Economics International Conference*, Wellington, New Zealand. Available at: http://www.iaee.org/en/publications/proceedingssearch.aspx?conference=Wellington+IAEE+International+Conference

State of California (2010). *California Legislature Assembly Bill No 2514*. Available at: http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2501-2550/ab_2514_bill_20100219_introduced.pdf

Ueda. Y., Ogimoto, K. and Oozeki, T. (2009). The Japanese experience with large concentrations of PV in communities. Presentation to *International Energy Agency Photovoltaic Power Systems Programme Workshop*, Hamburg, Germany, 22 September. Available at: http://www.iea-pvps.org/workshops/0909hamburg/Presentations/4%20Ueda.pdf

World Business Council for Sustainable Development (2008). *Power to Change – A Business Contribution to a Low-carbon Electricity Future*. Geneva, WBCSD. Available at: http://www.wbcsd.org/includes/getTarget.asp?type=d&id=MzI3NTI