The Role of Advanced Metering and Load Control in Supporting Electricity Networks

Research Report No 5
Task XV of the International Energy Agency Demand Side Management Programme

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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. Since 1993, the following 20 member countries and the European Commission have been working to clarify and promote opportunities for DSM.

Australia	France	New Zealand
Austria	Greece	Norway
Belgium	Italy	South Africa
Canada	India	Spain
Denmark	Japan	Sweden
European Commission	Korea	United Kingdom
Finland	Netherlands	United States

A total of 20 Tasks (multi-national collaborative research projects) have been initiated by the IEA DSM Programme, 13 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

* Completed Task

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Also, visit our web site at: **http://dsm.iea.org**.

FOREWORD

This report is a result of work which was completed within Task XV of the International Energy Agency Demand-Side Management Programme. The title of Task XV is "Network-Driven Demand Side Management." Task XV is a multinational collaborative research project which is investigating demand-side management (DSM) measures which may provide viable alternatives to augmentation of electricity networks and also provide network operational services.

Task XV is organised into six subtasks as follows:

- **Subtask 1:** Worldwide Survey of Network-Driven DSM Projects.
- **Subtask 2:** Assessment and Development of Network-Driven DSM Measures.
- **Subtask 3:** Incorporation of DSM Measures into Network Planning.
- **Subtask 4:** Evaluation and Acquisition of Network-Driven DSM Resources.
- **Subtask 5:** Communication of Information About Network-Driven DSM.
- **Subtask 6:** Role of Load Control and Smart Metering in Achieving Network-related Objectives.

This report summarises the results from Subtask 6.

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

The work of Task XV is supported (through cost and task sharing) by the seven participating countries: Australia, France, India, New Zealand, South Africa, Spain and the United States. 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. Some countries nominated additional representatives who also contributed to the work of Task XV.

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 vii.

The Principal Investigator for, and main author of, this report is Dr David Crossley of Energy Futures Australia Pty Ltd. Any errors and omissions are the sole responsibility of the Principal Investigator.

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EXECUTIVE SUMMARY

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 XV of the IEA DSM Programme, and consequently this report, are concerned with a particular type of DSM – "network-driven DSM". Network-driven DSM comprises demand-side measures used to relieve network constraints and/or to provide services for electricity network system operators.

The purpose of this report is to summarise ways in which advanced metering and load control technology can be effectively utilised to support electricity networks.

Currently, recording the quantities of energy consumed by end-users is mostly carried out by using ***accumulation meters*** which simply record energy consumption progressively over time. However, more advanced meters are increasingly being used. ***Interval meters*** record the quantities of energy consumed over set, frequent time intervals. ***Smart meters*** include, in addition to the interval metering capability, one-way or two-way communications between the energy supplier and the meter.

The report identifies three ways in which advanced metering and load control technology can be used to support electricity networks.

First, advanced meters enable the implementation of time-varying pricing which sends price signals to customers that reflect the underlying costs of generating, transporting and supplying electricity. Price-based demand response programs can reduce or shape customer demand and particularly can reduce peak loads on the electricity network and therefore reduce the amount of investment required in network infrastructure.

Second, analysing data from advanced meters provides end-users with detailed information about the ways in which they use electricity and can enable businesses to identify and implement energy, cost and carbon savings. Energy savings reduce the overall load on the electricity network, therefore contributing to supporting the network.

Third, load control technologies can be used to directly reduce peak loads on the electricity network by remotely switching appliances and equipment at customers' premises. This is arguably the most effective mechanism for reducing peak loads since remote switching requires only one "set and forget"decision by end-use customers.

This report also identifies and reviews a number of low cost technology products that enable various load control functions. The review draws the following conclusions:

- **interval metering** is not necessary to carry out load control functions – available technology can remotely switch loads without requiring connection to a meter;
- **one-way communication** is essential to carry out remote switching of loads;
- **two-way communication** is not essential to carry out remote switching of loads; and
- **metering** in some form is required for settlement of the financial transactions associated with load control programs.

1. INTRODUCTION

1.1 Network-driven DSM

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 XV of the IEA DSM Programme, and consequently this report, are concerned with a particular type of DSM – "network-driven DSM"[1].

Network-driven DSM comprises demand-side measures used to relieve network constraints and/or to provide services for electricity network system operators. In Task XV, network-driven DSM is defined as follows:

> *Network-driven demand-side management is concerned with reducing demand on the electricity network in specific ways which maintain system reliability in the immediate term and over the longer term defer the need for network augmentation.*

Task XV has identified the following two prime objectives for network-driven DSM:

- to relieve constraints on distribution and/or transmission networks at lower costs than building 'poles and wires' solutions; and/or
- to provide services for electricity network system operators, achieving peak load reductions with various response times for network operational support.

In Task XV, the following network-driven DSM measures are considered:

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

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[1] For a more comprehensive discussion of network-driven DSM see the first report from Task XV: Crossley, D.J. (2008). *Worldwide Survey of Network-driven Demand-side Management Projects*. Second edition. International Energy Agency Demand Side Management Programme, Task XV Research Report No 1. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

1.2 Purpose of this Report

This is the fifth report from Task XV and it is intended to achieve the objective of Subtask 6 which is "to investigate in detail the role of load control and smart metering in achieving network-related objectives [2]."

The purpose of this report is to summarise ways in which advanced metering and load control technology can be effectively utilised to support electricity networks.

2. METERING FUNDAMENTALS

2.1 Types of Meters

For most of the 100 year history of electricity and gas industries throughout the world, recording the quantities of energy consumed by end-users has been carried out by using ***accumulation meters*** which simply record energy consumption progressively over time. With this type of meter, physical readings of the meter are required at set intervals to enable calculation of the quantity of energy used during a billing period.

In most countries, small electricity and gas end-users, particularly in the residential sector, are still billed using data from accumulation meters. However, more advanced meters are increasingly being used, particularly in the commercial and industrial sectors.

Interval meters record the quantities of energy consumed over set, frequent time intervals. Typically, the minimum time interval set for recording energy consumption is every fifteen minutes and the maximum interval is every hour. Interval meters enable time-varying energy pricing in which the energy price during the day can be set at high levels during peak periods when the energy system may be constrained, and at low levels during off-peak periods when there is spare capacity in the system.

Smart meters comprise a more advanced level of metering technology. In addition to the interval metering capability, smart meters typically include one-way or two-way communications between the energy supplier and the meter. This communication capability enables a range of other functionalities that may include:

- automated and remote meter reading;
- remote connection and disconnection of the energy supply to the end-user's premises;
- outage detection to monitor the status of the energy supply;
- tamper detection to identify theft of energy from the network;
- monitoring of power quality;
- remote time synchronisation to keep the meter's internal clock accurate without requiring a site visit to check and adjust;
- an interface for a display unit in the end-user's premises that shows the current level of energy consumption, the cost of the energy being consumed, plus other information such as the tariff currently being applied;
- an interface for load control devices that can remotely switch appliances and equipment on and off.

[2] Energy Futures Australia (2007). *Proposed Task XV Extension*. Hornsby Heights, NSW Australia, EFA.

Other functionalities that may be incorporated into smart meters include:

- a supply capacity control (circuit breaker) that disconnects the supply if the demand at the end-user's premises exceeds a set value[3];
- a capability to record quantities of energy both exported from the network to the end-user (as in normal energy supply) and imported to the network from the end-user (eg by a photovoltaic panel or other on-site generation installed at the end-user's premises).

2.2 Advanced Metering Infrastructure

A recent report by the United States Federal Energy Regulatory Commission (FERC) defines "advanced metering" as follows:

> *Advanced metering is a metering system that records 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*[4].

The key concept reflected in this definition is that advanced metering involves more than a meter that can measure energy consumption over frequent time intervals (ie an interval meter). Advanced metering refers to the full measurement and collection system, and includes customer meters (usually smart meters), communication networks, and data management systems. This full measurement and data collection system is commonly referred to as ***advanced metering infrastructure*** (AMI).

Figure 1 (page 4) shows diagrammatically a typical AMI system. For the purposes of this diagram, the electricity distributor is assumed to be the metering data provider.

The left of the diagram shows devices that could be in a customer's premises, including an in-home display unit and/or load management devices (which might control a range of appliances, eg pool pumps, air conditioners, dishwashers etc). These devices are typically considered external to an AMI system, but the AMI system is required to provide an interface or communications channel (shown as a dotted line in Figure 1) to enable the connection of such devices to retailers' systems. This connection may be through the meter, or directly through the AMI communications network, or through another communications channel.

Between the meter and the network management system a communications network cloud is shown. In some AMI systems, data concentrators would be part of this communications network.

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3 Such an arrangement is applied routinely to most dwellings in Italy where the circuit breaker/safety switch ('salva vita') is normally set to trip when the load exceeds 3 kW.

4 Federal Energy Regulatory Commission (2006). *Assessment of Demand Response and Advanced Metering*. Washington DC, FERC, p 17. Available at: www.ferc.gov/legal/staff-reports/demand-response.pdf

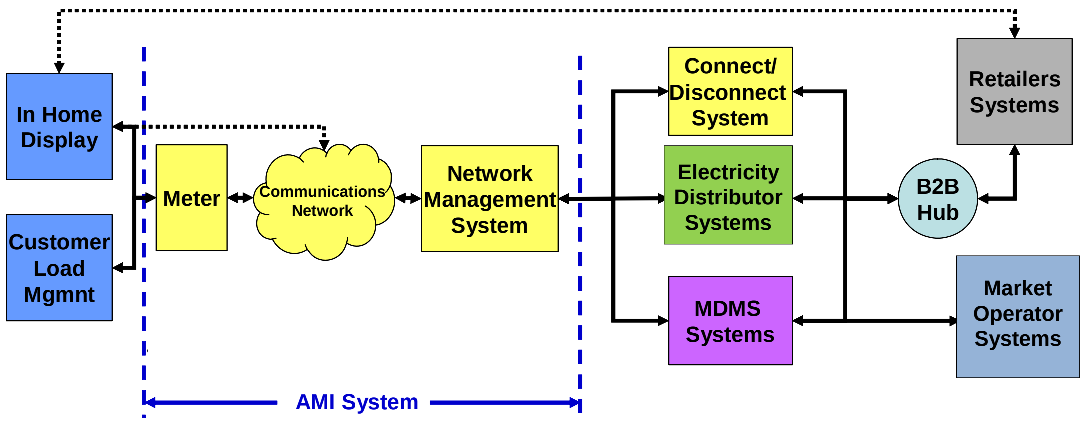

Figure 1. A Typical AMI System

The items on the right hand side of the diagram, including distributors' systems, metering data management system (MDMS), retailers' systems, B2B hub and market operator systems are not part of the AMI system. However, the AMI must be able to communicate with these various systems.

2.3 Benefits of Advanced Metering

2.3.1 Benefits for Electricity Businesses

The FERC report[5] identifies the following categories of benefits available to electricity businesses from the deployment of advanced metering technology:

- meter reading and customer service benefits;
- asset management benefits;
- ability to provide value-added services;
- outage management benefits;
- financial benefits.

Meter Reading and Customer Service Benefits

Implementation of advanced metering can significantly reduce meter reading expenses and capital expenditures, and can also increase the accuracy and timeliness of meter reading and billing. In particular, eliminating estimated bills and load profiling[6] is a key benefit available from automated meter data collection systems. Electricity businesses rarely are able to accurately estimate total electricity consumption over a billing period, even using weather and historical monthly consumption data. This is especially true for residential customers during vacations and during periods when the number of household members change. Also, the actual consumption over time by an individual customer may vary markedly from the aggregate consumption of a group of

5 Federal Energy Regulatory Commission (2006). *Op. cit.*

6 Load profiling may be used when a customer does not have an interval meter. Under load profiling, the cumulative kilowatt-hours consumed by a customer in a day are allocated across each hour (or other time period) based on the aggregate consumption over time of a group of similar customers.

similar customers. Currently, estimated bills and customer profiling, particularly in the residential sector, make it difficult for customers to obtain accurate information about their electricity consumption and significantly hinder attempts to provide incentives to customers who reduce their peak loads and/or implement energy efficiency measures.

Asset Management Benefits

Advanced metering can provide important information to assist in managing electricity network assets, particularly detailed and accurate data on customer demand and usage patterns. This enables electricity network businesses to significantly improve asset management including: proper sizing of equipment, predictive maintenance of equipment, theft detection, improved cost allocation across the customer base, and the ability to use accurate data on customer demand to defer investment in network infrastructure.

Ability to Offer Value-added Services

Advanced metering enables electricity businesses to offer new or improved services to customers with advanced metering, including additional tariff options (particularly time-varying pricing), flexible billing cycles, benchmarking of energy usage with similar customers, real time or near-real time information on actual electricity consumption and its cost, the aggregation of accounts and/or synchronization of multiple account billing and meter reading, web services based on the more timely information provided by advanced metering, and bill prediction for large and small customers, including weather forecast data.

The combination of time-varying electricity tariffs and the ability to provide real time information to customers about their actual electricity consumption and its cost (eg through an in-home display) enables electricity businesses to devise programs that provide incentives to customers who reduce their peak loads and/or implement energy efficiency measures.

Outage Management

The ability to detect outages provided by advanced metering technology can significantly improve outage management, for example by providing accurate information about the location of outages, thereby enabling more efficient scheduling of work by maintenance crews. Responding faster to small outages is another important benefit, especially in terms of improving customer service. Over time, as customers learn that AMI systems enable automatic detection and location of outages, it is expected that call centre volume during outages will be significantly reduced. When customers do call in, electricity businesses will be able to provide a better estimate of repair times.

Financial Benefits

Electricity businesses gain significant financial benefits from the implementation of advanced metering, particularly from the avoided cost of manual meter reads[7]. Financial benefits also accrue from general efficiency gains and improved cash flow from reducing the time it takes to produce a bill after the meter is read.

2.3.2 Benefits for End-use Customers

A study by Sustainability First in the United Kingdom[8] identified three categories of benefits available to end-use customers from the deployment of advanced meters:

- improvements in billing accuracy and payment arrangements;
- more comprehensive information about energy consumption; and
- dynamic market effects.

Billing Improvements

Customer benefits from improvements in billing include:

- more accurate billing which avoids underpayment (risk of debt) and overpayment (possible cash flow problems) by customers;
- no manual meter reading is required, therefore there is no need for customers to let meter readers into their property;
- more payment options for customers, eg variable direct debits from bank accounts based on actual use, might suit some customers.

More Comprehensive Information

Comprehensive information from advanced meters, such as real time information about the current energy consumption in the customer's premises and its cost, can be provided to customers via a conveniently sited in-home display or via the internet. Such information may motivate behavioural change by customers to achieve absolute reductions in energy use (energy saving) or shifting energy use to off-peak times (encouraged by time-varying pricing). Smart meters with communications functionality can also be used by electricity businesses to send messages to customers, such as information about energy saving measures, time of use tariff schedules, etc.

Dynamic Market Effects

More comprehensive data from advanced metering may have a significant impact on retail contestability by making it easier for electricity retailers to enable customer switching. This could make customers more likely to switch retailers, with a potential dynamic effect on the market. If more customers switch, retailers may have to offer

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7 CRA International and Impaq Consulting (2005). *Advanced Interval Meter Communications Study*. Melbourne, CRAI International. Available at: http://www.dpi.vic.gov.au/dpi/dpinenergy.nsf/93a98744f6ec41bd4a256c8e00013aa9/e56b1c9515d349a4ca2572c10003b843/$FILE/AMI_Study.pdf

8 Owen, G. and Ward, J. (2006). *Smart Meters: Commercial, Policy and Regulatory Drivers*. London, Sustainability First.

better loyalty deals to customers who stay. Also lower costs through smart meters may enable retailers to offer better deals, reducing prices for all customers.

Advanced metering also enables retailers to provide a wider range of value-added services, such as time-varying tariffs; energy services packages; possibly micro-generation using solar photovoltaic panels or micro-cogeneration fuelled by natural gas. These new offers could also help to induce more retailer switching with further price effects.

Advanced metering could lower costs sufficiently to facilitate market entry by new retailers, increasing the number of retailers from which customers may choose. This increased competition may also contribute to reducing retail prices.

3. USING TIME-VARYING PRICING TO REDUCE PEAK LOADS

3.1 Time-Varying Pricing

One of the major benefits of the introduction of advanced meters is that they enable the implementation of time-varying pricing of electricity. Under time-varying pricing, the price per unit of electricity varies according to the time of the day at which the consumption occurs. Seasonal variation in prices is also possible.

Varying electricity prices with the time of day is only possible if the customer has an interval meter. It is not possible with accumulation meters, because this type of meter does not record the quantities of electricity consumed during different time periods within a day.

The primary objective for exposing retail electricity customers to time-varying tariffs is to send price signals to customers that reflect the underlying costs of generating, transporting and supplying electricity. By exposing at least some customers to prices based on these marginal production costs, resources can be allocated more efficiently.

Furthermore, price-based demand response programs[9] can be used to reduce or shape customer demand. This is particularly important in locations where electricity usage is particularly affected by weather. Periods where temperatures are significantly colder or hotter than average can impose large peak loads on electricity networks during particular times of the day and force massive expenditure on network infrastructure (“poles and wires”) to cope with these peak loads. The resulting additional network capacity may be significantly under-utilised during non-peak times. Price-based demand response programs may be able to reduce some peak loads and therefore reduce the amount of investment required in network infrastructure.

[9] Demand response comprises actions taken by end-use customers to change (usually reduce) their electricity use in response to high prices in the electricity market and/or problems on the electricity network.

3.2 Time-Varying Tariff Structures

There are three main types of time-varying tariff structures:

- time of use (TOU) pricing;
- critical peak pricing (CPP); and
- real time pricing (RTP).

These programs expose customers to varying levels of time-varying price exposure – the least with TOU and the most with RTP. Figure 2 (page 9) illustrates the hourly price variations customers would face under the different time-varying tariff structures.

3.2.1 Time of Use Pricing

Most time of use (TOU) tariff structures establish two or more daily periods that reflect hours when the system load is higher (peak) or lower (off-peak), and charge a higher rate during peak hours. The length of the peak period varies, based on the timing over the day and week of the peak system demand in the service territory of the electricity business. Off-peak hours are usually some part of the evening and night, as well as weekends. TOU tariff structures sometimes have only two prices, for peak and off-peak periods, while other tariffs include a shoulder period or partial-peak rate depending on the particular characteristics of the load.

TOU tariffs can also be implemented on a seasonal basis with prices that vary by seasons. For instance, a summer-peaking electricity business may charge a higher price during summer months than during the off-peak winter months.

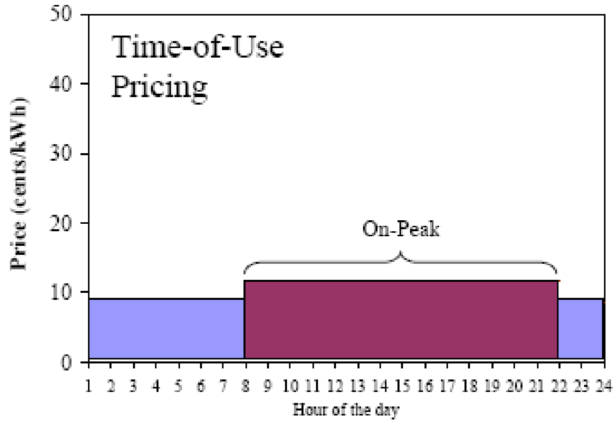
In some countries, such as Australia and New Zealand, time of use tariffs have been used for many years for particular residential loads such as storage water heaters and, more recently, pool pumps. Because these tariffs were implemented using accumulation meters, the off-peak loads had to be specially wired to meters which only supplied power during off-peak periods. The introduction of interval and smart meters will now enable the application of TOU pricing to all loads in customers' premises.

In TOU pricing, the size of the price-spread between peak and off-peak hours should be set so that customers perceive real price signals that motivate them to change behaviour (eg switching off appliances and equipment during peak periods). Trials of time-varying pricing currently being carried out in many countries are providing some indication about the price-spreads that are required to achieve behaviour change (see section 3.3, page 12).

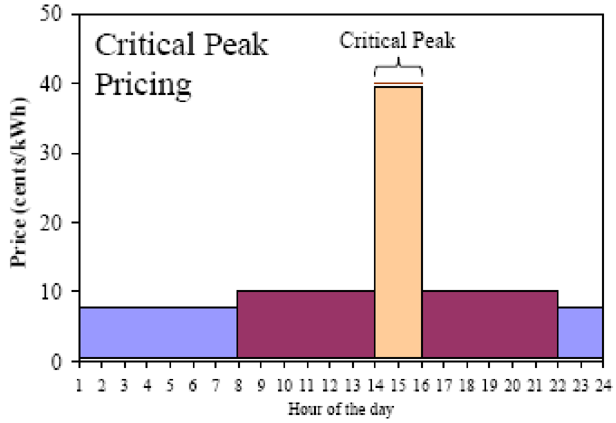
Another aspect that must be addressed in introducing TOU tariffs is the financial impact on the relevant electricity businesses[10]. Ideally, TOU tariff structures should achieve two goals: customers who change behaviour should receive bill savings as an incentive, while the electricity businesses maintain the same or similar revenue levels. Achieving both these goals simultaneously can be difficult and may require some fine-tuning of tariff structures once it becomes clear how customers are reacting to the TOU tariffs.

[10] TOU tariffs can be introduced by either an electricity network business or a retailer, but the financial positions of both businesses are likely to be impacted by any significant behaviour changes by customers.

Time-of-Use (TOU) Pricing:
These daily energy or energy and demand rates are differentiated by peak and off-peak (and possibly shoulder) periods.



Critical Peak Pricing (CPP):
CPP is an overlay on either TOU or flat pricing. CPP uses real-time prices at times of extreme system peak. CPP is restricted to a small number of hours per year, is much higher than a normal peak price, and its timing is unknown ahead of being called.



Real-Time Pricing:
RTP links hourly prices to hourly changes in the day-of (real-time) or day-ahead cost of power. One option is 'one-part' pricing, in which all usage is priced at the hourly, or spot price. A second approach is 'two-part' pricing.

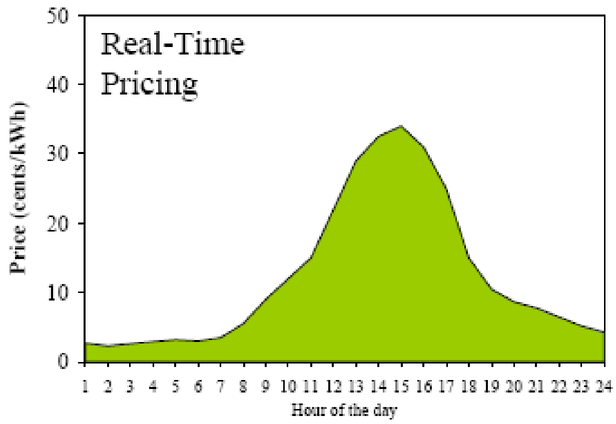


Figure 2. Typical Hourly Variation in Electricity Prices Under Time-varying Tariff Structures[11]

[11] Source: Federal Energy Regulatory Commission (2006). *Op. cit.*

3.2.2 Critical Peak Pricing

Critical peak pricing (CPP) is a relatively new form of pricing that can be superimposed on either a TOU or time-invariant tariff structure. CPP relies on very high critical peak prices, as compared with the ordinary peak prices in TOU pricing or the flat prices in time-invariant tariff structures. This high per-unit price is in operation during times that the electricity business (distributor or retailer) defines as critical peak periods. CPP events may be triggered by contingencies on the electricity network or high prices faced by retailers in procuring power in competitive electricity markets.

Unlike TOU blocks, which are typically in place for 6 to 10 hours during every day of the year or season, the days in which critical peaks occur are not designated in the tariff, but dispatched as needed, on relatively short notice, for a limited number of days during the year. Electricity businesses call critical peak events in real time and customers are usually given advance notice for periods varying from a maximum of about 24 hours to a minimum of about two hours in advance of the event. Shorter or no advance notice is possible, and could be useful in relation to high price spikes in competitive electricity markets.

In critical peak pricing, the size of the differential between the price during CPP events and the prices at other times is even more important than with TOU pricing. Because CPP events occur relatively infrequently, the impact of critical peak prices on electricity bills is relatively small and consequently the motivation to change behaviour can be low. However, because CPP events, by definition, are called only when electricity businesses are facing critical financial and/or operational contingencies, heavy reliance is placed on customers delivering firm peak load reductions. A tentative conclusion from the results of CPP trials carried out in several countries is that a price differential of about 10 times between the critical peak price and the off-peak price is required to achieve significant and firm peak load reductions.

Several variants of critical peak pricing have been developed in the United States[12], including:

Fixed-period CPP (CPP-F). In CPP-F, the time and duration of the price increase are predetermined, but the days when the events will be called are not. The maximum number of called days per year is also usually predetermined. CPP-F events are typically called on a day-ahead basis.

Variable-period CPP (CPP-V). In CPP-V, the time, duration, and day of the price increase are not predetermined. CPP-V events are usually called on a day-of basis. CPP-V is typically paired with load control devices such as communicating thermostats that allow automatic responses to critical peak prices.

Variable peak pricing (VPP). This is a recent form of critical peak pricing that has been proposed in the New England region of the United States. The off-peak and shoulder period energy prices would be set in advance for a designated length of time, such as a month or more. The price for each peak-period hour would be set each day based on the average of the relevant price in the New England wholesale electricity market, adjusted to account for delivery losses and other costs typically recovered

[12] Federal Energy Regulatory Commission (2006). *Op. cit.*

volumetrically. The advantage of VPP is that it more directly links prices in the wholesale electricity market to retail pricing.

Critical peak rebates. In critical peak rebate programs, customers remain on fixed tariffs but receive rebates for load reductions that they produce during critical peak periods.

3.2.3 Real Time Pricing

Under real time pricing (RTP), prices vary continuously during the day, directly reflecting the wholesale price of electricity, as opposed to tariff structures such as TOU or CPP that are largely based on preset prices. In competitive electricity markets, RTP would link half-hourly[13] prices for retail customers to the half-hourly changes in the cost of purchasing electricity from the market. The direct connection between wholesale prices and retail tariffs introduces price responsiveness into the retail market, and serves to provide important linkages between wholesale and retail markets.

Several RTP variants are in place across the United States[14]: day-of versus day-ahead pricing, and one-part versus two-part pricing.

Day-Ahead Real Time Pricing (DA-RTP). DA-RTP customers are given one-day notice of the prices for each of the next day's 24 hours. This gives customers time to plan their responses, such as shifting use (often by shifting load to off-peak hours or by using onsite generation) or to hedge day-ahead prices with other products if they cannot curtail their demand.

Two-Part Real Time Pricing. Under two-part real time pricing, only a portion of the electricity purchased by a customer is subject to retail prices directly linked to prices in the wholesale market. Two-part RTP designs include an historical baseline for customer usage, layered with hourly prices only for marginal usage above or below the baseline. Customers thus see wholesale market prices only at the margin. Figure 3 (page 12) shows how two-part RTP tariffs operate. Typically, two-part real time pricing is only applied to large commercial and industrial customers who have detailed information about past energy usage that can be used to construct an historical baseline.

The baseline design serves as a hedge for customers against real time pricing volatility, and allows them to achieve savings by curtailing their marginal use at times when prices are higher and by using more during lower-priced periods. This type of RTP design could be suitable for competitive electricity markets that are characterised by occasional spikes of very high wholesale prices.

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13 Retail pricing periods are linked to the settlement period in the competitive market. Half-hourly prices are specified here for illustrative purposes; other settlement periods and linked retail pricing periods are possible.

14 Federal Energy Regulatory Commission (2006). *Op. cit.*

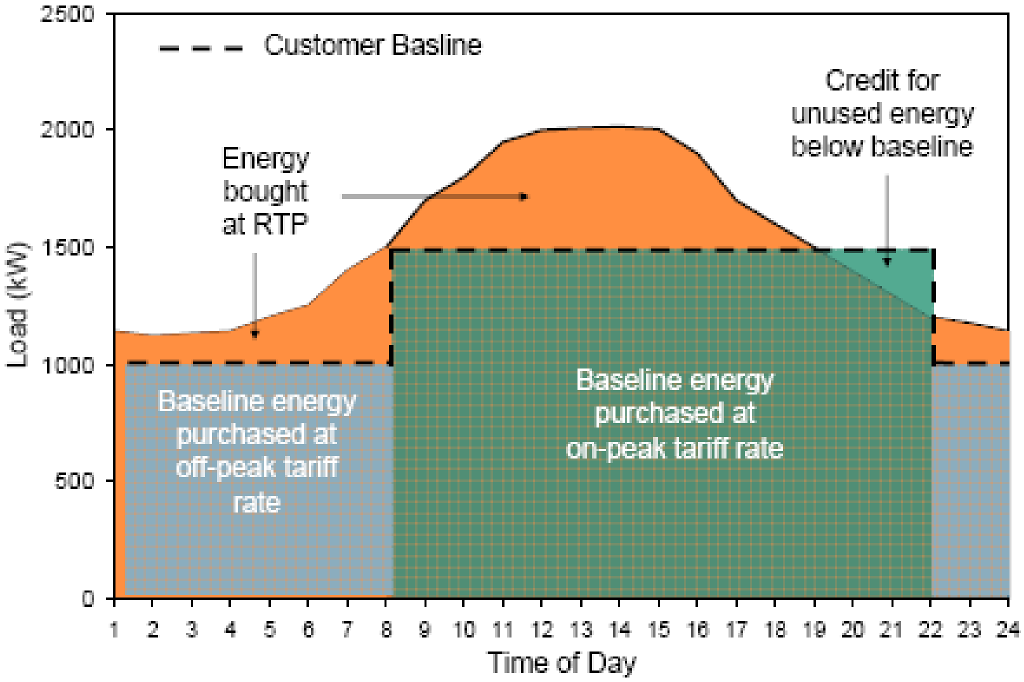

Figure 3. Typical Operation of a Two-Part Real Time Pricing Tariff[15]

3.3 Implementation of Time-Varying Tariffs

The first report from Task XV[16] includes several case studies of the implementation of time-varying tariffs, particularly to support electricity networks. The case studies are also available on the Task XV website at:
http://www.ieadsm.org/CaseStudies.aspx

Following are summaries of some of these case studies.

3.3.1 Queanbeyan Critical Peak Pricing Trial - Australia

The Queanbeyan Critical Peak Pricing Trial was carried out by the electricity distributor and retailer Country Energy to investigate the feasibility of promoting peak load reductions by residential sector customers to relieve distribution network constraints.

In the trial, implementation of time of use and critical peak pricing tariffs required the installation of interval meters and in-home information display units in the dwellings of about 200 participants. The in-home information display unit comprised a LED alphanumeric display which provided customers with specific information about the amount of electricity they were using, and how much it was costing. A beeping sounds alerted customers to the start of a critical peak period.

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[15] Source: Federal Energy Regulatory Commission (2006). *Op. cit.*

[16] Crossley, D.J. (2008). *Worldwide Survey of Network-driven Demand-side Management Projects*. Second edition. International Energy Agency Demand Side Management Programme, Task XV Research Report No 1. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

Two seasonal tariff schedules were applied. In summer, the peak period was from 2 pm to 8 pm to coincide with the period of maximum use of domestic air conditioners. In winter the peak period was from 7 am to 9 am and 5 pm to 8 pm to coincide with the period of maximum use of domestic space heaters.

The tariff levels were as follows:

Off Peak: AUD0.0703/kWh
Shoulder: AUD0.127/kWh
Peak: AUD0.1887/kWh
Critical Peak: AUD0.3774/kWh

Critical peak events were called by Country Energy when the load on the local network was reaching maximum capacity or when high price events occurred in the competitive wholesale electricity market. Critical peak events could be called for a maximum of 12 times per year; customers were given a minimum 2 hours notice.

Country Energy reported that the results of the trial showed mixed, but mainly positive results. The results varied from customer to customer with the majority achieving a saving on their electricity bill. Illustrations of the impact of critical peak pricing (CPP) alerts are shown in Figure 4 and Figure 5 (page 14). In both cases, demand decreased significantly during the CPP period, but increased after the end of the period. On 1 February 2006, the increase in demand resulted in a peak later in the evening that was higher than that on the comparison day without a CPP event.

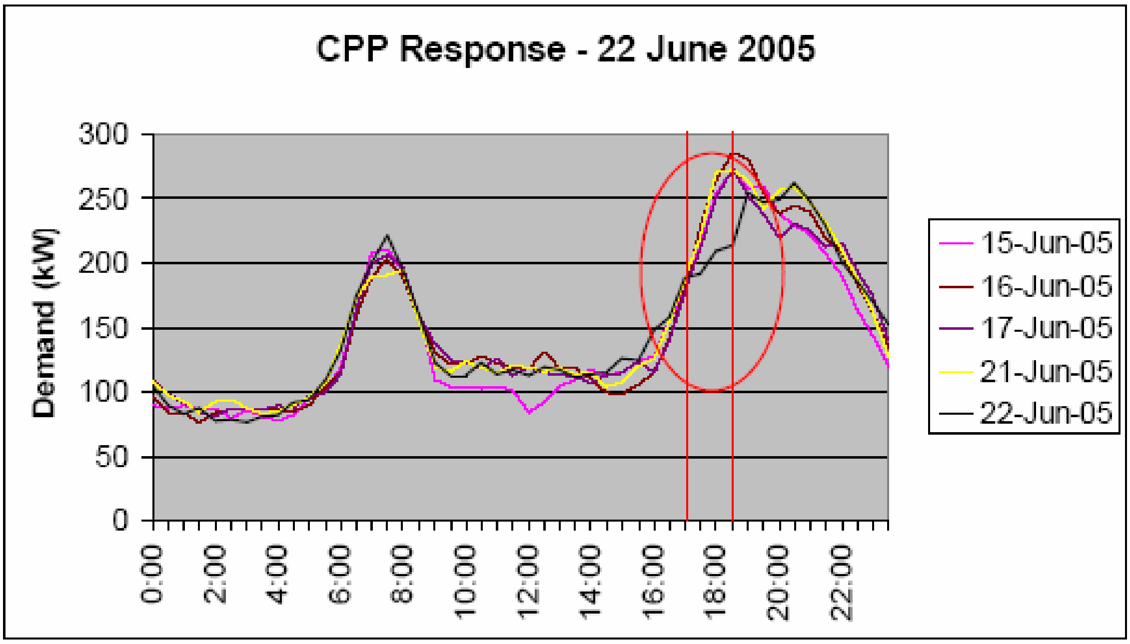

Figure 4. Impact of 22 June 2005 CPP Event in the Country Energy Trial[17]

[17] Source: Soussou, R. (2006). *Country Energy: Home Efficiency Trial in Queanbeyan*. Presentation to the Demand Response and DSM Conference, Sydney 27 to 28 March.

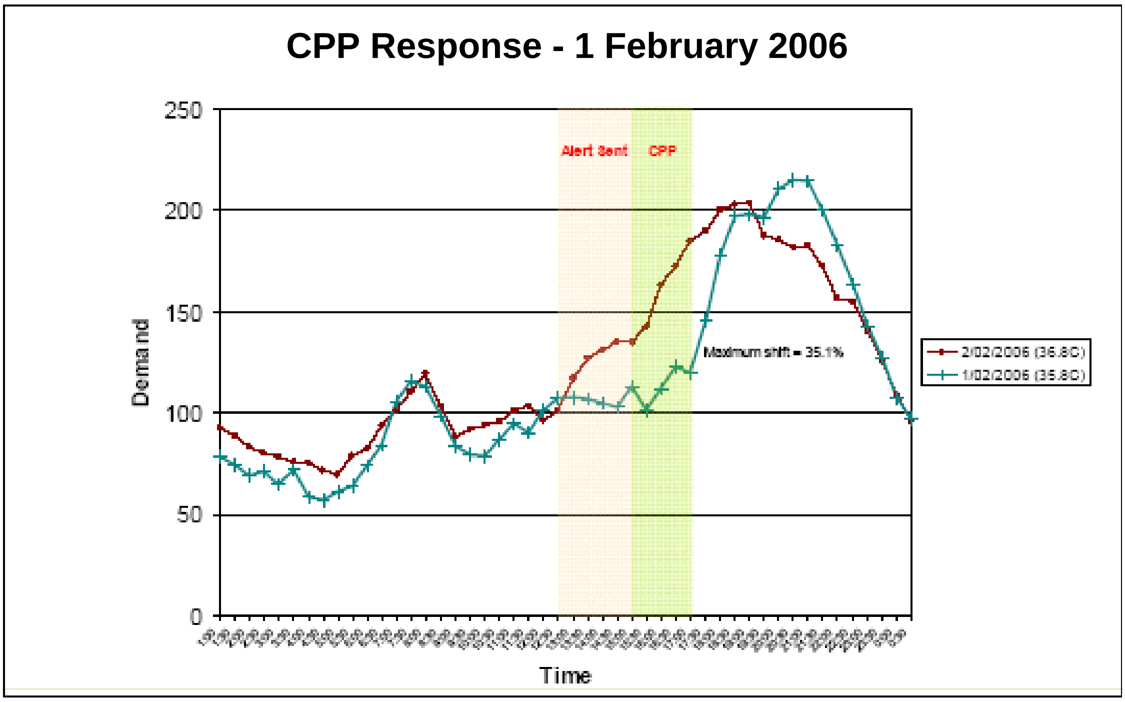

Figure 5. Impact of 1 February 2006 CPP Event in the Country Energy Trial[18]

3.3.2 EnergyAustralia Pricing Strategy Study - Australia

EnergyAustralia comprises two businesses, an energy retailer that sells electricity and gas to retail customers and an electricity distributor that owns and manages an electricity distribution network covering the eastern part of metropolitan Sydney, the New South Wales Central Coast and the regional city of Newcastle.

Peak loads on the Energy Australia distribution network are growing. Figure 6 (page 15) shows the annual aggregated load curve for the distribution network on weekdays in 2005/06; peak loads above 5000MW are coloured red. In winter, quite narrow peaks occur in the early evening caused by the use of electricity for space heating and cooking. In summer, broader peaks occur across most of the working day caused mainly by increased use of air conditioning. Figure 7 (page 15) demonstrates this more clearly by showing the occurrence during 2006/07 of peak loads above 5000MW.

The Pricing Strategy Study was initiated by EnergyAustralia's distribution business to investigate whether pricing measures could be used to reduce peak loads on the network. The purpose of the study was to investigate the effectiveness of critical peak pricing (CPP) in achieving peak load reductions on the distribution network.

[18] Source: Soussou, R. (2006). *Op. cit*.

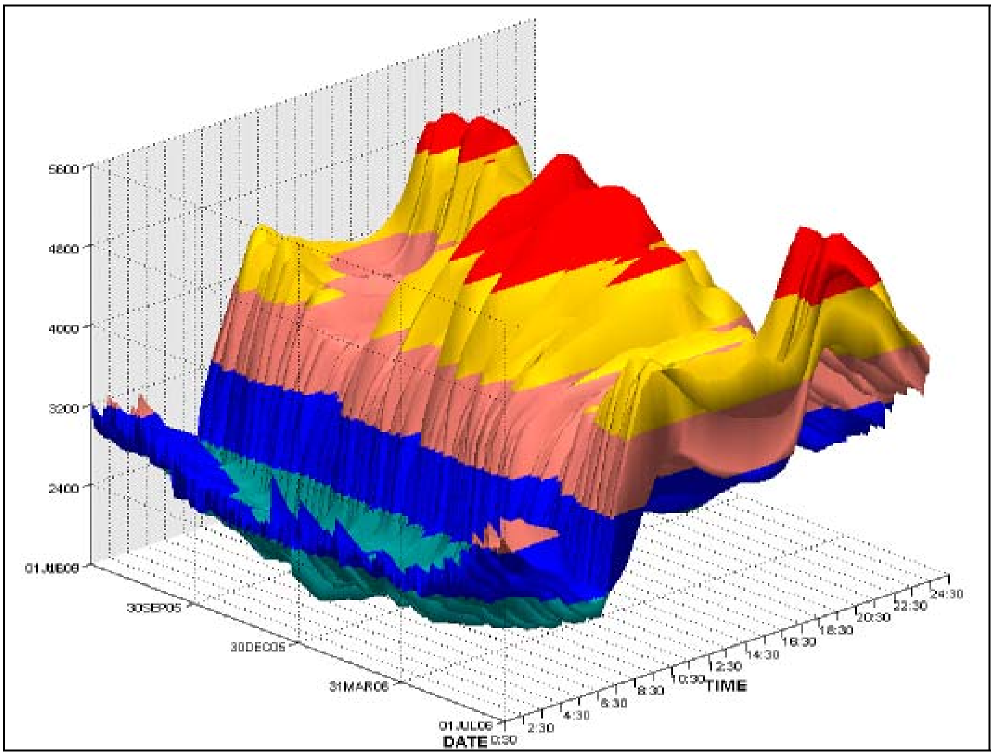

Figure 6. Aggregated Load Profile for the EnergyAustralia Network, July 2005 to June 2006[19]

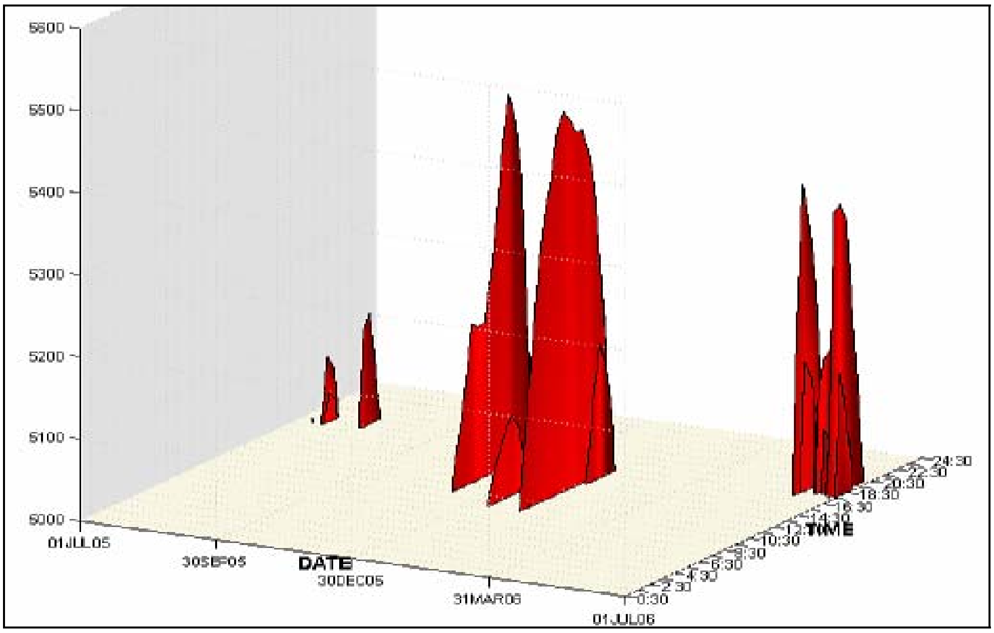

Figure 7. Peak Loads above 5000MW on the EnergyAustralia Network, July 2005 to June 2006[20]

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[19] Source: Miller, A. (2007a). *Strategic Pricing Study (SPS): Demand Response Results*. Presentation to EnergyAustralia Retailer Information Forum. Sydney, 9 May.

[20] Source: Miller, A. (2007a). *Op. cit.*

The study included about 750 residential customers and 550 business customers. All had a smart meter with GPRS communications installed in their premises and some had an in-house display connected to the meter by power line carrier technology.

The experimental groups comprised:
- a control group;
- a group provided only with information about peak load reductions;
- a group placed on a seasonal TOU tariffs;
- one group placed on a medium critical peak pricing tariff with an in-home display;
- two groups placed on a high critical peak pricing tariff with and without an in-home display.

The price levels for the critical peak pricing[21] tariffs are shown in Table 1. In the case of the DPP-M tariff the critical peak price level was set at 1052% of the Shoulder rate and for the DPP-H tariff the multiple was 2352%. The latter was one of the highest multiples set in any CPP tariff worldwide. The "shock" price of AUD2.00 per kilowatt-hour provided a stimulus for customers to manage or reduce consumption during the peak events.

Table 1`. Tariff Schedules Used in the EnergyAustralia Trial[22]

Tariff Component	SAC* ($/day)	Peak (¢/kwh)	Shoulder (¢/kwh)	Off peak (¢/kwh)
Tariff EA057 powerAlert medium (DPP-M)				
NUoS**	0.128	40	3.13	2.885
Retail	0.192	60	6.37	4.615
Total	**0.32**	**100**	**9.5**	**7.5**
Tariff EA058 powerAlert high (DPP-H)				
NUoS**	0.128	80	2.8	2.3
Retail	0.192	120	5.7	4.2
Total	**0.32**	**200**	**8.5**	**6.5**

*SAC = system availability charge
**NUoS = Network use of system charge

Some initial results with the DPP-H tariff are shown in Figure 8 and Figure 9 (page 17). As with the Country Energy trial, demand decreased significantly during the CPP period, but increased after the end of the period. On 22 February 2007, the reduction in peak demand was lower than on 11 January. This was probably because the temperature on 22 February was lower and therefore less discretionary load (eg from air conditioning) that could be reduced was available.

21 EnergyAustralia refers to critical peak pricing as "dynamic peak pricing" (DPP).

22 Amos, Chris (2006). *Advanced Tariff Design.* Presentation to Workshop on Advanced Metering. University of NSW, Sydney, 17 May.

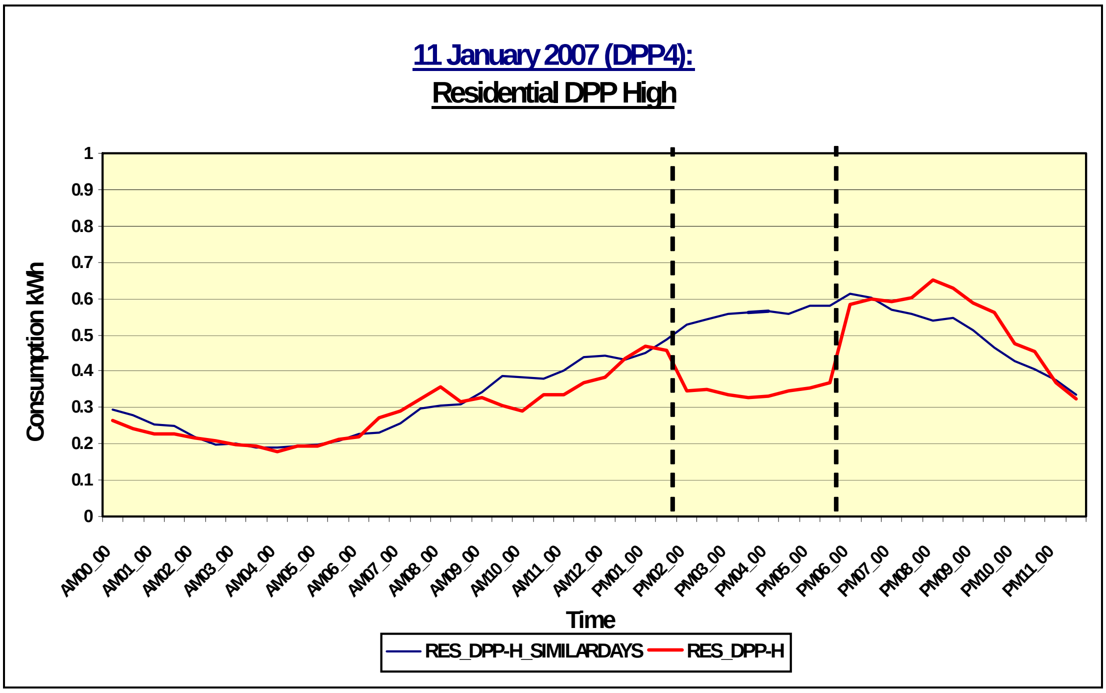

Figure 8. Impact of 11 January 2007 CPP Event in the EnergyAustralia Trial[23]

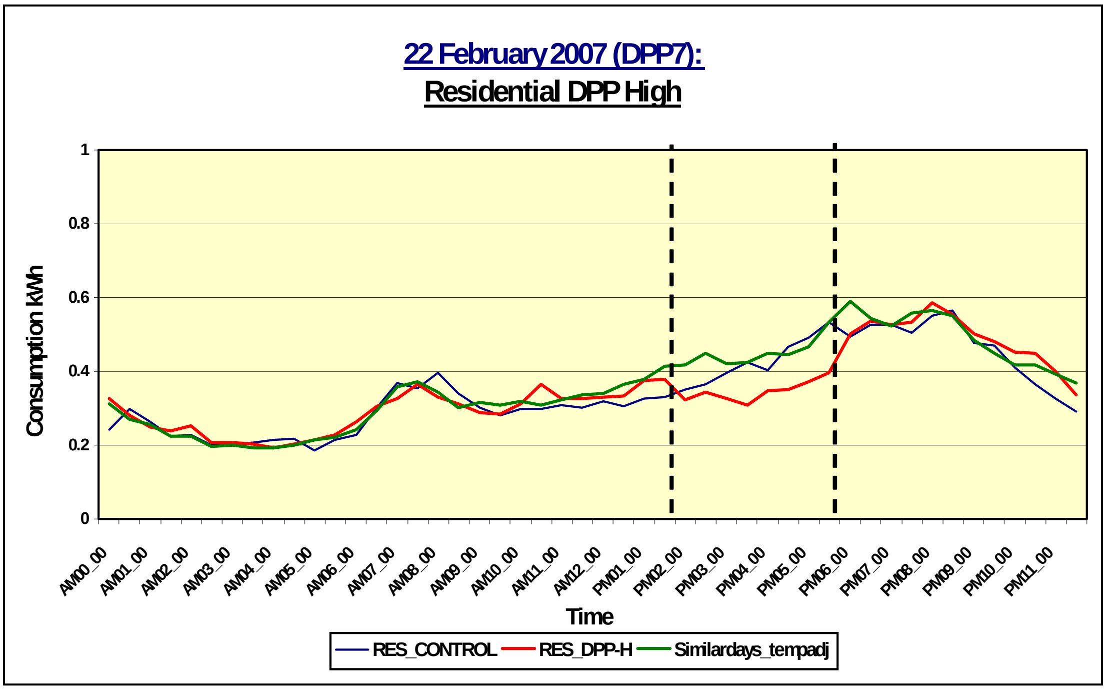

Figure 9. Impact of 22 February 2007 CPP Event in the EnergyAustralia Trial[24]

[23] Miller, A. (2007a). *Op. cit.*
[24] Miller, A. (2007a). *Op. cit.*

Figure 10 shows the average percentage consumption reductions on a day with a critical peak pricing event, for three situations:

- households with the medium DPP tariff plus an in-home display (DPPM);
- households with the high DPP tariff plus an in-home display (DPPH); and
- households with the high DPP tariff and no in-home display (DPPH-NIHD).

Figure 8 shows that, in summer, CPP tariffs achieved reductions in consumption during critical peak periods equivalent to reductions in total daily energy use on days with a CPP event of between 5.5% and 7.8%. The majority of this reduction came from energy conservation. On critical peak days, there was not a great deal of shifting of consumption from the critical peak period to shoulder, off-peak or non peak periods.

The EnergyAustralia trial also found that energy consumption during the critical peak period was between 21% and 25% of the total average daily consumption on non-critical peak day.

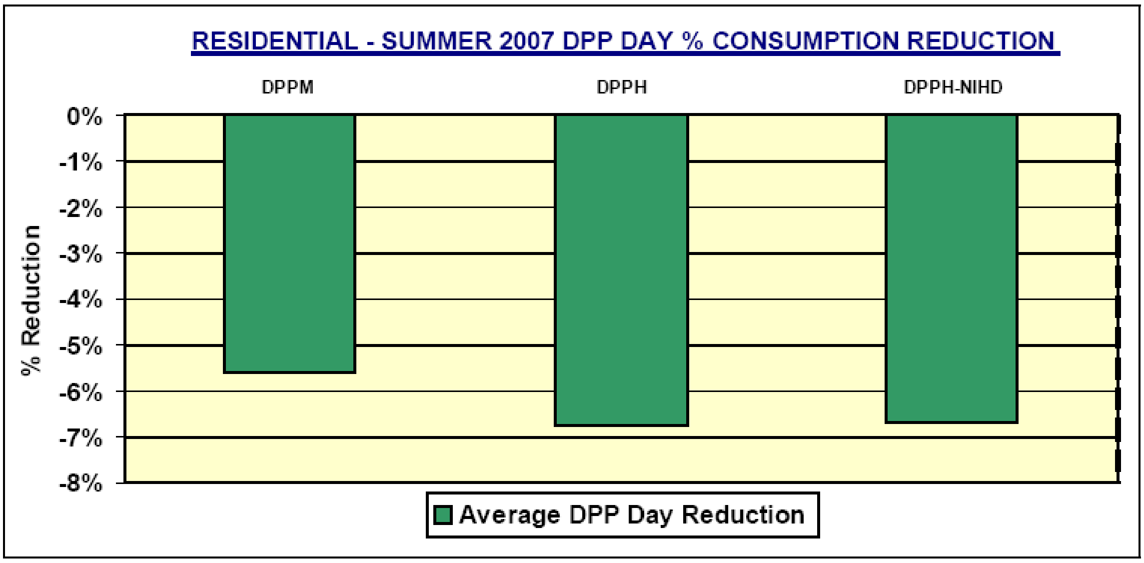

Figure 10. Average Reductions in Consumption on Days with a CPP Event in the EnergyAustralia Trial[25]

[25] Miller, A. (2007b). *Summer and Winter Demand Response from EnergyAustralia's Strategic Pricing Study*. Presentation to Demand Response and DSM Conference. Adelaide, 20 June.

3.3.3 California Statewide Pricing Pilot for Small Customers - USA

In 2000 and 2001, California experienced a so-called "energy crisis" that comprised short-term shortages of electricity generation capacity following the failure of the introduction of a competitive electricity market in the State. By 2002, the immediate short-term problems had been resolved, but longer-term shortages of both generation and transmission network capacity remained.

One of the lessons gleaned from California's energy crisis was that the lack of demand response in retail markets makes it very difficult to clear wholesale markets at reasonable prices. One method for introducing demand response in retail markets is time-varying pricing.

In December 2002, a working group established by the California Public Utilities Commission (CPUC) recommended that the State conduct a carefully designed pricing experiment with different tariff options prior to making a decision on full-scale deployment of the automated metering infrastructure required to support such time-varying rates.

The decision was made to implement a statewide experiment rather than utility-specific experiments to better leverage scarce budget resources and also to ensure consistency in results across the State. The CPUC approved the experiment, called the Statewide Pricing Pilot (SPP), in March, 2003. The SPP involved some 2,500 customers and ran from July 2003 to December 2004 for residential customers and to December 2005 for small commercial and industrial customers.

The experimental tariffs tested in the SPP for small customers with average monthly demands of less than 200 kW included a traditional time of use (TOU) rate and two dynamic pricing rates[26].

The TOU rates were implemented among a statewide sample of customers. Under the TOU rate, the price during the peak period was roughly 70 percent higher than the standard rate and about twice the value of the price during the off-peak period.

The dynamic rates included a critical peak pricing (CPP) element that involved a substantially higher peak price (about USD0.50 to USD0.75 per kilowatt-hour) for 15 days of the year and a standard TOU rate on all other days.

One type of CPP rate (CPP-F) was implemented among a statewide sample of customers. The CPP-F rate had a fixed peak period on both critical and non-critical days and day-ahead customer notification for critical day events. The peak period for residential customers was between 2 pm and 7 pm weekday afternoons and the peak period for small commercial and industrial customers was from noon to 6 pm on weekdays.

The other type of CPP rate (CPP-V) was implemented for residential customers only. The CPP-V rate had a variable-length peak period on critical days, which could be called not less than four hours ahead on the day of a critical event.

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[26] Charles River Associates (2005). *Impact Evaluation of the California Statewide Pricing Pilot. Final Report*. Oakland, California, CRA. Available at: http://www.energy.ca.gov/demandresponse/documents/group3_final_reports/2005-03-24_SPP_FINAL_REP.PDF

All SPP rates were seasonally differentiated with summer running from May through October inclusive for residential customers, and from the first Sunday in June through the first Sunday in October for small commercial and industrial customers.

In addition to the pricing initiatives described above, an “Information Only" program for residential customers was also tested. The program involved notifying customers on critical days and asking them to avoid energy use during the peak period. However, prices were the same on critical days as they were on all other days and customers did not face time-varying prices on any day.

CPP-V customers had the option of having an enabling technology installed free of charge to help facilitate demand response. One group of residential CPP-V customers ("Track A") could choose to go on the CPP-V rate with or without the installation of an enabling technology. Customers who chose a technology were given the option of having a control device installed on their central air conditioner, their electric water heater or their pool pump. A second group of CPP-V residential customers ("Track C") were recruited from participants in a pre-existing smart thermostat pilot. All Track C customers lived in single-family households with central air conditioning and had smart thermostats that automatically adjusted their air conditioning setting when critical peak prices were in effect.

Table 2 (page 21) summarises the key findings on reductions in peak-period energy use by residential customers resulting from the various tariff options tested in the Statewide Pricing Pilot.

Across the whole of California, CPP-F prices resulted in an estimated average reduction in peak-period energy use on critical peak days of 13.1 percent compared with an average reduction on normal (ie non-critical peak) weekdays of 4.7 percent.

With CPP-V rates, the reduction in energy use for Track A customers was almost 16 percent, which is about 25 percent higher than with the CPP-F rate; while the reduction in energy use for Track C customers was about 27 percent. Roughly two-thirds of the reduction observed for Track C customers could be attributed to the smart thermostat and the remainder was attributable to price-induced behavioural changes.

The 27 percent average reduction in energy use for the CPP-V rate with Track C customers is roughly double the 13 percent impact for the CPP-F rate. It is also substantially larger than the reduction achieved with the CPP-V rate and Track A customers, where only some customers took advantage of the enabling technology offer.

Table 2. Summary of Peak-Period Impacts by Treatment Type for Residential Customers in the California Statewide Pricing Pilot[27]

Treatment	Day Type	Avg. Price (¢/kWh)[1]	Impacts	Comments
Track A CPP-F	Critical Weekday	P = 59 OP = 9 D = 23 C = 13	-13.1% average summer -14.4% inner summer -8.1% outer summer	No statistically significant difference for inner summer between 2003 and 2004 (differences across the two years can not be estimated for the outer summer or the average summer)
	Normal Weekday	P = 22 OP = 9 D = 12 C = 13	-4.7% average summer -5.5% inner summer -2.3% outer summer	Difference between critical & normal days is primarily due to price differences and secondarily to differences in weather
Track A TOU	All Weekdays	P = 22 OP = 10 D = 13 C = 13	-5.9% inner summer 2003 -0.6% inner summer 2004 -4.2% outer summer 2003/04	Results are suspect because of the small sample size and observed variation in underlying model coefficients across the two summers. Recommend using normal weekday CPP-F model to predict for TOU rate.
Track A CPP-V	Critical Weekday	P = 65 OP = 10 D = 23 C= 14	-15.8% average summer 2004 Represents average across households with and without enabling technology—could not separate price & technology impacts	Not directly comparable to CPP-F results due to differences in population (CAC saturation for CPP-V treatment group twice that of CPP-F; CPP-V average income much higher; 2/3 of CPP-V customers had enabling tech.; all households located in SDG&E service territory)
	Normal Weekday	P = 24 OP = 10 D = 14 C = 14	-6.7% average summer 2004	See above comments about population differences
Track C CPP-V	Critical Weekday	Same as for Track A	-27.2% combined tech & price impact for average summer 2003/04 -16.9% impact for tech only -11.9% incremental impact of price over & above tech impact	Not directly comparable to Track A results due to population differences (All Track C customers are single family households with CAC located in SDG&E service territory). Some evidence that impacts fell between 2003 & 2004
	Normal Weekday	Same as for Track A	-4.5% average summer 2003/04	See above comments about population differences
Track A Info Only	Critical Weekday	13 for all periods	Statistically significant response in one of two climate zones in 2003. No response in 2004.	Analysis provides no evidence of sustainable response in the absence of price signals.

[1] P = peak period price; OP = off-peak price; D = daily price; C = control group price

The Information Only program was implemented in two climate zones. In 2003, demand response was statistically significant in one of the two zones, while in the other zone it was not. In 2004, there was no evidence of any response in either zone. From these results, it is possible to conclude that there is little demand response to requests to reduce energy use in the absence of a price signal. This conclusion is strengthened if the statistically significant impact in 2003 in a single climate zone is considered to be an anomaly.

[27] Charles River Associates (2005). *Op. cit*.

3.3.4 Tempo Electricity Tariff - France

The Tempo tariff is a longstanding TOU and CPP tariff that has been implemented in France since the early 1990s[28]. The purpose of introducing the Tempo tariff was to enable smoothing of both annual and daily electricity load profiles, therefore reducing marginal generation and network costs.

The Tempo tariff has six rates based upon the actual weather on particular days and on hours of use. Each day of the year is colour coded. There are three colours, blue, white and red which correspond to low, medium and high electricity prices. The number of days per year of each colour is fixed - there are 300 blue days, 43 white days and 22 red days. The colour of each day is determined mostly by the electricity generator and retailer, Electricité de France, based on the forecast of electricity demand for that day - the level of demand is mainly influenced by the weather (see Figure 11). Red days are usually called on the coldest days in winter. The French transmission network operator, Réseau de Transport d'Electricité (RTE), has the ability to determine the day colour if there is significant congestion on the electricity network.

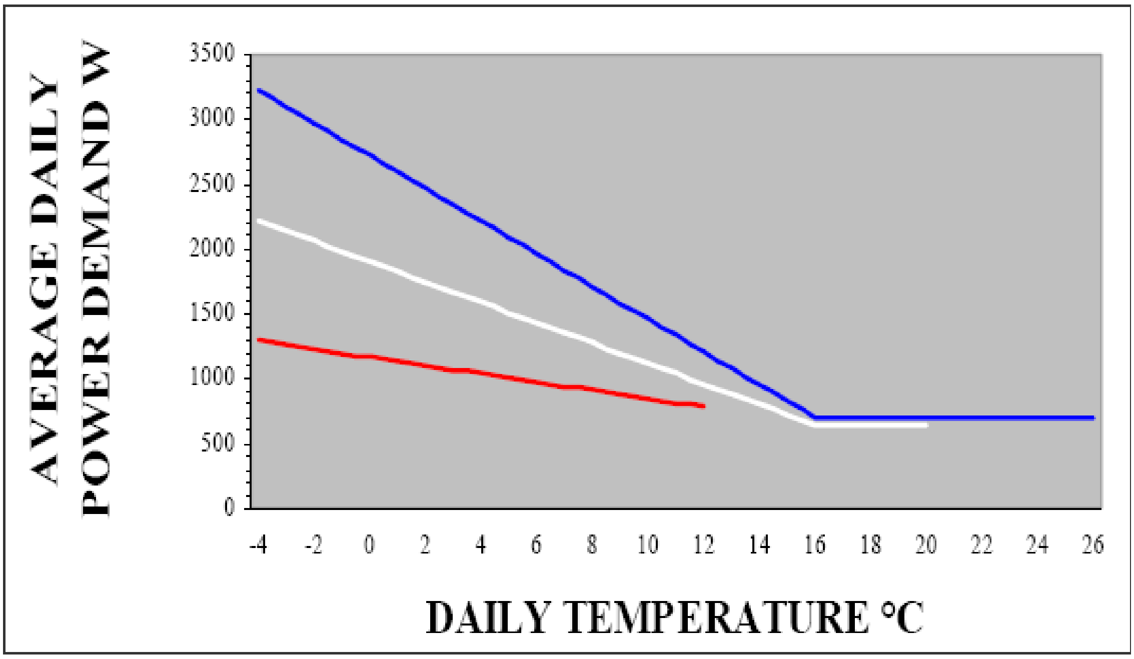

Figure 11. Tempo Customer Power Demand vs Outdoor Temperature[29]

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28 Kärkkäinen, S. (ed) (2004). *Energy Efficiency and Load Curve Impacts of Commercial Development in Competitive Markets: Results from the EFFLOCOM Pilots.* EU/SAVE 132/01 EFFLOCOM Report No 7. Available at: http://www.efflocom.com/pdf/EFFLOCOM report no. 7 Pilot Results.pdf

29 Giraud, D. (2004). *The Tempo Tariff*. Presentation to: EFFLOCOM Workshop. Trondheim, 10 June. Available at: http://www.efflocom.com/pdf/EDF.pdf

In June 2005, the prices for electricity purchased under the Tempo tariff were as follows:

Blue days off-peak:	2.99 euro cents
Blue days normal:	3.81 euro cents
White days off-peak:	6.51 euro cents
White days normal:	7.79 euro cents
Red days off-peak:	12.42 euro cents
Red days normal:	35.46 euro cents.

There are four different versions of the Tempo tariff, depending on the metering, communications and load control equipment installed at the customer's premises:

- standard Tempo (the customer has only an electronic interval meter);
- dual energy Tempo (the customer's space-heating boiler can be switched from one energy source to another);
- thermostat Tempo (the customer has load control equipment which is able to adjust space heating and water heating loads according to the electricity price);
- comfort Tempo (the customer has a sophisticated energy controller).

Customers who choose the Tempo tariff are informed each night about the colour for the next day. At 8 pm a signal is sent down powerlines using a ripple control system. Most Tempo customers have a display unit that plugs into any power socket and picks up the signal. The display unit shows the day colour with lights, both for the current day and (from 8pm) for the next day. An (optional) beep informs the consumer if the following day will be a red day. The display unit also shows whether or not the current electricity price is at the off-peak rate. For older systems without a display unit, the information is available over the telephone or via the internet.

Customers can adjust their electricity consumption manually by switching off appliances, adjusting thermostat settings, etc. Some customers who have the necessary communications and load control equipment are able to select load control programs which enable automatic connection and disconnection of separate water-heating and space-heating circuits.

There are approximately 100,000 customers on the Tempo tariff in France. Compared with blue days, the tariff has led to a reduction in electricity consumption of 15% on white days and 45% on red days. The average reduction is 1 kW per customer.

3.4 Effectiveness of Time-varying Tariffs

The results of trials and implementations of time-varying pricing show that this pricing strategy is effective in reducing peak loads. However, with the exception of the Tempo tariff in France, all the results reported here are from pricing trials that were implemented over relatively short time periods. There are some indications from other studies that the peak load reductions achieved may decrease over time as customers lose interest in carrying out the actions necessary to reduce their peak loads. Time-varying pricing coupled with load switching technology programmed to automatically respond to electricity prices (as in the California trial) may prove to be a more effective strategy for achieving customer behaviour change than pricing alone.

In some countries, the introduction of effective time-varying pricing is particularly complicated by the unbundling of the network and retail functions into separate electricity businesses. These separate businesses have quite different motivations for introducing time-varying pricing: network businesses want to reduce end-use customer loads at peak times on the network while retailers want to reduce loads at times of high prices in wholesale electricity markets.

In some countries with unbundled network and retail functions, customers receive separate electricity bills from the network and retail businesses. In other countries, customers receive a single bill in which the bottom line includes both network and retail charges set by the respective businesses. In this case, the bill is usually rendered to the customer by the electricity retailer. The retailer can choose to pass through any time-varying pricing established by the network business, or to simply charge the customer a time-invariant price, or to introduce time-varying pricing differently structured from that of the network business. Consequently, the pricing signal to the customer provided by the introduction of time-varying pricing by a network business may be diluted by the retailer in rendering the bill to the customer.

4. USING METERING DATA ANALYSIS TO REDUCE OVERALL LOAD

4.1 Analysing Data from Advanced Meters

Analysing data from advanced meters provides end-users with detailed information about the ways in which they use electricity and can enable businesses to identify and implement energy, cost and carbon savings. Energy savings reduce the overall load on the electricity network, therefore contributing to supporting the network.

4.2 Metering Data Analysis Programs

The first report from Task XV[30] includes one case study of a program that analysed data from advanced meters to achieve overall load reductions by small and medium enterprise businesses. The case study is also available on the Task XV website at: http://www.ieadsm.org/CaseStudies.aspx. Following is a summary of this case study.

4.2.1 Carbon Trust Advanced Metering Trial - United Kingdom

The Carbon Trust was set up by the United Kingdom Government in 2001 as an independent company and is funded by various government agencies. The Trust's mission is to accelerate the move to a low carbon economy by working with organisations to reduce carbon emissions and develop commercial low carbon technologies.

[30] Crossley, D.J. (2008). *Worldwide Survey of Network-driven Demand-side Management Projects*. Second edition. International Energy Agency Demand Side Management Programme, Task XV Research Report No 1. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

From 2004 to 2006 the Carbon Trust carried out the first UK field trial of advanced metering for small and medium enterprise (SME) end-users[31]. The trial aimed to demonstrate the potential benefits of the technology and understand the business case for encouraging widespread adoption of advanced metering by SMEs.

To deliver the field trial, the Carbon Trust contracted with seven consortia, all of which were already operating commercially in the metering market in the United Kingdom. The delivery consortia each recruited portfolios of SMEs or SME-like sites and installed advanced metering for electricity, gas and water at these sites as appropriate (not all utilities were metered at every site). A total of 582 sites across the United Kingdom were involved in the trial.

A total of 64 trial participants already had advanced electricity meters installed. For these sites no meter installation was necessary; all that was required was access to the existing half-hourly data. These sites were treated as a control group to investigate differences in use of advanced metering services between sites with and without existing interval metering. The findings from these sites were excluded from the bulk of the analysis in order to understand the potential for advanced metering in the SME sector where sites do not currently have interval metering in place.

Of the remaining sites, 73 made use of 'pulsed-output' meters with the capability to record half-hourly data through the use of clip-on readers. These readers allowed half-hourly data to be obtained without the need for upgrading the primary meter. At the remaining 455 sites, existing manually read meters were replaced with new advanced meters.

In addition to installing clip-on readers or new advanced meters at sites that did not already have interval metering in place, a variety of different types of energy saving advice were provided to sites during the trial. These services ranged from basic data provision to detailed advice on energy saving communicated through phone calls and site visits. Following are summaries of the types of energy saving advice provided.

Data Only. (134 sites, including 39 sites with pre-existing interval meters). The most basic offering was the provision of metered data only, normally via a website. Simple online tools were provided to allow sites to conduct basic analysis of their energy use profiles.

Data and Advice. (112 sites, including one site with a pre-existing interval meter). This intermediate level of service typically consisted of data provision together with a review of the site energy consumption and some basic energy saving recommendations relating to the site's energy use profile. This information was normally communicated via email.

[31] The Carbon Trust (2007). *Advanced Metering for SMEs: Carbon and Cost Savings*. London, the Trust. Available at: http://www.carbontrust.co.uk/Publicsites/cScape.CT.PublicationsOrdering/PublicationAudit.aspx?id=CTC713

Personal Contact. (336 sites, including four sites with pre-existing interval meters). This level of service involved two-way communications with the site including detailed discussion of the energy use profiles, either via telephone or site visits. The delivery consortia provided site-specific recommendations and advice.

Figure 12 shows how detailed half-hourly load profile data from advanced metering was used to identify opportunities for energy savings. Three key types of potential energy saving measures (corresponding to the numbers in Figure 10) could be derived from advanced meter data:

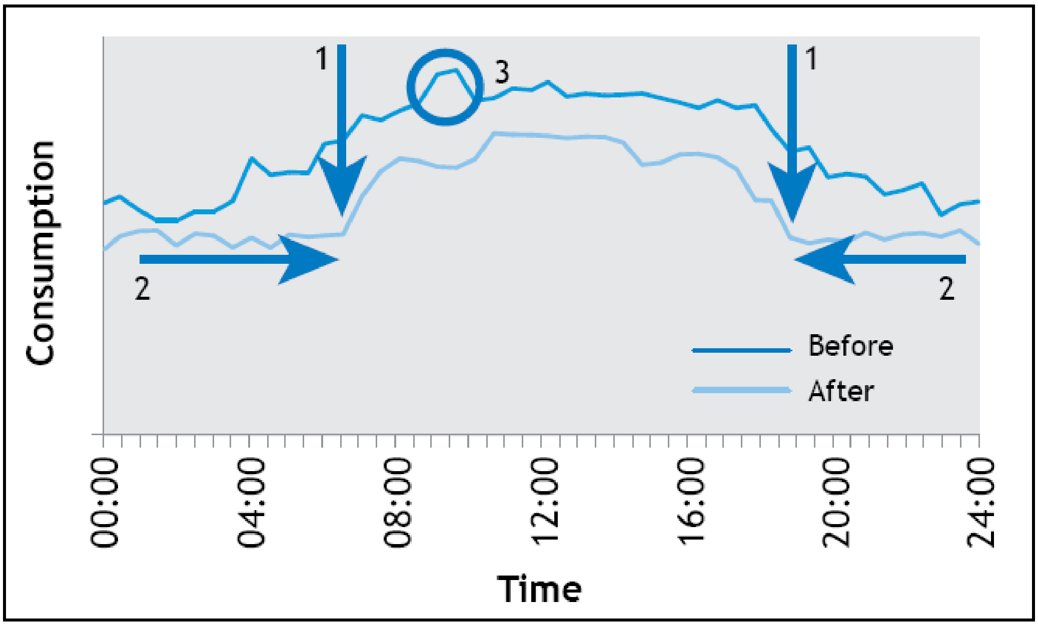

Figure 12. Using Load Profile Data from Advanced Metering to Identify Opportunities for Energy Savings [32]

1. **Base load reductions.** – the overall base load of the site could be studied and reduced, for example, by identifying unnecessary constant energy use.
2. **Process optimisation.** – the load profile could be used to identify what equipment is running and when. Altering the start-up and shutdown times of key processes and equipment could reduce consumption by limiting the duration of high energy usage at the start and end of working schedules.
3. **Peak usage reduction.** – the load profile could be used to analyse timings and frequencies to identify the causes of peaks in energy usage, such as particular activities or equipment.

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[32] Source: The Carbon Trust (2007). *Op. cit.*

The consortia completed log books for each site, tracking the estimated energy savings for each recommendation and the extent to which each recommendation was successfully implemented.

A case study was also produced for each site to describe the overall actions taken and associated savings made. These case studies recorded the situation at the site prior to installation of advanced metering, including details about the organisation and annual energy consumption levels. Case studies included graphical data showing energy consumption and areas where potential savings had been identified. They also included the financial case for implementing energy saving actions and the levels of potential savings in terms of energy consumption, carbon emissions and costs.

As part of this process, the consortia reviewed the half-hourly meter data to identify and validate actual energy savings achieved. Where it was not possible to implement energy saving recommendations, the reasons for this were discussed with the site personnel and recorded for reference.

Detailed results of the energy savings identified and successfully implemented by the SMEs involved in the trial are shown in Figures 13 and 14 (page 28).

Figure 13 shows that, on average, sites in the trial saved around 13,500 kilowatt-hours of electricity and 30,000 kilowatt-hours of gas per year by using the information gained from advanced metering. This equates to annual total savings across all sites in the trial of about 7,860 megawatt-hours of electricity and 17,460 megawatt-hours of gas.

Figure 14 shows the average cost savings identified and implemented per year. On average, sites in the trial saved around GBP870 on their electricity bills and GBP405 on their gas bills per year.

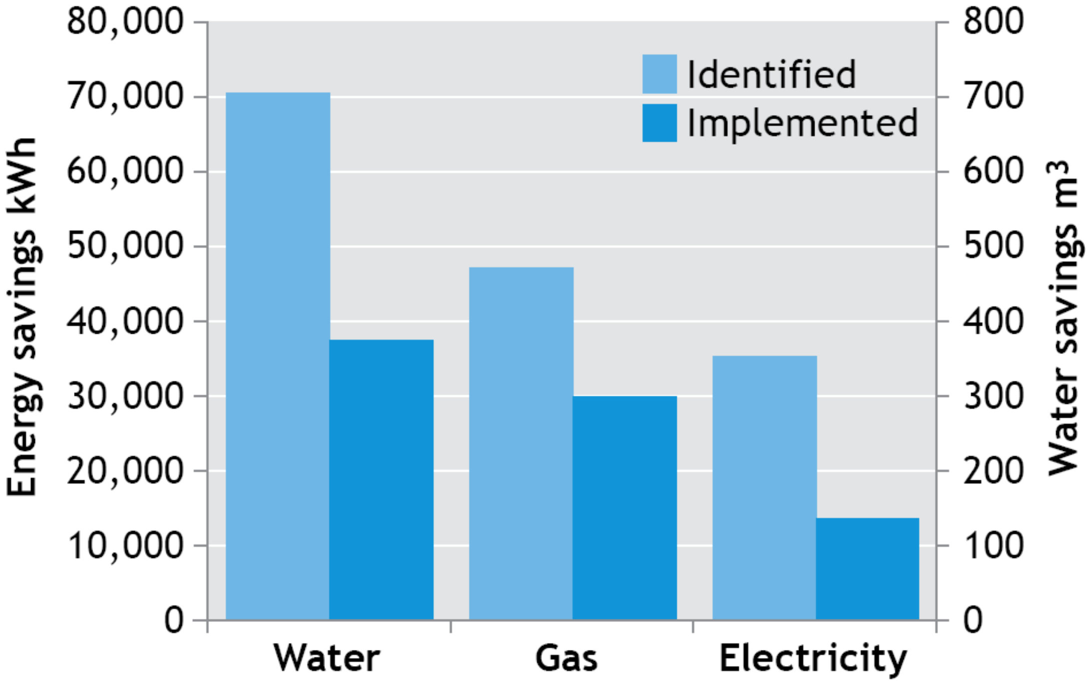

Figure 13. Average Annual Energy Savings per Site in the Carbon Trust Advanced Metering Trial [33]

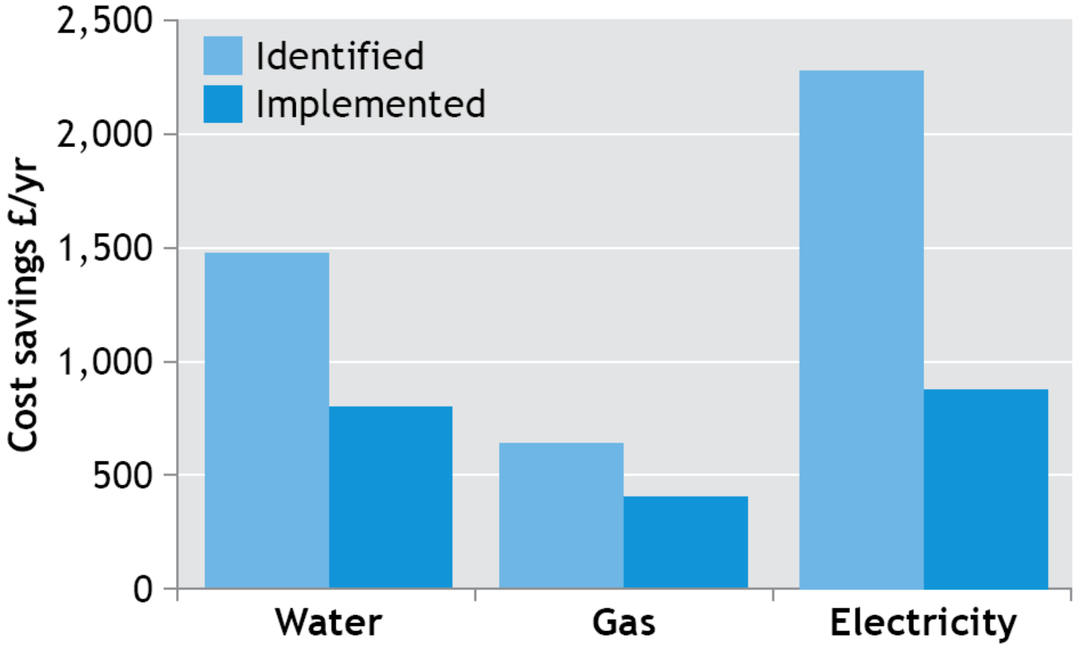

Figure 14. Average Annual Cost Savings per Site in the Carbon Trust Advanced Metering Trial [34]

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[33] Source: The Carbon Trust (2007). *Op. cit.*
[34] Source: The Carbon Trust (2007). *Op. cit.*

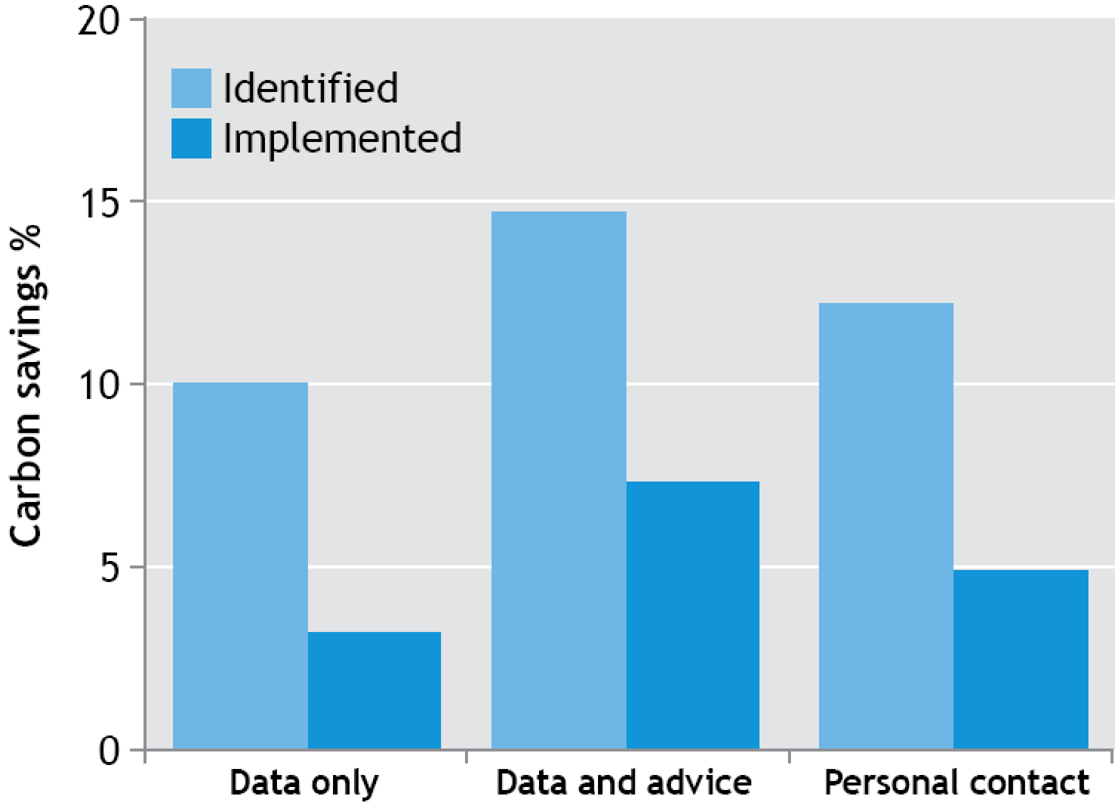

Figure 15. Carbon Savings by Type of Energy Saving Advice Provided in the Carbon Trust Advanced Metering Trial[35]

Figure 15 shows the percentage carbon savings achieved by the type of energy saving advice provided. The way in which energy saving advice was delivered to SMEs resulted in marked differences in the savings achieved.

The Data Only service, where customers were simply provided with remote online access to their energy usage data, led to the lowest levels of savings. However, even here 10% energy savings were identified and 3% implemented on average. These were significant savings, especially as this service was considerably less resource-intensive for the service provider to deliver.

Most notably, the Data and Advice service, where energy saving advice was provided remotely via email, led to the highest levels of energy savings, with an average of 15% savings identified and 7.5% successfully implemented. These savings are higher than those achieved for the Personal Contact service, in which advice was provided directly via site visits and telephone calls, where an average of 12.5% savings were identified and 5% implemented successfully.

[35] Source: The Carbon Trust (2007). *Op. cit.*

4.3 Effectiveness of Metering Data Analysis

The Carbon Trust trial showed that carrying out analysis of data from advanced metering can be highly effective in reducing overall load on electricity (and gas) networks, even when the data analysis is carried out by customers themselves rather than by an external service provider. However, the most effective mechanism comprised a service provider emailing to the management of a site tailored energy saving advice based on analysis of metering data from that particular site. This is a significant finding and there appears to be two key potential reasons for this result[36].

Firstly, when service companies provide advice via site visits and telephone calls, the advice is generally highly customised and there is a tendency to focus on high value-added recommendations. These are likely to lead to more complex process-based changes or more expensive investment-based actions. There is also less focus on providing generic energy saving recommendations, such as simple information-based or process-based changes.

Secondly, energy saving advice which arrives via email is readily available and more likely to be looked at and acted upon directly than more conventional energy audit reports. This is especially true when the email contains simple, intuitive graphical information, such as daily energy consumption profiles. Also, the email format allows the information to be easily forwarded on to staff within the organisation to take the relevant actions, for example operations or facilities management personnel.

A key implication of this finding is the possibility of providing advanced metering services at significantly lower costs in the future. The email service model is highly scalable and it would appear feasible that automated systems could be used to analyse energy usage profiles, identify appropriate recommendations and automatically email these to the customer, with supporting graphical evidence. Such an automated service, backed up with call centre support, would allow for a significantly lower-cost service model than one involving on-site or telephone-based analysis and discussion.

This model for delivering energy saving advice could be easily adapted to deliver advice on reducing peak loads rather than reducing overall energy consumption.

5. USING LOAD CONTROL TO REDUCE PEAK LOADS

5.1 Characteristics of Load Control

Load control comprises a system or program that enables end-use customer loads to be changed in response to particular events such as periods of high electricity prices or problems on the electricity network.

Load control systems have the following characteristics:

- the program operator for the load control system may be:
  - an electricity retailer or distributor;
  - a market or system operator; or
  - a demand response service provider.

[36] The Carbon Trust (2007). *Op. cit.*

- switching of end-use customer loads may be:
  - carried out *locally* by the customer manually turning down or switching off appliances and equipment in response to a request from the program operator, or
  - initiated *remotely* by a signal sent from the program operator[37] through direct communication links to the customers' electrical equipment; a second signal is sent to restore normal operation at the conclusion of a program event;
- switching of loads may involve:
  - *cycling* loads on and off according to pre-set timing schedules;
  - *reducing* loads to pre-set levels; or
  - *switching off* loads completely.

5.2 Load Control Technologies

A complete load control system consists of three basic elements as shown in Figure 16:

- technology located at the program operator's premises;
- communications technology; and
- technology located at the customer's site.

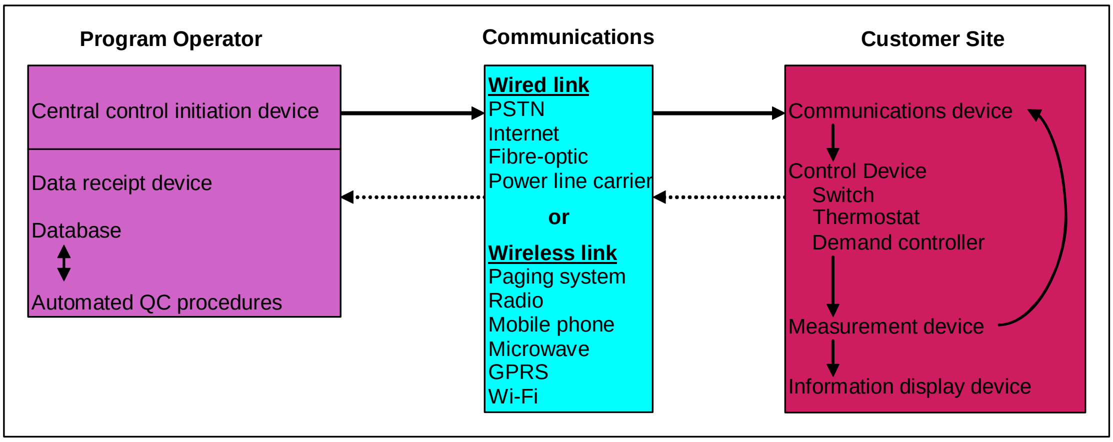

Figure 16. Load Control System Components[38]

[37] The signal may be sent manually by the program operator or automatically in response to trigger events such as exceedances of pre-set electricity price levels or pre-set load levels on particular network elements, or excursions outside pre-set frequency or voltage parameters.

[38] Modified from: Lockheed Martin Aspen (2006). *Demand Response Enabling Technologies for Small-Medium Businesses*. Rockville, Maryland, LMA. Available at: www.energetics.com/madri/pdfs/LMADRT_060506.pdf

5.2.1 Technology at the Program Operator's Premises

Load control technology at the program operator's premises has two functions:

- **Load Control Initiation:** The program operator must be able to generate and send signals to initiate (and terminate) a load control program event. With locally-switched load control, the signals are sent to the customer, and can be as simple as phone calls or email messages. With remotely-switched load control, coded signals are sent directly to the customers' appliances and equipment and instruct them how to respond[39].
- **Data Receipt and Storage:** For operational and billing purposes, the program operator requires data about the quantity and timing of load reductions achieved through the load control program. Some load control systems include two-way communication links between the program operator and the controlled loads which allow this data to be collected in near real time. However, many load control programs have only one-way communications and rely on data acquired some time after load control events, eg from electricity meters at customer sites.

5.2.2 Communications Technology

Communication technology for load control programs enables signals to be sent by the program operator and, if the communications links are two-way, also enables the program operator to receive data from the controlled loads.

A range of wired and wireless communications technologies can be used in load control programs, as shown in Figure 14 (page 28). Costs vary quite widely depending on the actual communications technology used.

5.2.3 Technology at the Customer Site

Load control technology at the customer site has four functions:

- **Communications:** Signals sent by the program operator must be received at the customer site and conveyed to selected customers' appliances and equipment. If the communications technology is two-way, it will also enable communication of information about the controlled loads back to the program operator, including data from a load measurement device, such as an electricity meter, and verification that remote switching has been successful.
- **Controlling Appliances and Equipment:** The appliances or equipment which are to be controlled must be able to respond to the signals sent by the program operator. With locally-switched load control, the customer will simply use the existing switches in the appliances or equipment to manually turn them down or switch them off. With remotely-switched load control, a range of control devices that can respond to signals from the program operator may be attached to the appliances or

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[39] In some countries, ripple control signals have been used for over 50 years to remotely switch off-peak appliances such as water heaters and storage space heaters. Ripple control works by superimposing a small coded audio frequency wave on to the normal 240 volt 50 herz electricity supply. Signals are sent very slowly to ensure reliable reception by ripple control receivers located anywhere on the electricity network. More recently, other technologies have been developed to carry out this remote switching function.

equipment. These devices may include simple on-off switches, programmable thermostats, and sophisticated programmable demand controllers.

- **Load Measurement:** The program operator must be able to measure the load reductions achieved through the load control program. This requires a load measurement device which is usually an electricity meter. Accumulation meters measure total energy consumption but the information is recorded relatively infrequently when the meter is read. With accumulation meters, statistical methods must be used to estimate the load reductions resulting from a load control program. Interval meters automatically measure and record energy use over many, relatively short, time intervals. Interval meters can be used to directly measure load reductions resulting from a load control program.
- **Information Display:** Some load control programs make use of information display devices ("in-home displays") to provide information to end-use customers about their electricity usage and costs. The information provided may include: the current electricity tariff, the current energy consumption in the customer's premises, the cost of the current energy consumption, and various messages and alerts about load control events, times at which TOU tariff levels will change, etc.

5.3 Load Control Programs

The first report from Task XV[40] includes several case studies of the implementation of load control to support electricity networks, particularly by reducing peak loads. The case studies are also available on the Task XV website at: http://www.ieadsm.org/CaseStudies.aspx. Following are summaries of some of these case studies.

5.3.1 ETSA Utilities Air Conditioner Direct Load Control Program - Australia

ETSA Utilities is an electricity distributor in the State of South Australia. ETSA is undertaking trials of residential air conditioner cycling to assist with the summer supply/demand imbalance coupled with an extremely peaky load profile in South Australia.

Following an initial trial involving 20 residential customers, ETSA developed a much larger air conditioner direct load control pilot program for the 2006/07 summer[41]. An area in metropolitan Adelaide (Glenelg/Morphettville) was selected for the pilot program. This area was chosen because it is supplied by two substations that are expected to become constrained by 2011. In the absence of initiatives to reduce peak

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40 Crossley, D.J. (2008). *Worldwide Survey of Network-driven Demand-side Management Projects*. Second edition. International Energy Agency Demand Side Management Programme, Task XV Research Report No 1. Hornsby Heights, NSW, Australia, Energy Futures Australia Pty Ltd.

41 Essential Services Commission of South Australia (2007). *ETSA Utilities Demand Management Program Progress Report*. Adelaide, the Commission. Available at: http://www.escosa.sa.gov.au/webdata/resources/files/070628-R-DemandManagementProgress_Report-_Final_.pdf

demand, augmentation of the distribution network would be required by that date. A target load reduction of 2.2 MVA was established for the pilot program.

ETSA initiated the pilot program in June 2006 with a media marketing and community education campaign, entitled "Beat the Peak". The campaign primarily targeted the 12,000 residential customers in the selected region and was designed to secure volunteers to participate in the program. Participating customers were offered a cash incentive of AUD100. A direct marketing campaign (mailout, local advertising, etc) was also used. The marketing campaign attracted significant media coverage, with general support expressed for DSM.

Approximately 4,000 residential customers expressed interest in participating in the pilot program as a result of the overall marketing campaign. From this response, ETSA Utilities identified about 1,700 residential air conditioners that were suitable for the program, comprising either split or ducted refrigerative systems. In many cases, air conditioners were deemed unsuitable, being either window installed or portable refrigerative systems, ducted or portable evaporative systems, or ceiling fans. ETSA also visited every commercial customer in the trial area and identified a further 700 air conditioners in commercial premises that were suitable for the trial.

In total, about 2,400 air conditioners were identified for the pilot program. To monitor demand impacts during the program, ETSA installed metering equipment in some customer premises, as well as on ten 11 kV feeders and 86 street transformers.

For this pilot program, ETSA, in conjunction with the Adelaide-based Saab Systems Pty Ltd, developed a small direct load control device (the "Peak Breaker") to be attached to the external compressor of air conditioners (see Figure 17, page 35). This device requires only a simple installation procedure lasting up to 30 minutes with no internal access to premises needed.

However, about half of the 2,400 air conditioners initially deemed suitable for the pilot program were found to be "new generation" units with advanced internal electronic diagnostics that effectively prevented the Peak Breaker from overriding the compressor. These air conditioners were unsuitable for the installation of the Peak Breaker.

The penetration of new generation air conditioners was far higher than had been expected (the air conditioning industry had advised a likely figure of 10%). Ultimately, ETSA determined that approximately 1,100 (from the sample of 2,400) air conditioners were suitable for installation of the Peak Breaker, while a further 1,160 new generation units would require the development of a different form of direct load control device.

Figure 17. Saab Systems “Peak Breaker” Direct Load Control Device

For the summer of 2006/07, approximately 750 air conditioners (from the pool of 1,100) were fitted with the simple Peak Breaker device that switched the air conditioner compressors directly. The system for communicating with the devices is shown in Figure 18 (page 36). The Peak Breakers were activated in a random sequence when signals were sent via the internet to a public radio station which then transmitted the signals to the Peak Breakers. The system was able to communicate with subsets of the Peak Breakers based on substation, product group or individual customer level.

Site level monitoring with interval meters was carried out during peak demand days at 90 randomly selected sites, with the remaining sites being monitored at the street transformer level. Monitoring also occurred through the SCADA system operated by ETSA to demonstrate the impact at the 66 kV sub-transmission system at times of peak demand. In addition, the distribution transformers and 11 kV substation feeders were equipped with metering equipment with remote communications capability allowing interval data to be collected as required.

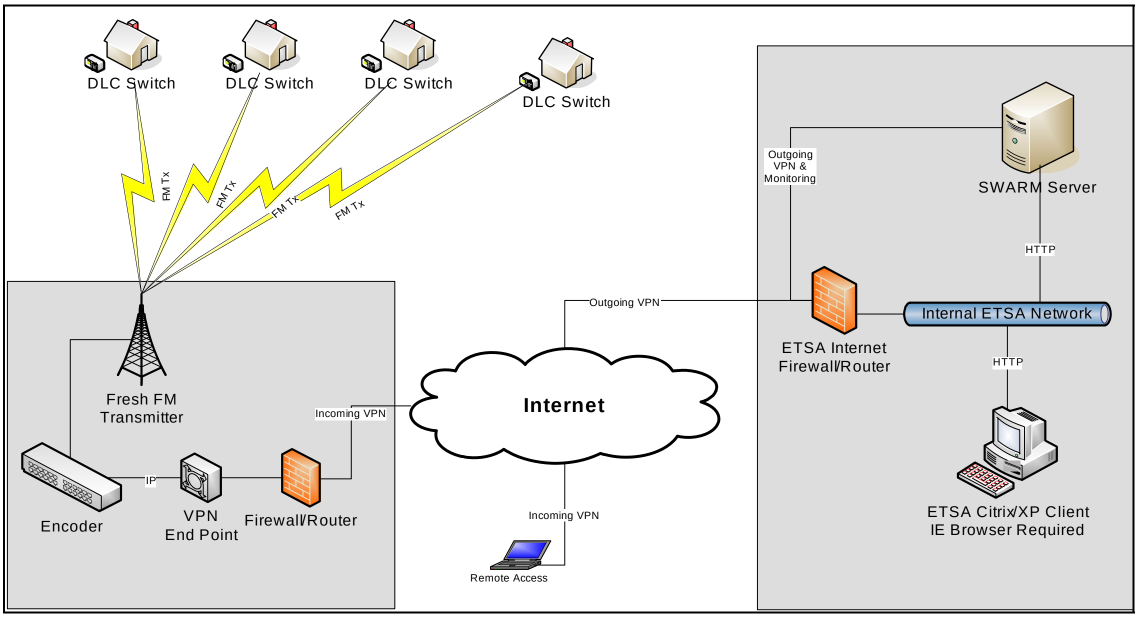

Figure 18. Communication System for the ETSA Utilities Air Conditioner Cycling Pilot Project [42]

Application of direct load control at the 750 sites commenced in December 2006. A range of control strategies were tested at various times on peak demand days, including cycling the air-conditioners for different lengths of time over different periods of the day. The following switching periods were used to assess the impacts of different switching protocols:

- 8 minutes off in 30 minutes;
- 15 minutes off in 30 minutes (the 'normal' switching period used in the United States);
- 30 minutes off in 60 minutes – used twice on selected street transformers;
- 25 minutes off in 60 minutes – used for one period.

Switching of 15 minutes off in 30 minutes was tested on four occasions and no customer complaints were received regarding comfort levels. ETSA Utilities concluded that residential air conditioning customers can sustain that level of switching.

Figure 19 (page 37) demonstrates the impacts on peak demand resulting from the cycling of air conditioners in a group of 68 premises during the pilot program. The Figure shows the aggregate load profile, with no load curtailment, for days with maximum temperatures of 35 degrees and 40 degrees Celsius, and the average profile for those two days.

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42 Source: Twisk, R. (2007). *ETSA Utilities Demand Management Program*. Presentation to Demand Response and DSM Conference. Adelaide, 20 June.

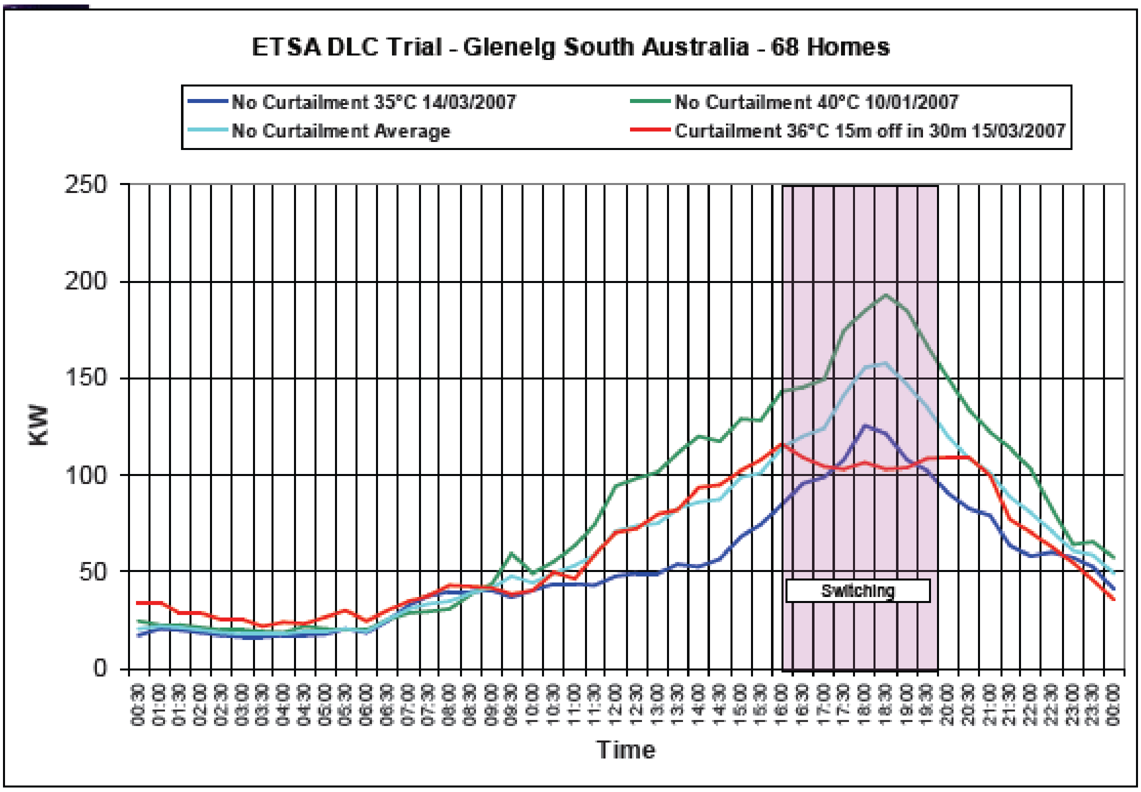

Figure 19. Results of the ETSA Utilities Air Conditioner Cycling Pilot Project [43]

Figure 19 also shows the profile for a day with maximum temperature of 36 degrees Celsius in which the air conditioner at each premises was cycled between 4pm and 7.30pm. A significant reduction in peak demand was achieved for this day, equivalent to about 40 kW, in comparison with the average peak demand of the two days for which there was no air conditioner cycling.

One important conclusion from the pilot program was that achieving effective load reductions requires a random overlapping switching program; non-random switching protocols resulted in a "saw tooth" demand profile.

5.3.2 LIPAedge Direct Load Control Program - USA

The LIPAedge program was developed by Long Island Power Authority (LIPA) to use central control of residential and small commercial air-conditioning thermostats to achieve peak load reduction[44].

[43] Source: Twisk, R. (2007). *Op. cit.*

[44] Long Island Power Authority (2002). *LIPAedge*. PowerPoint presentation to the New York Independent System Operator Price-Responsive Load Working Group, November 21. Available at: www.nyiso.com/public/archive/webdocs/committees/Price-Responsive_Load_WG/2002-11-21/3_lipa_presentation.pdf

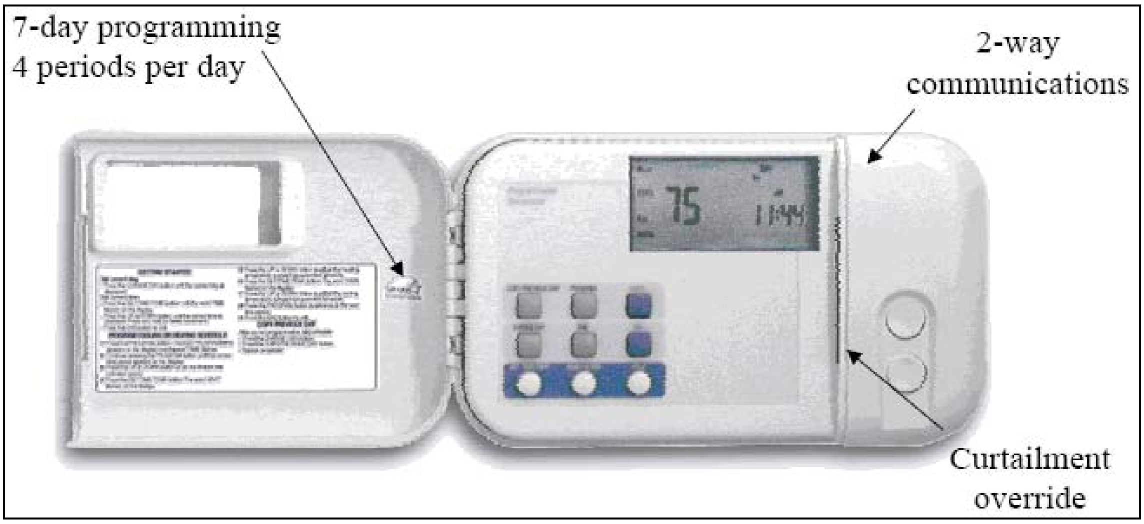

Figure 20. ComfortChoice Thermostat Used in the LIPAedge Program

The LIPAedge program is based on the programmable ComfortChoice thermostat (see Figure 20). The system operator uses an internet-based system to control a demand-side resource comprising about 20,000 thermostat-controlled air conditioners. Skytel two-way pagers are used to transmit a curtailment order to the thermostat and to receive acknowledgment and monitoring information. One or more pager signals are generated and transferred to the SkyTel pager network (see Figure 21).

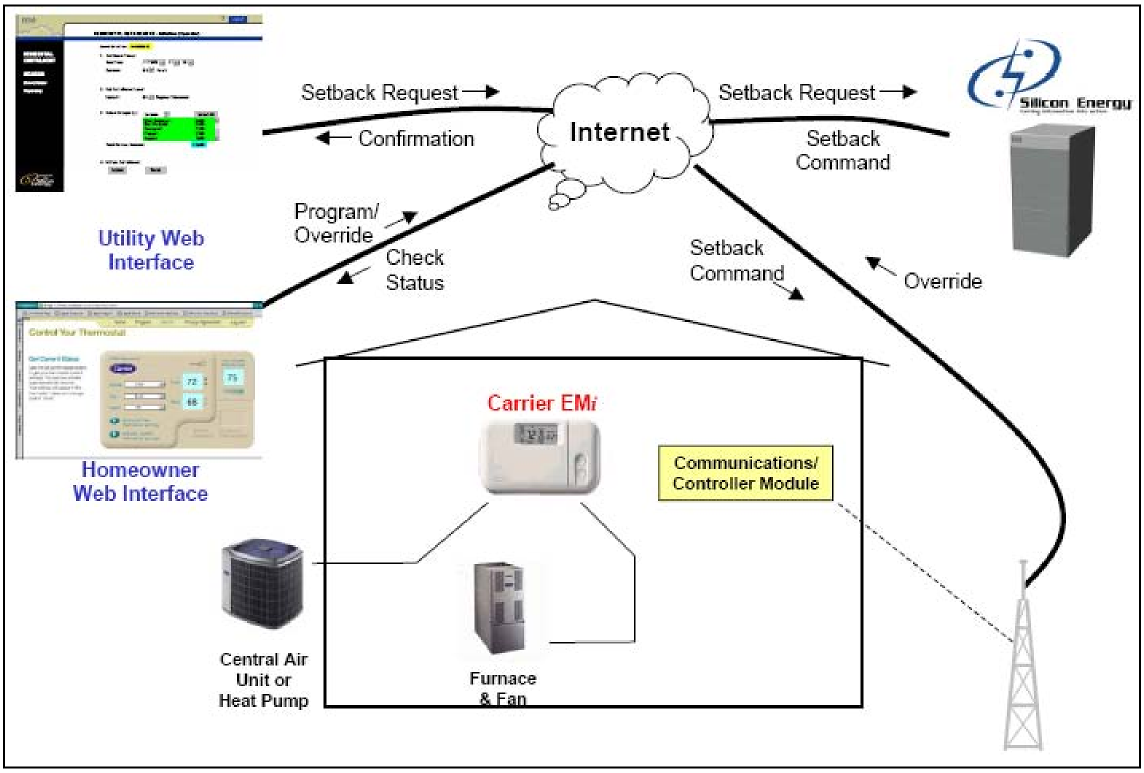

Figure 21. The Carrier/Silicon Energy Direct Load Control System for the LIPAedge Program

Commands go via satellite to pager towers, where they are broadcast to the thermostats. The thermostats take immediate action or adjust their schedules for future action, depending on what the system operator ordered. The thermostats log the order and respond via pager, enabling LIPA to monitor the response to the event. The thermostats also collect data every minute on temperature, set point, and power consumption (hourly duty cycle). They retain this information as hourly averages and report it to the utility. The thermostat itself holds 7 days of hourly data.

For a summer load curtailment, the system operator might send a command at 9:00 am directing all thermostats to move their set points up four degrees, starting at 2:00 pm and ending at 6:00 pm. Alternatively, the system operator could send a command directing all thermostats to completely curtail immediately. The command would be received and acted upon by all loads, providing full response within about 90 seconds. This is far faster than generator response, which typically requires a 10-minute ramp time.

Thermostats can be addressed individually, in groups, or in total. This important advantage provides both flexibility and speed. System operator commands that are addressed to the entire resource are implemented through a single page that all thermostats receive. Similarly, 15 subgroups can be addressed if response is required in a specific area to alleviate a transmission constraint. Thermostats can be addressed individually as well. This capability is useful for monitoring the performance of the system (each thermostat is checked weekly for a “heartbeat”).

The customer also receives benefits. The thermostat is fully programmable and remotely accessible, with all of the associated energy savings and convenience benefits. A web-based remote interface is provided for customer interaction. Customers can also override curtailment events. This feature appears to be important to gain customer acceptance and it probably increases the reliability of the response.

Two-way paging communication enables the utility to monitor load performance both during response events and under normal conditions. Response from the thermostats is staggered over a time period set by the utility to avoid overwhelming the paging system. It typically requires 90 minutes for 20,000 thermostats to respond. Thus the system provides for performance monitoring but not in the 2 to 8-second intervals typical for large generators.

The LIPAedge program is available for Residential Central Air Conditioning customers and Small Business customers, though the program is now closed to new participants. Customers who sign up to the LIPAedge program receive a ComfortChoice thermostat and installation free of charge. Customers also receive a one-time bonus payment of USD 25 (residential customers) or USD 50 (small commercial customers).

LiPAedge customers agree to have their central air conditioning system adjusted between the hours of 2 pm and 6 pm for a maximum of seven days throughout the four month summer season. Customers have access to a dedicated web page for their thermostat and are able to remotely change the set point of their air conditioner whenever they want.

LIPA initiates curtailment events by either increasing the set point on LIPAedge thermostats by 3 to 4 degrees, or by cycling air conditioner compressors off for a portion of each hour

Customers can override curtailment messages sent to their thermostat, though LIPA encourages its customers not to override during a curtailment event. If the customer decides to override the curtailment, the change is recorded by the thermostat and a wireless message is then sent back to the central server.

LIPA collected name-plate power consumption information on the air-conditioning equipment being controlled when it installed the ComfortChoice thermostats for the LIPAedge program. It also directly measured the power consumption of a subset of those loads to estimate the actual load of the aggregation. LIPA determined that the average capacity of residential air-conditioning units being controlled was 3.84 kW, while the average capacity of small commercial units was 6.38 kW. The total 23,400 individual loads had a peak capacity of 97.4 MW if all the units were on at 100% duty cycle.

LIPA monitored the performance of 400 units from 1 May 2002 through 29 September 2002. Hourly data were collected from each unit for duty cycle and facility temperature. Those data were used to estimate the performance of all 23,400 responsive loads. LIPA found that each controlled load provided an average of 1.06 kW of demand reduction (1.03 kW per residential air-conditioner and 1.35 kW per small commercial air-conditioner). LIPA expected 24.9 MW of peak reduction response from the full 23,400 controlled air-conditioners.

5.3.3 California Automated Demand Response System Pilot – USA

Following the so-called 'energy crisis' during 2000 and 2001 in California, the California Public Utilities Commission (CPUC) approved several trials and pilot programs designed to achieve increased demand response in the State. One of these was a pilot of an automated demand response system (ADRS) in the residential sector. The pilot ran from July 2004 to the end of December 2005. The ADRS pilot was a small-scale exploratory program deploying automated energy management technology in 175 California households.[45]

The ADRS pilot was closely associated with the Statewide Pricing Pilot (SPP), a pricing experiment with several different time-varying tariff options. The SPP was approved by the CPUC prior to making a decision on full-scale deployment of the automated metering infrastructure required to support such time-varying rates.

The ADRS pilot participants were first recruited in 2004 from owner-occupied, single-family homes in a warm climate zone, located in neighbourhoods served by appropriate television cable providers. Householders who participated in the ADRS pilot received incentive payments of USD100 in 2004 and USD125 in 2005.

[45] Rocky Mountain Institute (2006a). *Automated Demand Response System Pilot Final Report. Volume 1: Introduction and Executive Summary*. Boulder, Colorado, RMI. Available at: http://www.energy.ca.gov/demandresponse/documents/group3_final_reports/2006-08-09_DR_VOL1_EXECUTIVE_SUMMARY.PDF

The original 175 homes that participated in the ADRS pilot were recruited at random regardless of historical consumption, although homes were screened for eligibility with respect to presence of central air conditioning, within prescribed zip codes. Because ADRS technology is capable of controlling end uses in the home in addition to central air conditioning, homes were screened for availability of other loads (ie swimming pool pumps and spas), but not disqualified from participation in their absence.

The ADRS pilot participants had the GoodWatts system, an Invensys Climate Controls product, installed in their homes. GoodWatts is an "always on", two-way communicating, automated home climate control system with web-based programming of user preferences for control of home appliances. Via the internet, homeowners with GoodWatts can set climate control and pool or spa pump runtime preferences and view these settings at any time both locally and remotely. Participants can also view whole-house or end-use specific demand in real time and display trends in historical consumption.

The energy management technology included the following components:

- wireless RF communications network connecting all system components;
- two-way communicating whole-house interval electricity meter capable of recording consumption data in 15-minute intervals;
- wireless internet gateway and cable modem;
- programmable smart thermostats used to control air conditioning loads;
- load control and monitoring (LCM) devices to manage other selected loads (eg pool pumps and spas), where these were present;
- web-enabled user interface and data management software.

GoodWatts allows users to view at all times the current electricity price on-line or via the thermostat. It also allows users to program the thermostat and the pool/spa LCMs to automatically respond to changes in electricity prices. For example the devices can be set to automatically reduce load once a threshold electricity price is reached.

To complement the installed ADRS technology, ADRS participants were placed on a time-varying electric tariff schedule called CPP-F. CPP-F was a time-of-use (TOU) tariff, which included a critical peak pricing (CPP) element. Prices were high during the peak period between 2 pm and 7 pm on every weekday ("non-event" days). Higher critical peak prices were imposed during the peak period on event days ("Super Peak" days).

With slight variations, the CPP-F rate charged ADRS participants USD0.09/kWh in off-peak times, USD0.23/kWh during the peak period on non-event days and USD0.73/kWh during the peak period on Super Peak days. These rates compared with the participants' typical previous rate of USD0.13/kWh throughout the day.

Participating households received instruction manuals, online personalised energy information, and access to a customer service help desk to help them cope with the CPP-F tariff.

In 2004, 12 Super Peak events were called and in 2005 there were 11 such events. ADRS customers were notified by phone and email during the day before a Super Peak event.

The results for the ADRS pilot were generally reported as load reductions achieved by "high consumption" households. Households were designated as "high consumption" if average daily usage (ADU) during the summer season was greater than or equal to 24 kWh per day. Households with an ADU of less than 24 kWh per day were designated as "low consumption".

Figure 22 shows the statewide average peak period load reductions achieved by high consumption households participating in the ADRS pilot during 2004. The households achieved substantial peak load reductions, at least twice as much reduction on Super Peak event days as compared with non-event days.

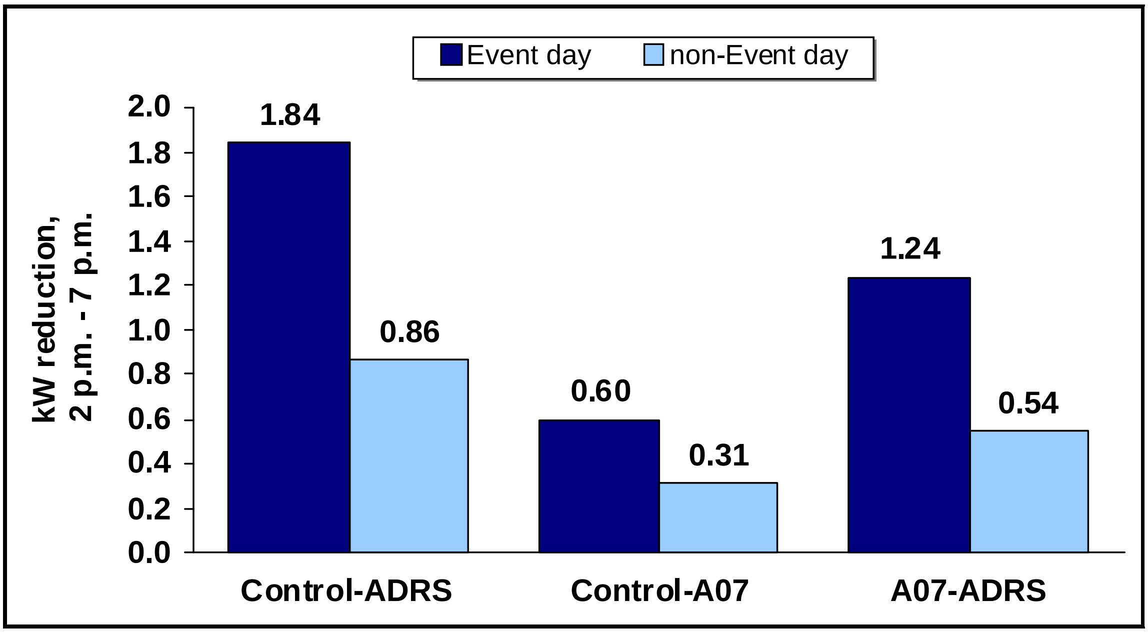

Figure 22. Statewide Average Peak Period Load Reductions Achieved by High Consumption Households in the ADRS Pilot, 2004[46]

The results shown in Figure 22 were calculated as reductions from the average loads of households in a matching population that did not have an ADRS installed and was not subjected to the CPP-F tariff (identified as "Control" in Figure 22). In 2004 only, the ADRS participants' results were also compared with the load reductions achieved by households from a matching population in the Statewide Pricing Pilot that were on the CPP-F tariff but did not have an ADRS installed (identified as "A07" in Figure 22).

The CPP-F tariff without the ADRS technology had a small effect in achieving load reductions ("Control-AO7" in Figure 22). Adding the ADRS technology to the CPP-F tariff produced a larger load reduction ("AO7-ADRS" in Figure 22) and an even larger

46 Source: Rocky Mountain Institute (2006b). *Automated Demand Response Pilot. 2005/2004 Load Impact Results and Recommendations.* Presentation to the California Energy Commission, 18 April. Available at: http://www.energy.ca.gov/demandresponse/documents/group3_april18_workshop/ADRS2005_04LoadImpactResults&Recs.PPT

load reduction when compared with the population on a standard tariff ("Control-ADRS" in Figure 22).

Figures 23 and 24 (page 44) show the average load profiles of high consumption households on Super Peak event days and on non-event days during 2004 and 2005.

During the period July to September 2004, high consumption ADRS households successfully and consistently reduced load relative to control homes by 1.84 kW or 9.21 kWh on average during the Super Peak period across 12 event days, called statewide. This translated to a 51% reduction relative to high consumption control homes statewide.

From July through September 2005, high consumption ADRS households successfully and consistently reduced load relative to control homes by 1.4 kW or 7.1 kWh on average during the Super Peak period, across seven event days, called statewide. This translated to a 43% reduction relative to high consumption control homes statewide.

The average load reduction by high consumption ADRS households was greater in 2004 than 2005, by 25% on Super Peak event days and by 15% on non-event days, statewide. The smaller load reduction on event days in 2005 is attributed mostly to lower loads in control homes in 2005. Average Super Peak period consumption by control households in 2005 decreased by 8% compared to 2004, in spite of the fact that 2005 was a hotter summer on average.

The lower average load in control homes on event days in 2005 is counter-intuitive, and this difference in behaviour by control households could not be explained with available data. In contrast, loads in high consumption ADRS households increased by 7% on average during Super Peak periods in 2005, as expected during a hotter summer.

For both summers, there was a dramatic increase in loads in ADRS homes during the two hours immediately following the Super Peak and peak periods, from 7 pm to 9 pm. At the end of the Super Peak period, the thermostats in ADRS homes automatically reset from their warmer Super Peak setting to their cooler off-peak setting. This resulted in a sudden jump in load at 7 pm as the air conditioners suddenly turned on to meet the new, cooler set point. This 'overshoot' could cause problems on network elements near their loading limits. In a full-scale implementation of ADRS technology, this issue would have to be managed by modifications to the load control technology to ensure that all the air conditioners did not turn on at the same time.

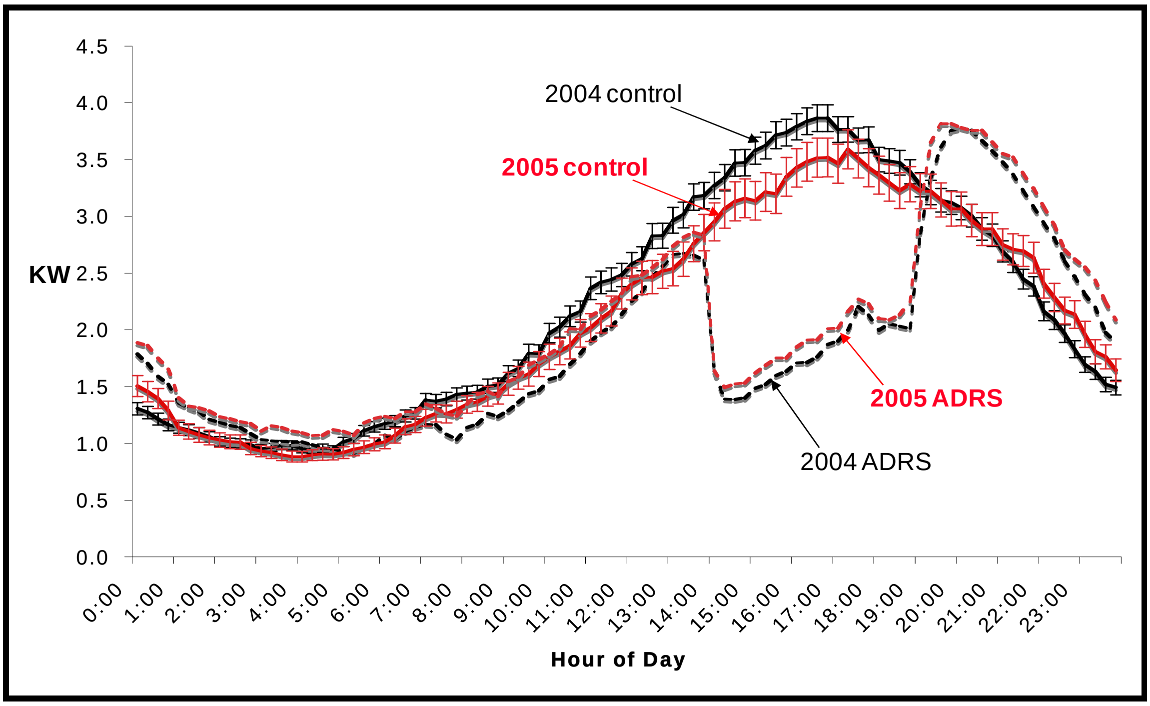

Figure 23. Average Load Profiles of High Consumption Households on Super Peak Event Days in the ADRS Pilot, 2004 and 2005[47]

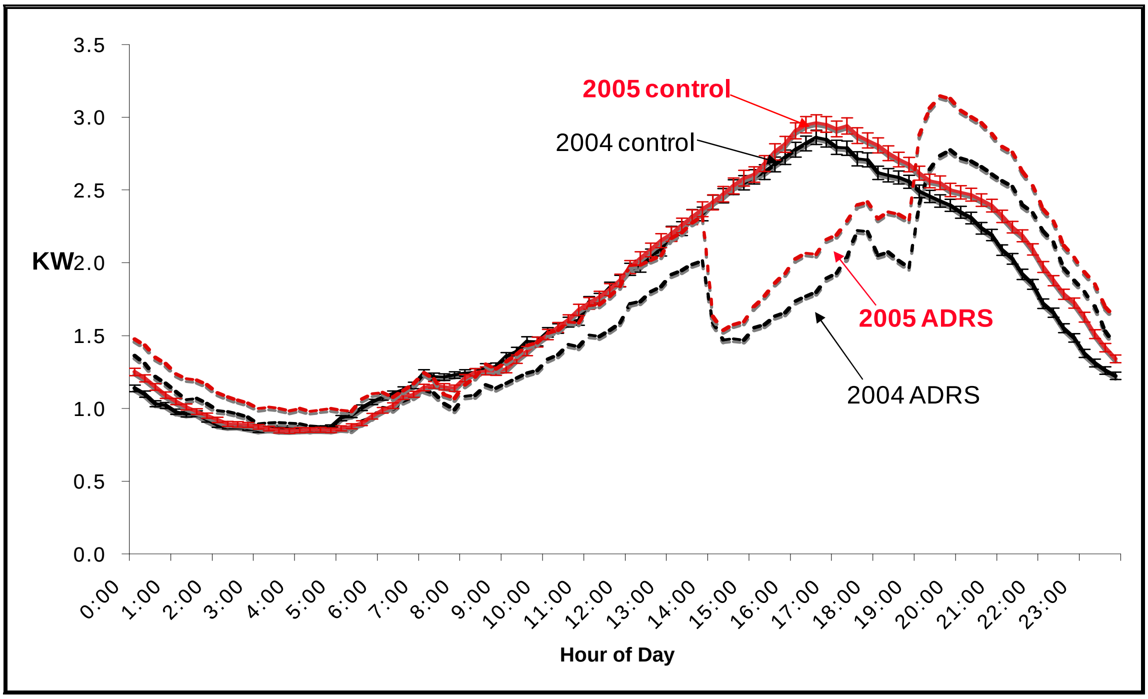

Figure 24. Average Load Profiles of High Consumption Households on Non-event Days in the ADRS Pilot, 2004 and 2005[48]

47 Source: Rocky Mountain Institute (2006b). *Op. cit.*
48 Source: Rocky Mountain Institute (2006b). *Op. cit.*

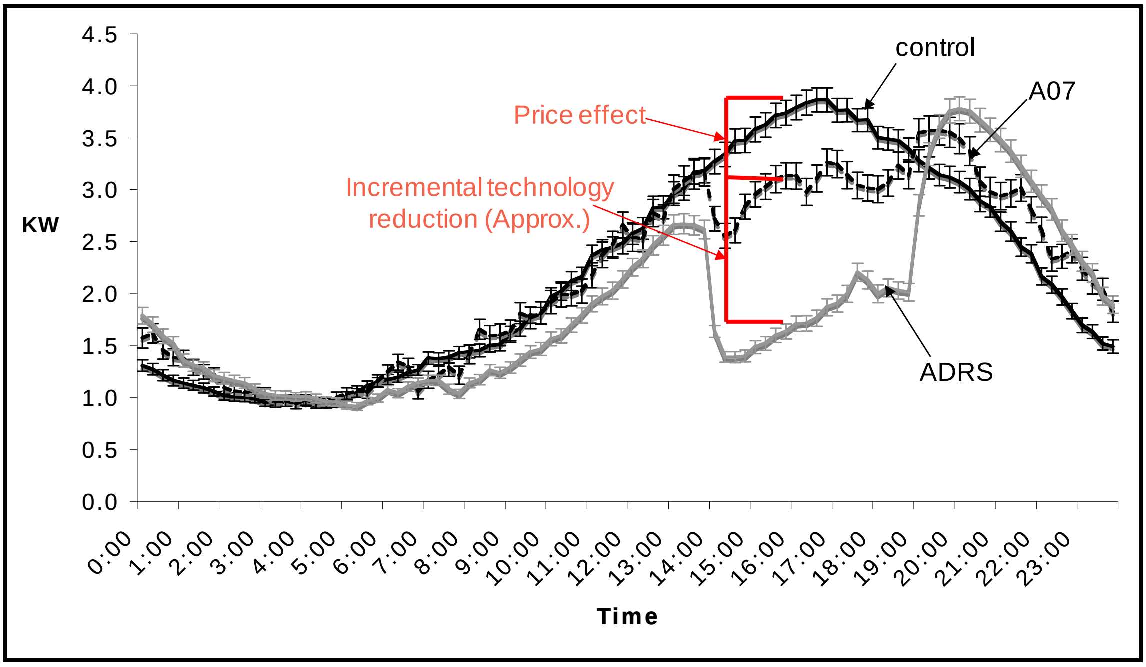

Figure 25. Impact of Price and Technology in High Consumption Households on Super Peak Event Days in the ADRS Pilot, 2004[49]

Figure 25 shows estimates of the relative impacts of price and of the ADRS technology in reducing peak load in high consumption households on Super Peak event days in 2004.

5.3.4 Effectiveness of Load Control Programs

Load control programs that involve remote switching of customer loads, like the three programs outlined in this section, are obviously effective in achieving peak load reductions. They offer customers a single "set and forget" decision making option which is much more attractive than programs that rely on the customer to manually switch appliances and equipment each time there are high electricity prices or messages from a system operator.

When the load control infrastructure includes interval metering, load control programs can be made even more attractive to customers by enabling systems in which customers can themselves set the price levels at which loads will be automatically switched. Such a system was used in the California ADRS trial described in section 5.3.2 (page 37).

Whether or not a program using load control technology is cost effective will depend on this incremental savings attributed to the technology compared to the technology cost. If the technology cost (eg smart thermostat, other automated load controls, and software) is small relative to the savings achieved in supplying the peak load, then it will be more likely that the incremental load reduction from technology will compensate for the technology cost and the demand response program will more likely to be cost effective. If the technology cost is large relative to the savings achieved, then it is less likely that the technology will capture enough incremental savings to compensate for its cost. Then the program is not likely to be cost effective.

49 Source: Rocky Mountain Institute (2006b). *Op. cit.*

5.4 Technology Review

The survey in the Appendix (page 58) identifies and reviews a number of low cost technology products that enable various load control functions. The products described in this survey have been chosen to represent the broad range of existing applications for load control technology. Several conclusions can be drawn from the detailed product information contained in the Appendix.

- **Interval metering** is not necessary to carry out load control functions. There are many products available that can carry out simple remote switching of loads. Some of the products in the survey can carry out remote switching that is automatically triggered by threshold events, including high price levels and network constraints, without requiring a connection to an interval meter, or even to any type of meter. However, where interval metering with communications capability is available, information about threshold events can be transmitted through the meter. Interval metering also enables the implementation of "set and forget" load control programs in which customers can themselves set the price levels at which loads will be automatically switched.
- **One-way communication** is essential to carry out remote switching of loads. A one-way communication link is required to transmit control signals from the program operator to the connected loads. Depending on the specific capability of the communications technology, a one-way communication link can also be used to transmit information about threshold events, such as high price levels and network constraints, without requiring a connection to a meter.
- **Two-way communication** is not essential to carry out remote switching of loads. However, it can greatly assist with the management of a load control program by enabling the transmission of information back to the program operator about whether remote switching has been successful and about the current status of the connected load. If the return communication link is connected through an interval meter, the program operator can also receive specific information about the quantity and timing of any load reduction achieved.
- **Metering** in some form is required for settlement of the financial transactions associated with load control programs. Accumulation meters are sufficient when the only information required is the quantity of energy used over the billing period. Interval metering may be required if time-varying pricing is in place, particularly with CPP and RTP, and when TOU pricing applies to all loads at the customer site, rather than to particular specified loads. However, some technology products are now available that can provide pulsed output from legacy electro-mechanical accumulation meters (eg the Rippleband Load Control System, see page 79). Theoretically, this output could be integrated over specified time periods to generate data similar to that obtained from an interval meter.

5.5 Options for Low Cost Load Control Programs

The following options for low cost load control programs have been developed to provide generic descriptions of the types of programs that can be implemented to support electricity networks:

- distribution of low cost information display devices;
- installation of frequency sensors in household appliances;
- rollout of low cost plug-in appliance controllers;
- rollout of smart air conditioner thermostats;
- promotion of integrated direct load control systems.

5.5.1 Distribution of Low Cost Information Display Devices

Purpose: To raise end-use customers' awareness about their electricity usage and cost and encourage a change in their electricity-using behaviour.

Target Audience: Primarily residential customers, though small businesses could also be targeted.

Technology: A device that displays information to end-use customers about their electricity usage and costs, and may also provide information about other factors such as greenhouse gas emissions resulting from a customer's electricity usage.

Communications: None

Type of Metering Required: None

Infrastructure Required: None

Pricing Initiatives: Could be accompanied by the introduction of time-varying price structures, eg TOU, RTP and/or CPP.

Education and Awareness Raising: The distribution of the information display devices should be accompanied by a promotion and education campaign encouraging customers to change their electricity-using behaviour.

Examples of Technology Products: Power-Mate™ (see page 58); Cent-A-Meter™ (see page 60)

Likely Effectiveness: The effectiveness of the promotion and education campaign would be crucial in determining how successful this option is in changing customers' behaviour. Any behavioural changes may not persist over time because they would require customers to undertake manual switching of appliances and equipment.

5.5.2 Installation of Frequency Sensors in Household Appliances

Purpose: To achieve automated switching of household appliances in response to system frequency variations.

Target Audience: Manufacturers of household appliances

Technology: A device comprising a circuit board containing a simple computer chip that can sense frequency disturbances on an electricity network and can turn an appliance off for a few minutes to allow the network to stabilize during a crisis; the sensor can be installed in appliances that regularly cycle on and off during normal use, so that end-use customers will not notice when the device is in operation.

Communications: None

Type of Metering Required: None

Infrastructure Required: None

Pricing Initiatives: None required

Education and Awareness Raising: The large scale incorporation of frequency sensors in household appliances could be accompanied by an education campaign explaining the technology to householders.

Examples of Technology Products: Grid Friendly™ appliance controller (see page 63)

Likely Effectiveness: The effectiveness of the technology has been proven through test installations and field trials. The effectiveness of the rollout program will depend on the willingness of appliance manufacturers to incorporate the technology into their products and its acceptance by householders.

5.5.3 Rollout of Low Cost Plug-in Appliance Controllers

Purpose: To enable low cost direct load control of appliances and equipment.

Target Audience: Primarily residential customers, though small businesses could also be targeted.

Technology: A device that plugs into an electrical wall socket; an appliance is plugged into the device which then receives ripple control signals sent through powerlines by the program operator.

Communications: One-way

Type of Metering Required: None

Infrastructure Required: Ripple control infrastructure (already existing in NSW, Queensland and South Australia; would have to be installed in other jurisdictions)

Pricing Initiatives: The introduction of time-varying price structures, eg TOU, RTP and/or CPP, is not essential but could act to motivate customers to install the controllers. Alternatively, or in addition, incentive payments could be used.

Education and Awareness Raising: The rollout of the appliance controllers could be accompanied by a promotion and education campaign explaining the purpose and objectives of the program and encouraging customers not to override load control signals from the program operator.

Examples of Technology Products: SWITCHit™ (see page 64); Rippleband Plug-in Relay (see page 79)

Likely Effectiveness: Once the appliance controllers are installed, load reductions are highly likely to persist over time because the switching of appliances and equipment would be automated. However, it would always be possible for customers to override load control events by simply unplugging the controllers.

5.5.4 Rollout of Smart Air Conditioner Thermostats

Purpose: To enable low cost direct load control of air conditioners.

Target Audience: Residential and small commercial customers

Technology: A device that operates as a standard programmable thermostat, but also includes two-way communications with the load control program operator. The thermostat and the associated control system are capable of performing either: cycling control, whereby a fixed allowable maximum on-cycle is maintained, or temperature control, whereby the set-point of the thermostat can be remotely adjusted. The customer can also program the thermostat directly using controls on the thermostat itself or through the internet.

Communications: Two-way

Type of Metering Required: None

Infrastructure Required: Two-way communications infrastructure (eg radio paging, mobile phone communications or broadband internet)

Pricing Initiatives: Introduction of time-varying price structures, eg TOU, RTP or CPP would be required to motivate customers to install the thermostats. Alternatively, or in addition, incentive payments could be used.

Education and Awareness Raising: The rollout of the thermostats could be accompanied by a promotion and education campaign explaining the purpose and objectives of the program and encouraging customers not to override load control signals from the program operator.

Examples of Technology Products: ComfortChoice^{SM} Demand Management Solution (see page 72)

Likely Effectiveness: Once the thermostats are installed, load reductions are highly likely to persist over time because the switching of the air conditioners would be automated. However, it would always be possible for customers to override load control events by adjusting the controls on the thermostats.

5.5.5 Promotion of Integrated Direct Load Control Systems

Purpose: To enable relatively complex demand response programs.

Target Audience: Primarily residential and small commercial customers, but could be extended to larger customers at additional cost

Technology: Integrated load control systems combining appliance and equipment controllers with two-way communications technology to enable remote-switching of appliances and transmission of data from the controlled loads to the program operator. These systems provide flexible management solutions for complex load control programs.

Communications: Two-way

Type of Metering Required: Interval

Infrastructure Required: Two-way communications infrastructure (eg radio paging, mobile phone communications, broadband internet, two-way advanced ripple control or power line carrier).

Pricing Initiatives: Introduction of time-varying price structures, eg TOU, RTP or CPP would be required to motivate customers to install the necessary load control equipment. Alternatively, or in addition, incentive payments could be used.

Education and Awareness Raising: The rollout of the technology should be accompanied by a promotion and education campaign explaining the purpose and objectives of the planned demand response program(s)

Examples of Technology Products: LeKey Energy Management System (see page 76); SD Electricity Manager (see page 77); Rippleband Load Control System[50] (see page 79); Wattwatcher Smart Monitoring System (see page 85); Saab Direct Load Control System (see page 92).

Likely Effectiveness: Once the load control equipment is installed, demand responses are highly likely to persist over time because the switching of appliances and equipment would be automated. However, it may be possible for customers to override load control events, depending on the specific equipment installed.

5.6 Creating a Forward Path for Load Control Technology

The product survey of low cost load control technology in the Appendix (page 58) demonstrates that considerable product design and development is currently taking place. Much of this development is being carried out by information and communications technology firms rather than by firms traditionally involved in designing, developing and manufacturing equipment for the electricity industry.

One consequence of this is that product lifetimes for newly-developed load control equipment are much shorter than those for other equipment in the electricity industry. Traditionally, lifetimes of 50 years or more have been expected for equipment such as electro-mechanical electricity meters. In contrast, lifetimes for electronic meters are now expected to be about 15 years. Some of the electronic equipment now being developed for load control applications may be superseded in three to five years (typical lifetimes in the ICT industry) not because the equipment breaks down but because new, cheaper products able to carry out more functions have been developed.

The rapidly increasing availability of sophisticated load control equipment at comparatively low cost, opens up major opportunities to implement load control programs. However, given the diversity of products available, there is a danger that too rapid deployment of load control technology without a clearly defined strategy may result in a range of problems, including:

- a **"rail gauge" problem** in which multiple different proprietary load control products are installed that are unable to interface with each other;
- a **stranded assets problem** in which existing load control equipment currently installed in the Australian electricity industry becomes uneconomic and has to be replaced with more cost-effective technology; and

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[50] This product can also use data from legacy electro-mechanical accumulation meters.

- an **uneconomic lifetimes problem** in which the short lifetimes of new load control products force massive and costly physical replacement and re-installation programs on a regular basis.

To prevent such problems occurring, a policy development process should be established to create a forward path for the implementation of load control. Such a policy development process should aim to ensure:

- that open standards and protocols are developed for all the important load control functions and that load control equipment complies with these standards and protocols;
- that technology products are developed to expand existing load control functions and add new functions to equipment already in, eg the existing very large stock of accumulation meters;
- that new load control technology products are designed so that additional capabilities and functions can be added without requiring the physical replacement of whole units or parts of units, eg changes could be made by using communication links to implement mass upgrades of firmware installed in load control products.

6. CONCLUSION

This report has identified three ways in which advanced metering and load control technology can be used to support electricity networks.

First, advanced meters enable the implementation of time-varying pricing which sends price signals to customers that reflect the underlying costs of generating, transporting and supplying electricity. Price-based demand response programs can reduce or shape customer demand and particularly can reduce peak loads on the electricity network and therefore reduce the amount of investment required in network infrastructure.

Second, analysing data from advanced meters provides end-users with detailed information about the ways in which they use electricity and can enable businesses to identify and implement energy, cost and carbon savings. Energy savings reduce the overall load on the electricity network, therefore contributing to supporting the network.

Third, load control technologies can be used to directly reduce peak loads on the electricity network by remotely switching appliances and equipment at customers' premises. This is arguably the most effective mechanism for reducing peak loads since remote switching requires only one "set and forget"decision by end-use customers.

This report has also identified and reviewed a number of low cost technology products that enable various load control functions. The review drew the following conclusions:

- **interval metering** is not necessary to carry out load control functions – available technology can remotely switch loads without requiring connection to a meter;
- **one-way communication** is essential to carry out remote switching of loads;
- **two-way communication** is not essential to carry out remote switching of loads; and
- **metering** in some form is required for settlement of the financial transactions associated with load control programs.

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ABBREVIATIONS ACRONYMS AND GLOSSARY

Accumulation meter	A meter that records energy consumption progressively over time. The energy consumption information is accessed relatively infrequently only when the meter is read.
ADRS	Advanced Demand Response Systems (load control systems used in the California Statewide Pricing Pilot)
Advanced metering	A metering system that records 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
Advanced metering infrastructure	A full measurement and data collection system comprising customer meters (usually smart meters), communication networks, and data management systems.
AMI	Advanced metering infrastructure
AMR	Automated meter reading
AUD	Australian dollar
B2B	Business to business
CAD	Canadian dollar
CDMA	Code division multiple access (a type of mobile phone technology)
CPP	Critical peak pricing
Critical peak pricing	A form of time-varying pricing that can be superimposed on either a time of use or time-invariant tariff structure. Critical peak pricing relies on very high critical peak prices, as compared with the ordinary peak prices in time of use pricing or the flat prices in time-invariant tariff structures. This high per-unit price is in operation during times that the electricity business (distributor or retailer) defines as critical peak periods. Critical peak pricing events may be triggered by contingencies on the electricity network or high prices faced by the retailer in procuring power in the National Electricity Market.
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Demand management	Actions taken on the customer's side of the meter to change the amount or timing of energy consumption. Demand management programs offer a variety of measures that can reduce energy consumption and consumer energy bills. Electricity demand management strategies aim to maximize end-use efficiency to avoid or postpone the requirement to expand or augment the electricity network or to construct new electricity generating plant.

Demand response	Actions taken by end-use customers to change (usually reduce) their electricity use in response to high prices in the electricity market and/or problems on the electricity network.
DM	Demand management
DPP	Dynamic peak pricing
Dynamic peak pricing	Another name for critical peak pricing
FERC	Federal Energy Regulatory Commission (USA)
GBP	United Kingdom pound
GHG	Greenhouse gas
GPRS	General packet radio service (a type of mobile data transmission technology)
HVAC	Heating, ventilation and cooling
ICT	Information and communications technology
IT	Information technology
Interval meter	A meter that records the quantities of energy consumed over set, frequent time intervals.
kW	Kilowatt
kWh	Kilowatt-hour
LCD	Liquid crystal display
LCM	Load control and monitoring device
Load (electrical)	1. A device connected to the output of an electrical circuit, eg an electrical appliance. 2. The amount of electrical power required by connected electrical equipment.
Load control	A system or program that enables end-use customer loads to be changed in response to particular events such as periods of high electricity prices or problems on the electricity network.
Load reduction	A reduction in the amount of electrical power required by connected electrical equipment.
MDMS	Meter Data Management System
Mt CO2-e	Megatonnes of carbon dioxide equivalent
MW	Megawatt
MWh	Megawatt-hour
NUoS	Network use of system

PLC	Power line carrier (a type of technology for transmitting data across power lines)
Power (electrical)	Rate at which energy is released or consumed, expressed in watts.
PNNL	Pacific Northwest National Laboratory (an agency of the United States Department of Energy)
PSTN	Public switched telephone network
Real time pricing	A form of time-varying pricing in which prices vary continuously during the day, directly reflecting the wholesale price of electricity, as opposed to tariff structures such as time of use or critical peak pricing that are largely based on preset prices. In an Australian context, real time pricing would link half-hourly prices for retail customers to the half-hourly changes in the cost of purchasing electricity from the National Electricity Market.
Ripple control	A type of system applied to electrical networks to control loads. A small coded audio frequency wave is superimposed on to the normal 240 volt 50 herz electricity supply and travels through the network along powerlines. Signals are sent very slowly to ensure reliable reception by ripple control receivers located anywhere on the electricity network. Receivers are typically located in customer switchboards or even in individual appliances. The receivers are linked to switches that enable switching of circuits or individual appliances according to the coding implemented by the program operator.
RTE	The French transmission network operator, Réseau de Transport d'Electricité
RTP	Real time pricing
SAC	System Availability Charge
Smart meter	A meter that includes, in addition to an interval metering capability, one-way or two-way communications between the energy supplier and the meter.
SME	Small to medium enterprise
Super peak	Another name for critical peak
tCO2	Tonnes of carbon dioxide
Tempo tariff	A longstanding time of use and critical peak pricing tariff that has been implemented in France since the early 1990s.

Time of use pricing	A form of time-varying pricing in which tariff structures include two or more daily periods that reflect hours when the system load is higher (peak) or lower (off-peak), and charge a higher price during peak hours. A shoulder period or partial-peak price may also be included. TOU tariffs can also be implemented on a seasonal basis with prices that vary by seasons.
TOU	Time of use
USD	United States dollar
W	Watt
WAN	Wide area network
Wi-Fi	The embedded technology of wireless local area networks.

APPENDIX

EXAMPLES OF LOW COST LOAD CONTROL TECHNOLOGY PRODUCTS

The information in this Appendix is derived from the Load Management Technology Database available on the Task XV website at:
http://www.ieadsm.org/LoadManagement.aspx

The Appendix identifies and reviews a number of low cost technology products that enable various load control functions and which could either be used with AMI systems or could provide load control functionalities without requiring an AMI system. However, this survey of products is not intended be a comprehensive. The products described here have been chosen to represent the broad range of existing applications for load control technology. There are many other similar products available on the world market.

The products are classified as follows:

- information display devices (see page 58);
- appliance and equipment controllers (see page 63);
- advanced meters (see page 70); and
- integrated load control systems (see page 72).

A.1 INFORMATION DISPLAY DEVICES

Information display devices provide information to end-use customers about their electricity usage and costs, and may also provide information about other factors such as greenhouse gas emissions resulting from a customer's electricity usage.

The relevance of information display devices to load control is that access to increased information may induce customers to change their electricity usage in response to high prices in the electricity market; and/or problems on the electricity network.

A1.1 Power-Mate™

Developer and Manufacturer: Computer Control Instrumentation (CCI)

Country of Origin: Australia

Function: Information display

Communications: None

Type of Metering Required: None

Description: The Power-Mate™ (Figure A.1, page 59) provides various measurements for all types of equipment and appliances. The Power-Mate is plugged into a power point and then appliances and equipment can be plugged into the Power-Mate.

End-use customers can input electricity tariffs and greenhouse gas conversion factor and the Power-Mate then estimates and displays hourly, quarterly and yearly running costs and greenhouse gas emissions.

Figure A.1 Power-Mate™

The Power-Mate has several main menu modes: Instantaneous Volts, Current, Power, Energy, Cost, Greenhouse Gas and Elapsed Time. When in these main modes extra information is available from 3 other colour-coded buttons. Whilst in Volts, Current and Power modes, the maximum and minimum values can be displayed. When in the Cost, Energy and Greenhouse Gas modes, the hourly, quarterly and yearly amounts can be displayed.

The standard Power-Mate has a resolution down to 0.1W. For the more professional or industrial markets, the Power-Mate is available with a higher precision resolution down to 1/10000 Amp or 1/100 Watt. Units are supplied for either 10 Amp (2.4kW) or 15 Amp (3.6kW) applications. Internally all current and voltage conversions are to 24 bit precision, with digital filtering.

CCI are currently finalising the addition of a communication connector to the Power-Mate which will allow connection to a computer for direct analysis of usage / power / cost etc. CCI also intends to design a next generation unit which will essentially comprise an intelligent socket wired into a house / office environment, or a device similar to a timer unit that plugs into an existing wall socket. These units will communicate via the house wiring back to a local computer / data collection point, for further logging, analysis etc.

Deployment: Energy South Australia assisted CCI with the development of the Power-Mate prototype and purchased the first 230 production line units. These are being used by home energy auditors participating in the Energy Friends Program and the Energy Efficiency Program for Low Income Households.

Further Information: http://www.power-mate.com.au

A1.2 Cent-A-Meter™

Developer: Wireless Monitors Australia Pty Ltd

Manufacturer: Chinese manufacturer of electronic products

Distributor: Clipsal

Country of Origin: Australia

Function: Information display

Communications: One-way using low power radio within customer's premises

Type of Metering Required: None

Description: The Cent-A-Meter™ is an electronic device which measures electricity use and displays the cost per hour on a portable display located inside the home or small business. The information displayed includes: power consumption, cost per hour of electricity usage, corresponding greenhouse gas emissions, and indoor ambient temperature and humidity.

Figure A.2 Components of the Cent-A-Meter™

The Cent-A-Meter comprises a sensor, wireless transmitter and receiver (Figure A.2, page 60). The sensor is a clip-on current transformer that samples the electric current on each active phase wire inside the switchboard. These readings are aggregated and relayed by the 433 MHz wireless transmitter to the remote receiver/monitor.

End-use customers can input specific country currency, voltage, electricity tariff rate, greenhouse gas conversion factor and peak load alarm value. The receiver computes the approximate power use, energy cost and greenhouse gas emissions and displays the results on a large portable LCD screen.

The alarm feature included in the unit can be set to a pre-determined level and when exceeded during peak periods can act as a signal to induce a voluntary load reduction, when supported by appropriately targeted educational campaigns.

The Cent-A-Meter is not an accumulation revenue meter and cannot be used to check electricity bills. However, it may be used to monitor individual circuits of metered premises to estimate their share of electricity use.

Deployment: The Cent-A-Meter is recommended by electricity utilities and environmental organisations in Australia, Canada, New Zealand, USA and UK.

Further Information: http://www.centameter.com.au

A1.3 ecoMeter Home Energy Monitor

Developer and Manufacturer: Amy Email Metering

Country of Origin: Australia

Function: Information display

Communications: One-way

Type of Metering Required: Interval

Description: The ecoMeter Home Energy Monitor is an information display unit that communicates with an interval electricity meter in the end-use customer's home or premises through power line carrier technology.

The ecoMeter (Figure A.3, page 62) plugs into any power socket and is about the size of a regular wall phone. The main component of the ecoMeter is an LED alphanumeric display which provides customers with specific information about the amount of electricity they are using, and how much it is costing. This information is obtained from the electricity meter to which the ecoMeter is connected. The ecoMeter also includes green, amber, and red LED lights which show customers whether they are using electricity at low, medium, or high prices, corresponding to off peak/shoulder, peak and critical peak tariffs. A beeping sounds alerts customers to the start of a critical peak period.

Figure A.3 Ampy Email ecoMeter Home Energy Monitor

Ampy Email also offers the EM1200 series of interval electricity meters (Figure A.4) that can be connected to the ecoMeter. These meters incorporate up to two relays and a ripple controller to provide the capability to remotely switch appliances and equipment.

Figure A.4 Ampy Email EM1200 Interval Meter

Deployment: An early version of the ecoMeter was used in critical peak pricing trials carried out in Queanbeyan by Country Energy during 2005 and 2006.

Further Information: Brendan King <brendan.king@ampymetering.com.au>

A2. APPLIANCE AND EQUIPMENT CONTROLLERS

Appliance and equipment controllers enable remote switching of the appliances and equipment to which they are connected. There are several different types of controllers, including simple on-off switches, programmable thermostats, and sophisticated programmable demand controllers.

In load control programs, appliances and equipment may be remotely cycled, turned down or switched off by a signal sent by the program operator to large numbers of controllers. The signal may be sent manually by the program operator or automatically in response to trigger events such as exceedances of pre-set electricity price levels or pre-set load levels on particular network elements, or excursions outside pre-set frequency or voltage parameters.

A2.1 Grid Friendly™ Appliance Controller

Developer: Pacific Northwest National Laboratory (PNNL), United States Department of Energy

Manufacturer: None at this stage

Country of Origin: United States

Function: Automated switching of appliances in response to system frequency variations

Communications: None required

Type of Metering Required: None

Description: The Grid Friendly™ appliance controller (Figure A.5, page 64) is a five by six centimetre circuit board which contains a simple computer chip that can sense frequency disturbances on an electricity network and can turn an appliance off for a few minutes to allow the network to stabilize during a crisis.

Grid Friendly controllers can be installed in appliances that regularly cycle on and off during normal use, so that end-use customers will not notice when the Grid Friendly device is in operation. Customers actually become an integral part of electricity network operations.

Grid Friendly appliances can replace spinning reserve by providing automatic demand response to rebalance demand to match available supply almost instantaneously (within a half-second) when a crisis occurs. This is an improvement over the approximately 30 seconds it currently takes for power plants kept on standby to come up to speed. Grid-Friendly™ controllers can also be programmed to delay restart instead of all coming on at once after a power outage.

Figure A.5 Grid Friendly™ Appliance Controller

The present version of the Grid Friendly controller is configured to rapidly create an alert signal when the frequency of the network's voltage signal exceeds a user-defined threshold. Because Grid Friendly appliances assess the stability of the network using only the voltage available within the appliance, there is no need for costly communications to a regional control centre.

Deployment: The Grid Friendly controller has been tested in a laboratory environment and several field trials and is ready for licensing and installation in the next generation of appliances. PNNL is currently working with appliance manufacturers and utilities to use Grid Friendly Appliances in a variety of test-bed and demonstration projects.

Further Information: http://gridwise.pnl.gov/technologies/transactive_controls.stm

http://gridwise.pnl.gov/docs/pnnlsa36565.pdf

A2.2 SWITCHit™ Appliance Controller

Developer and Supplier: Enermet

Country of Origin: Australia

Functions: Remote switching of appliances

Communications: One-way, using ripple control

Type of Metering Required: None

Description: The SWITCHit™ appliance controller (Figure A.6) is a pre-programmed ripple control receiver and switching device intended for use primarily within the residential sector to control home appliances and other devices. The SWITCHit can also be used in the commercial and industrial sectors with appliances or equipment that plug into a standard 240 volt 10 amp power point.

Figure A.6 Enermet SWITCHit™ Appliance Controller

The SWITCHit is plugged into any power point and an appliance or other device is plugged into the SWITCHit. The appliance can then be remotely switched by ripple control signals sent through power lines by the load control program operator.

The SWITCHit can be pre-programmed to suit several different types of appliances. So far, two versions of the SWITCHit have been developed: one for pool pumps and the other for appliances and air-conditioners. Both versions have a rotary switch on the back that is used to select the particular ripple control coding that the SWITCHit will respond to and hence the type of device that is to be controlled.

For pool pumps, the slot of the switch is turned to match the size of pool - 'Small Pool', 'Medium Pool' or 'Large Pool'. For air-conditioners, the slot of the switch is turned to 'A/C Cycle'. For other appliances, the slot of the switch is turned to 'Appliance Cycle'. Peak period control is available in both versions of the SWITCHit by turning the slot of the switch to 'Peak Period Off'.

Enermet also offers the ROA hard-wired ripple control receiver (Figure A.7, page 66) that can be combined with a switching device to control three-phase appliances and equipment such as larger air conditioners.

Figure A.7 Enermet ROA Ripple Control Receiver

Deployment: At present, Energex is using the SWITCHit appliance controller in residential sector load control trials in Brisbane.

In addition, a 'greenfields' load control program using the SWITCHit and/or the ROA receiver would incur additional costs in establishing the ripple control infrastructure. However, electricity distributors in NSW, Queensland and South Australia already have this infrastructure in place for controlling off-peak water heaters.

Further Information: Garry Burke <garry.burke@enermet.com.au>

A2.3 Hunt Load Control Switch

Manufacturer: Hunt Technologies

Distributor: Ampy Email Metering

Country of Origin: United States

Functions: Remote switching of appliances

Communications: Two-way, using power line carrier

Type of Metering Required: None

Description: The Hunt Load Control Switch (Figure A.8, page 67) provides stand alone power line carrier-based remote switching of installed appliances including heat pumps, air conditioners and other significant loads in the home or business.

Figure A.8 Hunt Load Control Switch

Hunt Technologies' bi-directional power line carrier technology provides remote switching of appliances and equipment plus validation that the load control commands have occurred. Each relay accommodates trigger or cycle-based schedules, which may be defined for weekdays, Saturdays and Sundays. Two schedule sets may be stored for each relay.

Deployment: The Hunt Load Control Switch has been used extensively in demand response programs in the United States.

Further Information: Brendan King <brendan.king@ampymetering.com.au>

A2.4 CYCLEit® Ripple Control Receiver

Developer and Supplier: Enermet

Country of Origin: Australia

Functions: Forced cycling of domestic air conditioning

Communications: One-way, using ripple control

Type of Metering Required: None

Description: The Enermet CYCLEit® is a compact ripple control receiver aimed at reducing the energy consumption of domestic air conditioning units by forced cycling of the compressor modules.

The product is available in two different versions CYCLEit® Relay and CYCLEit® TSA, allowing for the connection of electrical appliances via a 10 amp relay or via a Thermistor Signal Adapter (TSA).

CYCLEit® Relay has been designed to be retrofitted within the condenser module of a refrigerative air conditioner to force a pre-set cycling routine upon the compressor modules to reduce the overall power consumption of the air conditioner.

CYCLEit® TSA has been designed to be retrofitted to the evaporator module of a refrigerative air conditioner, or wherever the return air sensor is connected to the control device. CYCLEit® TSA simulates a low return air temperature to force a pre-set cycling routine upon the compressor modules to reduce the overall power consumption of the air conditioner.

Both versions of the CYCLEit® are pre-programmed with the required cycling routine at the factory. No override of the ripple signal is possible, therefore providing firm load control.

The peak period during which cycling occurs is shown by an LED indicator. The on/off status of the air conditioner can be easily seen from the indicator.

The CYCLEit® is designed for retrofit application and must be installed by a qualified electrical technician.

Deployment: The CYCLEit® has been deployed in trials of air conditioner cycling by electricity distributors in Brisbane and Perth, Australia.

Further Information: Garry Burke <garry.burke@enermet.com.au>

A2.5 Conzerv Smart Demand Controller

Developer and Supplier: Conzerv Systems Private Limited

Country of Origin: India

Functions: Automated switching of predefined loads

Communications: Direct connection to meter through RS 485 port

Type of Metering Required: Requires interval metering

Description: The Conzerv Smart Demand Controller (see Figure A.9, page 69) offers comprehensive power and energy monitoring of feeders and individual loads and also retrieves previous energy reading to cross check utility meter readings or electricity bills.

The Smart Demand Controller monitors demand by ensuring automatic synchronisation of demand with the utility meter and displays maximum demand along with date and time of occurrence to set realistic demand targets.

The predictive features of the Smart Demand Controller enable prior indication of exceeding contracted demand (preset value) and facilitates automated switching of predefined non-essential loads which helps to optimise demand utilisation, improve system efficiency, and enables planning of load schedules.

Figure A.9. Conzerv Smart Demand Controller

The Smart Demand Controller includes the following functions

- monitors voltage – phase to phase, phase to neutral – average and phase wise, neutral to earth voltage;
- monitors current – phase wise and average;
- monitors phase angle – voltage and current – phase wise;
- monitors all power and energy parameters – total as well as phase wise;
- monitors demand parameters; instantaneous and maximum demand with day, date and time;
- records four high and low values for instantaneous and demand parameters with day, date and time of occurrence;
- generates demand profile at 19 demand levels for setting realistic demand targets according to user program;
- sets user programmable upper limit and lower limits for kW or kVA parameters, and enabes definition of essential loads and prediction intervals for sophisticated demand control.

Deployment:

Further Information:

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Conzerv Systems Private Limited
chainesh.patil@conzerv.com
www.conzerv.com

A3. ADVANCED METERS

A3.1 Liberty Electricity Prepayment Metering System

Developer and Supplier: Secure Meters Limited

Country of Origin: India

Functions: Interval metering with prepayment facility

Communications: GSM mobile phone network

Type of Metering Required: Interval metering

Description: The Liberty Electricity Prepayment Metering System is essentially a 'pay as you use' interval metering system. It offers a flexible and secure revenue management system to deliver a bill-less revenue cycle. The system also includes load limiting and load management features.

The system comprises a range of Liberty prepayment meters plus an optional consumer display unit.

The prepayment meters (see Figure A.10, page 71) include a 9-character alphanumeric starburst display which provides the following information:

- days left (based on consumption of last seven days) and the available account balance;
- value of recent consumption, eg previous day, previous week and previous month;
- the currently active tariff, the prices charged for consumption at each tariff rate, and the number of kilowatt-hours consumed at each rate;
- the currently connected load (kW) and the cost of that load in INR per hour;
- maximum demand with occurrence date and time;
- current date and time.

The Freedom consumer display unit (see Figure A.11, page 71) is connected to the meter via an RJ11 cable. All the displays available on the consumer display unit are replications of the meter display. On disconnection due to overload, the consumer can reconnect the meter by pressing the key on the consumer display unit.

The account balance information helps the consumer to decide when to buy electricity. When the account is exhausted, the meter will disconnect the supply at a convenient time. Reconnection occurs when further payment is made and the meter commences charging for the new consumption (see Figure A.12, page 72).

Deployment: The Liberty Electricity Prepayment Metering System has been deployed by electricity utilties in Bangladesh, India, New Zealand and Northern Ireland.

Further Information:
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Secure Meters Limited
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www.securemeters.com

Liberty1P Liberty3P

Figure A.10. Two Types of Liberty Prepayment Meters

Freedom

Figure A.11. Freedom Remote Consumer Display Unit

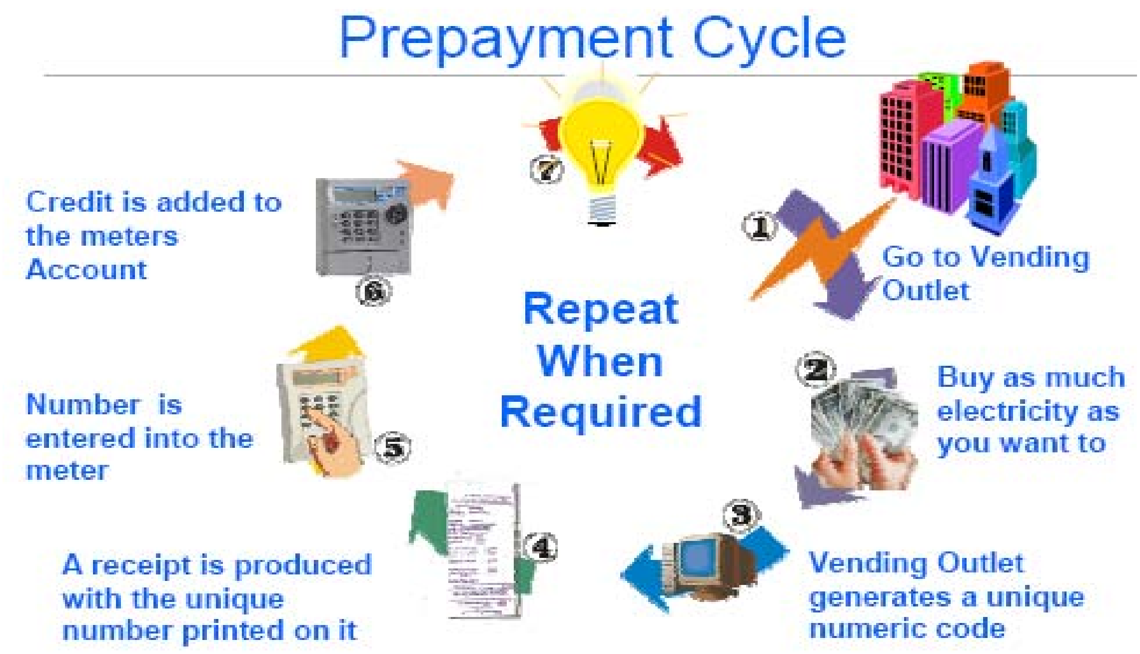

Figure A.12. Liberty Prepayment Cycle

A4. INTEGRATED LOAD CONTROL SYSTEMS

Integrated load control systems combine appliance and equipment controllers with two-way communications technology to enable remote-switching of appliances and transmission of data from the controlled loads to the program operator. These systems provide flexible management solutions for complex load control programs.

A4.1 ComfortChoice^{SM} Demand Management Solution

Manufacturer: Carrier

Country of Origin: United States

Function: Controlling and remote switching of air conditioners

Communications: Two-way, using radio and the internet

Type of Metering Required: None

Description: The ComfortChoice^{SM} Demand Management Solution comprises control and communications technology that enables load control of air conditioners in homes and small commercial premises.

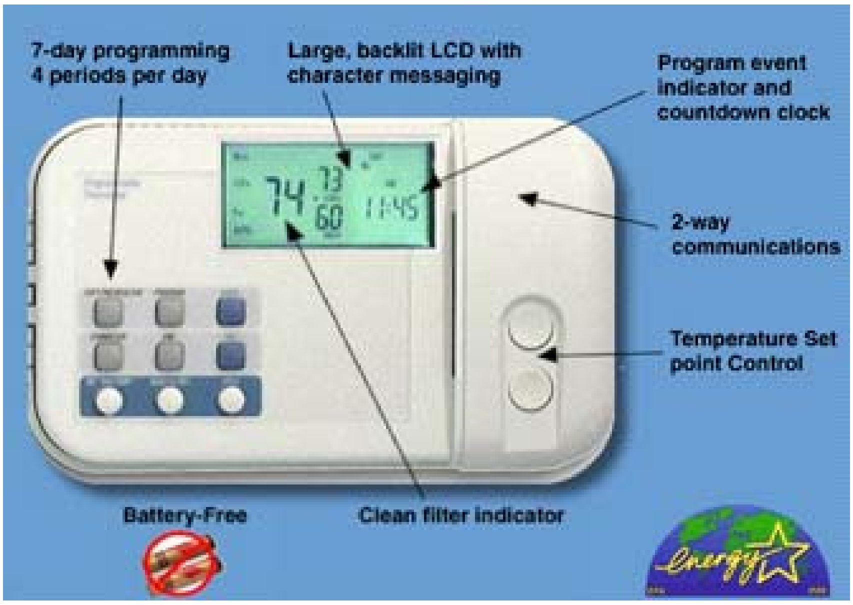

Figure A.13 Carrier EMi Thermostat

At the heart of the system is Carrier's 7-day programmable digital thermostat, EMi (short for Energy Management Interface). EMi thermostats (Figure A.13) are used to control the operation of air conditioners at end-use customers' homes or premises. The thermostats have internet functionality and two-way wireless paging.

The EMi thermostat operates as a standard programmable thermostat, but also features remote access through an I/O board installed in the home/business that communicates with the thermostat and transmits and receives radio signals through a commercial pager communication network. The paging system communicates the system status and transfers data (including temperature set-point, ambient temperature, and hourly runtimes for air conditioner compressors) between the EMi thermostat and the load control program operator.

EMi thermostats and the corresponding control system are capable of performing either:

- **cycling control**, whereby a fixed allowable maximum on-cycle (typically 50%) is maintained per hour or half hour, or
- **temperature control**, whereby the set-point of the thermostat can be remotely adjusted by a specific number of degrees.

Carrier provides the ComfortChoice Manager software, which is a internet-based application designed for use by program operators in performing load control of air conditioners by remote programming of EMi thermostats. During load control events, the program operator can access the ComfortChoice system using any standard web browser. The program operator logs in to a designated URL to access ComfortChoice's load control initiation web page. The ComfortChoice system will then use two-way wireless paging communication to adjust the EMi thermostat set-points. While a load control event is in progress, the program operator can monitor the amount of estimated load reduction in real time.

The two-way system provides real time verification, tamper detection, run-time data, remote diagnostic capability and overall higher utility and customer satisfaction. In contrast to one-way systems. the program operator will always know exactly how many air conditioners in customers' homes and premises can be deployed for demand reduction, without resorting to costly field surveys.

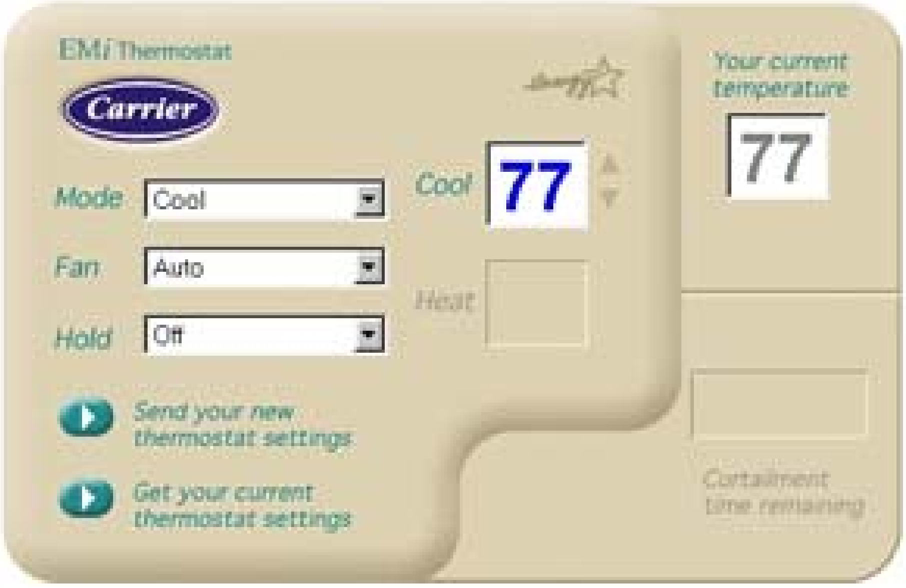

Figure A.14 Web-based User Interface for the Carrier EMi Thermostat

End-use customers can program their EMi thermostats directly using controls on the thermostat itself to specify different temperature set-points to compensate for times when homes or premises will be unoccupied or unused. The thermostat also includes web-based control software (Figure A.14), which allows customers to remotely view or change thermostat settings using any standard web browser. Customers retain control of their thermostats and can override set-point changes made by the load control program operator at any time, either locally at the thermostat or remotely via the web.

When a customer overrides the set-point changes, this will be logged into a database for future usage by the program operator. These override records can be used to make real time adjustments to the estimated load reduction of the load control event in progress. This allows program operators to extend or expand load control events to achieve the desired load reduction. Program operators can also designate load control events to be non-overrideable, in which case customers will not be able to override the new set-point setting.

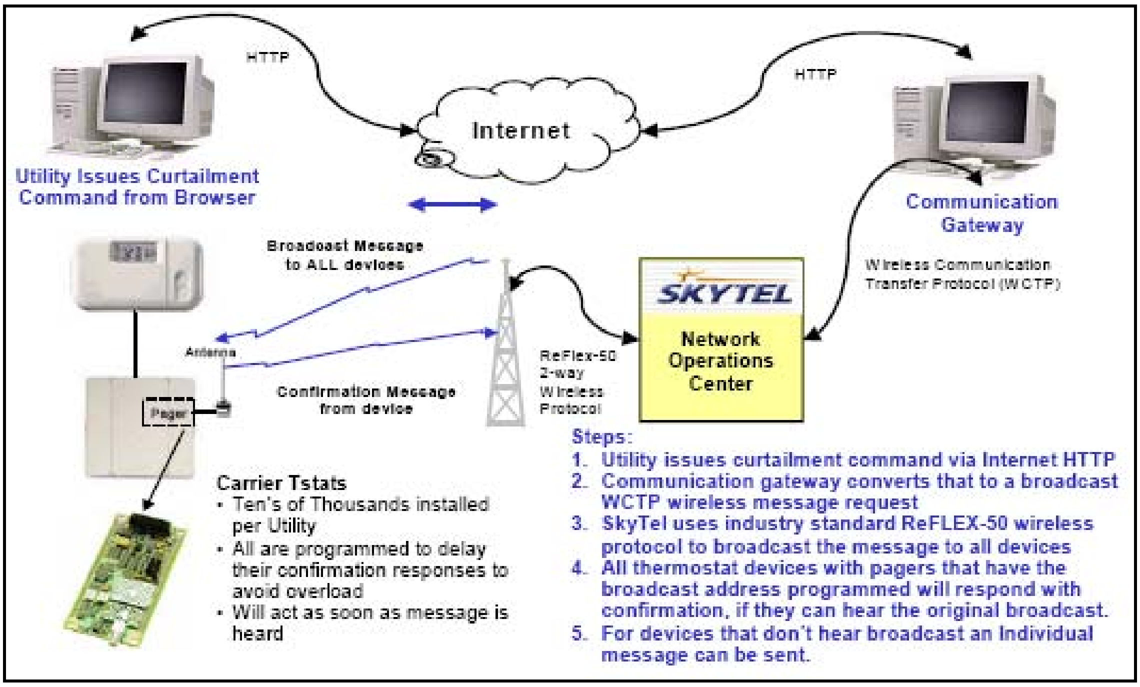

Figure A.15 Broadcast Message Flow in the ComfortChoice System

Figure A.15 represents the overall ComfortChoice system configuration showing message flows to and from the EMi thermostats. When a load control event is initiated, a software program causes a broadcast pager signal to be transmitted to a receiver (I/O board with paging module) located at each participating customer's home or premises. The pager signal triggers a shift of the thermostats' set-points, or initiates cycling action, which results in load reductions. A pager signal is sent back from each unit indicating that the instruction was received. The system also reports the operating times of the air conditioners' compressors, and whether the customer overrode the program operator's signal.

Deployment: The ComfortChoice system has been used in demand response programs and trials by several utilities in the United States since 2001.

Full deployments of the ComfortChoice system include:

- Long Island Power Authority – 24,000 residential, 4,400 small business
- ConEdison – New York City – 14,000 residential, expanding to 12,000 small Business
- Southern California Edison – 9,000 small business
- San Diego Gas & Electric – 5,000 residential

Ongoing pilot programs with the ComfortChoice system include:

- Public Services Gas & Electric – New Jersey – 120 residential, 140 small business
- Colorado Springs – 500 residential
- Nevada Power – 600 residential
- City of Anaheim, California – 100 small business

Further Information: http://www.comfortchoice.carrier.com

Raymond Archacki <raymond.archacki@carrier.com>

A4.2 LeKey Energy Management System

Manufacturer: ELink AS

Country of Origin: Norway

Functions: Real time monitoring and measurement of energy consumption; remote switching of appliances and equipment

Communications: Two-way, using radio and the internet

Type of Metering Required: Interval

Description: The LeKey Energy Management System comprises the LeKey energy management software and the LeKeyBox appliance controller.

The LeKey internet-based energy management software carries out real time monitoring, measurement, data capture and display of energy consumption information. Because the LeKey system is developed using real time two-way communication, a load control program operator can at any time use the internet to access information about the status of each individual controlled load. This allows the program operator to control all loads effectively based on price information and network capacity. The operator can enter contractual information like mandates, triggers, predefined load groups, load attributes, etc into the LeKey software. This information can then be used to automatically send load control initiation signals and/or to send warning messages to customer sites.

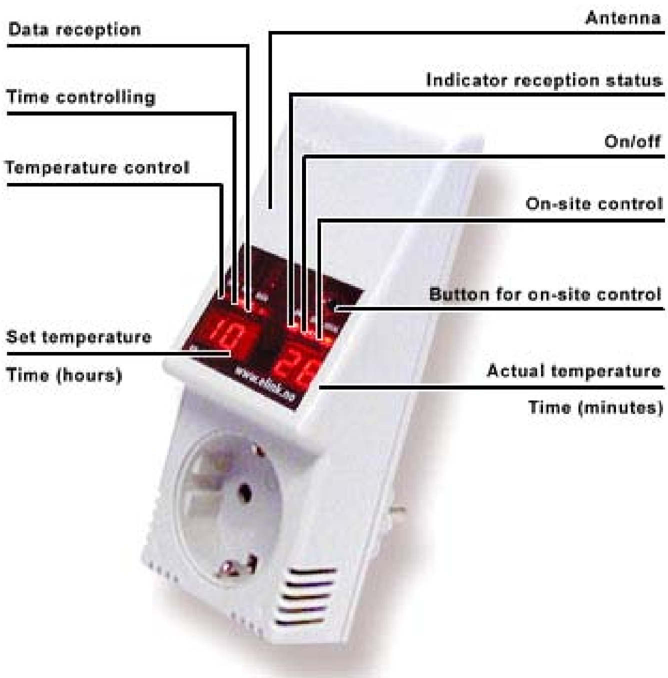

Figure A.16 LeKeyBox Appliance Controller

The LeKeyBox (Figure A.16) is a plug-in appliance controller with radio and internet communication which also includes a timer and a thermostat. A load control program operator can send a radio signal to remotely switch appliances and equipment plugged into multiple LeKeyBoxes. The program operator can also remotely change the settings of the thermostats included in LeKeyBoxes.

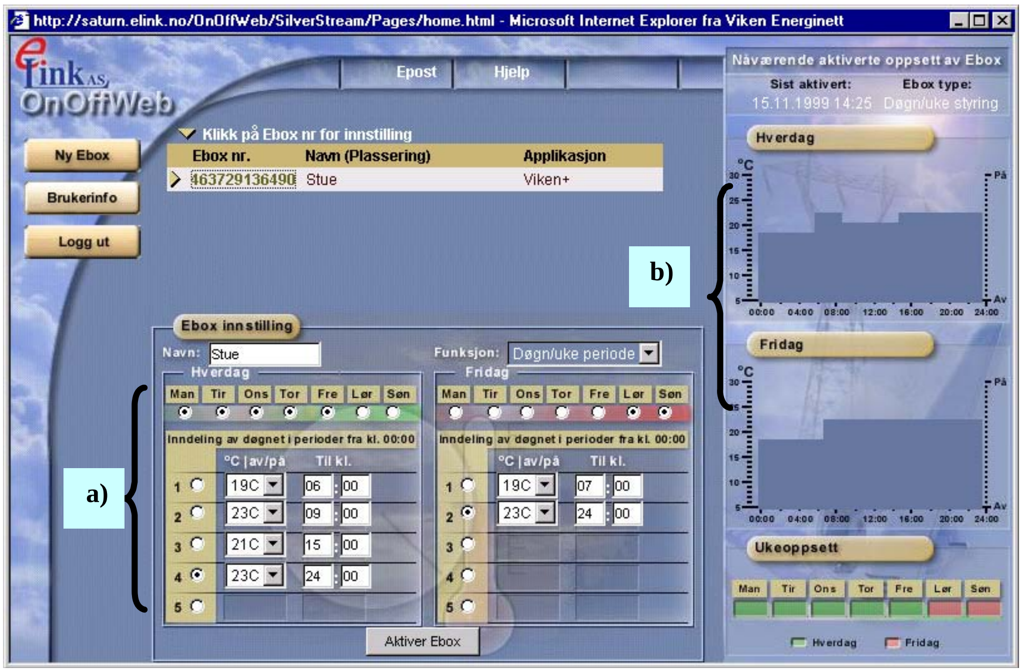

Figure A.17 Web-based User Interface for the LeKeyBox

Individual end-use customers can use a personal webpage (Figure A.17) to program the settings of LeKeyBox units located in their homes or premises; changes to the settings are transmitted to the units over the radio network. Customers can also change settings locally by using buttons on the LeKeyBox itself.

Deployment: LeKeyBoxes were one of the load control technologies used in a large scale trial in 10,000 homes in Norway during 2004 and 2005.

Further Information: www.elink.no/index.php?page=2-1

A4.3 SD Electricity Manager

Developer and Manufacturer: ShreeDutt Technologies Pvt Ltd

Country of Origin: India

Function: Real time monitoring and measurement of energy consumption; remote switching of appliances and equipment

Communications: Two-way using the internet, mobile phone technology and wireless mesh networking

Type of Metering Required: Interval meters with advanced metering infrastructure

Description: The SD Electricity Manager is a wireless mesh networking-based energy management solution than can be used in the residential, commercial and industrial sectors.

Figure A.18 Components of the SD Electricity Manager

The components of the SD Electricity Manager (Figure A.18) are:

- the **EM Wall Plug Module** – a plug-in unit that can be used with any electrical appliance or equipment; and
- the **EM Controller –** a controlling device that doubles up as thermostat.

The **EM Wall Plug Module** is designed to control and monitor the energy usage of an appliance or piece of equipment that is plugged into it. The module contains a remotely-addressable switch that provides On, Off and Variable Load functions. The module also calculates the actual electricity consumed by the appliance or equipment and meets the specification requirements for Class 1 AC Watt-hour meters.

The **EM Controller** is a wall-mounted unit capable of managing multiple EM Wall Plug Modules. The Controller provides start-up and coordination functions for the wireless mesh network and can also double up as thermostat. It is also connected to the electricity meter in the customer's home or premises using a standard metering interface. The load control program operator can send signals to the EM Controller through the electricity meter or through the internet.

The SD Electricity Manager communications network is shown in Figure A.19 (page 79). The EM Controller receives signals from the load control program operator:

- through the internet using the Electricity Manager software running on a personal computer; or
- through advanced metering communications using mobile phone technology (GPRS or CDMA).

The Controller then sends control commands to the EM Wall Plug Modules in the customer's home or premises through wireless mesh networking based on the ZigBee standard. The wireless mesh networking system adds reliability in data transmission without the need for direct point-to-point communication.

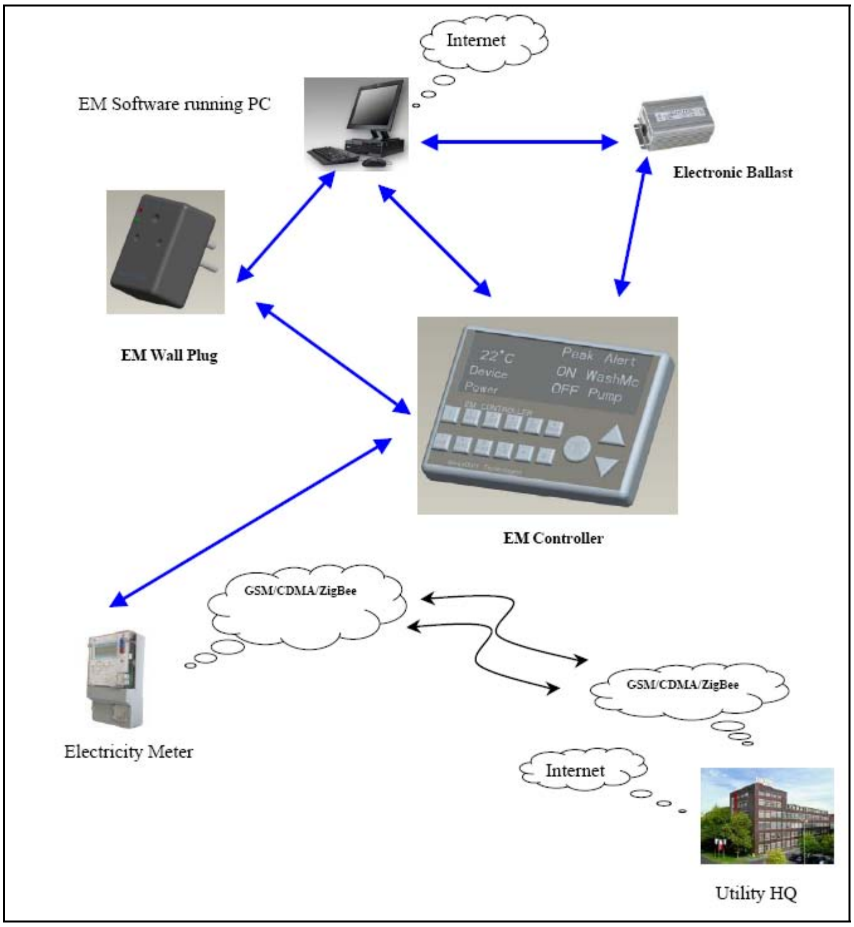

Figure A.19 SD Electricity Manager Communications Network

Deployment: Not yet deployed in large number.

Further Information: www.shreedutttech.com

Tejus Karnik <mailto:tejuskarnik@shreedutttech.com>

A4.4 Rippleband Load Control System

Developer: Phase 6

Manufacturer: Tytronics (a division of the Tyree Group)

Country of Origin: Australia

Function: Real time monitoring and measurement of energy consumption; remote switching of appliances and equipment

Communications: Two-way, using Rippleband (an advanced form of ripple control)

Type of Metering Required: Can use data from both accumulation and interval meters

Description: The Rippleband Load Control System comprises a local network load control and communications technology, designed specifically to deliver strong and reliable signals over any distance within the natural envelope of existing low-voltage powerlines.

Rippleband is an advanced form of ripple control that can deliver two-way communications, in contrast to the one-way communication delivered by standard ripple control systems. Rippleband operates 800 times faster than standard ripple control and has a symmetric path design, which means that signals go forward and back at the same rate. Rippleband travels any distance on the low-voltage network and does not require repeaters.

Figure A.20 Rippleband Neighbourhood Node, Load Agent and Meter Interfaces

The Rippleband Load Control System comprises a range of products (Figure A.20), including:

- for appliance control:
  - ♦ **Rippleband Load Agent –** a hard-wired programmable load control switch;
  - ♦ **Rippleband Plug-in Relay –** a plug-in programmable load control switch;
- for meter communications:
  - ♦ **Rippleband Meter Interface –** modems for meter data communications and load control;
  - ♦ **Meter Mouse –** an optical sensor that provides pulsed output from legacy electro-mechanical accumulation meters;

- communications gateway:
  - ♦ **Rippleband Neighbourhood Node** – an intelligent data concentrator with load control that can link to any WAN or meter format, and is also compatible with existing one-way power line carrier systems;
- control software:
  - ♦ **Demandor Utility Information System** (developed by OpenEnergy Pty Ltd) – load management software that can be used to deliver one- or two-way load control through Rippleband Load Agents. Demandor monitors electricity market prices or network loads and sends notifications when prices or loads satisfy given rules (eg go outside a certain range). Notifications can be sent via any WAN to Rippleband Load Agents commanding them to turn electrical appliances and equipment off or on.

Rippleband products are all designed to meet the needs of an advanced meter infrastructure (AMI) using powerlines as the carrier, and are compatible with the OpenAMI formats developed in the United States. Rippleband products are engineered for two-way load control, irrespective of whether only a one-way application is required.

All Rippleband products are intelligent and individually addressable up to IPV6 protocols, enabling addressing down to appliance level. Rippleband products are remotely programmable to implement changes in pricing, cycling and other variables as they occur.

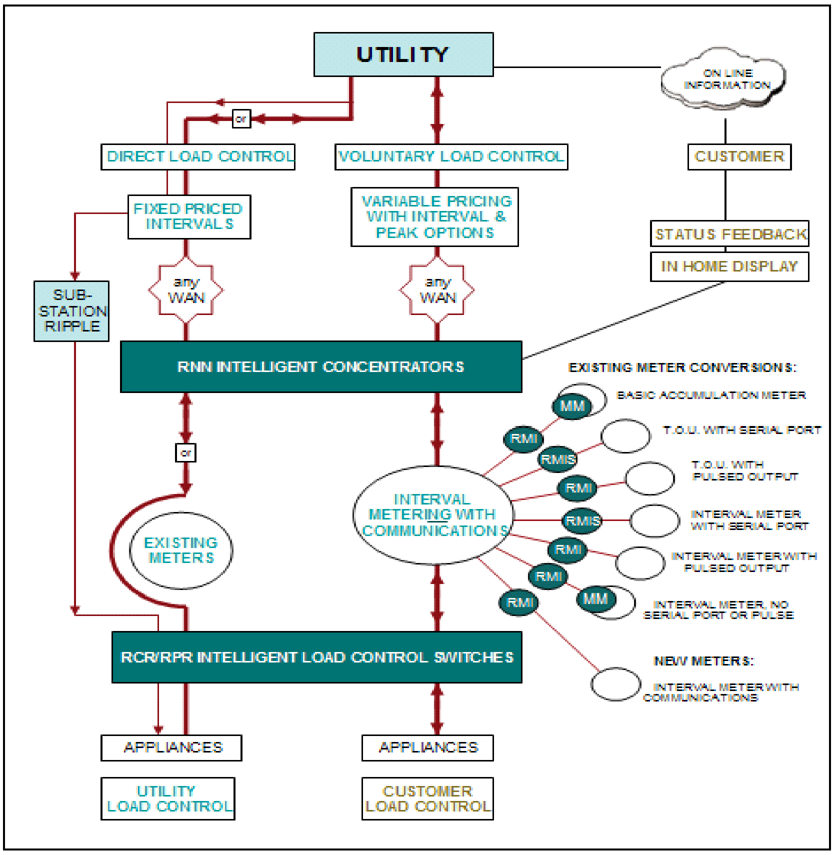

Figure A.21 Communications Network for the Rippleband Load Control System

Figure A.21 (page 81) shows the communications network for the Rippleband Load Control System which can operate one-way or two-way and can also use existing standard ripple control and any WAN format. The network can provide direct load control without requiring connection to electricity meters, and also enable a move to full AMI and variable pricing, without any system redundancy.

Deployment: Rippleband products are currently being used by a major Australian electricity distributor in large-scale demand response trials.

Further Information: Paul Wiszniak <pwiszniak@tytronics.com.au>

Christopher Bean <chris@phase6.com.au>

Ewan Parsons: <ewan@phase6.com.au>

A4.5 GridAgent Distributed Energy Management and Control System

Developer: CSIRO Energy Transformed Flagship

Manufacturer: None at present

Country of Origin: Australia

Function: Automated control of appliances

Communications: Two way, will work with any modern communications technology, from wireless to broadband over powerlines

Type of Metering Required: None required

Description: CSIRO's Energy Transformed Flagship is working on developing a distributed intelligence platform to aggregate and control on-site energy assets in a way that suits electricity retailers and distributors but also allows end-use customers to control and choose how their electricity supply is handled.

The platform and its capabilities are based on "intelligent agent" technology, particularly the installation of software to create an intelligent device situated in customers' homes or premises. Software agents sense, compute, switch, and communicate with each other across the premises to automatically switch loads and on-site generators according to an energy savings policy decided by, and optimised for, each customer.

An agent monitors the energy consumption of each appliance or piece of equipment in the premises and communicates to the rest of the agent system its capability to turn on or off and/or shed load. All these responses are aggregated into a system-wide response. As system needs change, new price signals or other cost functions can be communicated to the local agents, and depending on the customer preferences that steer these agents, they can choose how they will contribute to the overall response.

The actual control of appliances and equipment requires additional hardware into which the software intelligence can be installed. CSIRO uses a variety of hardware technologies in deploying the GridAgents system.

- **Wireless sensor network technology** is used to sense and communicate local environmental data (such as temperature, humidity, and room occupancy) back to agents. CSIRO's own wireless sensor devices, called *Flecks,* are able to form a robust radio communications environment amongst themselves, avoiding the need for expensive cable runs and other installation overheads.
- **Embedded computing devices** are used to deploy the actual agents that interface to electrical loads and generators. CSIRO uses a variety of computing devices, from consumer-PDA based devices, to embedded industrial controllers, in deploying the GridAgents system, where the particular device chosen is matched to the application environment. Considerations here include physical appearance, the need for a screen for local user interaction, and robustness in harsh environments. Overriding these is consideration of the cost of the hardware; CSIRO contends that for a distributed agent-based control system to enjoy widescale uptake, the hardware used must be as cheap as possible.
- **Interfacing hardware** is used to interface the distributed agents to the actual loads and generators they control. The GridAgents generally use relatively simple interfaces to the local load or generator ("on/off", "up/down", etc), leaving detailed plant operational considerations to the local device. Physical interfaces include wired serial communications, wireless Bluetooth based communications, and industry-standard communications protocols.

The software agents are managed through a web-based management console (Figure A.22, page 84). This enables the customer to "drill-down" to a particular agent and see exactly what it, and the unit it is controlling, is doing at a particular time. The console includes a Business Rule Editor, which allows the customer to create business rules for the system of agents, such as "Enable HVAC during the hours 9.00 am to 6.00 pm". A Utility Rate Editor enables the creation of complex tariff structures representing the actual tariff that applies to the customer. The business rules and tariff structures are inputs to the agent system and constrain how the agents can control appliances and equipment in the customers' homes or premises.

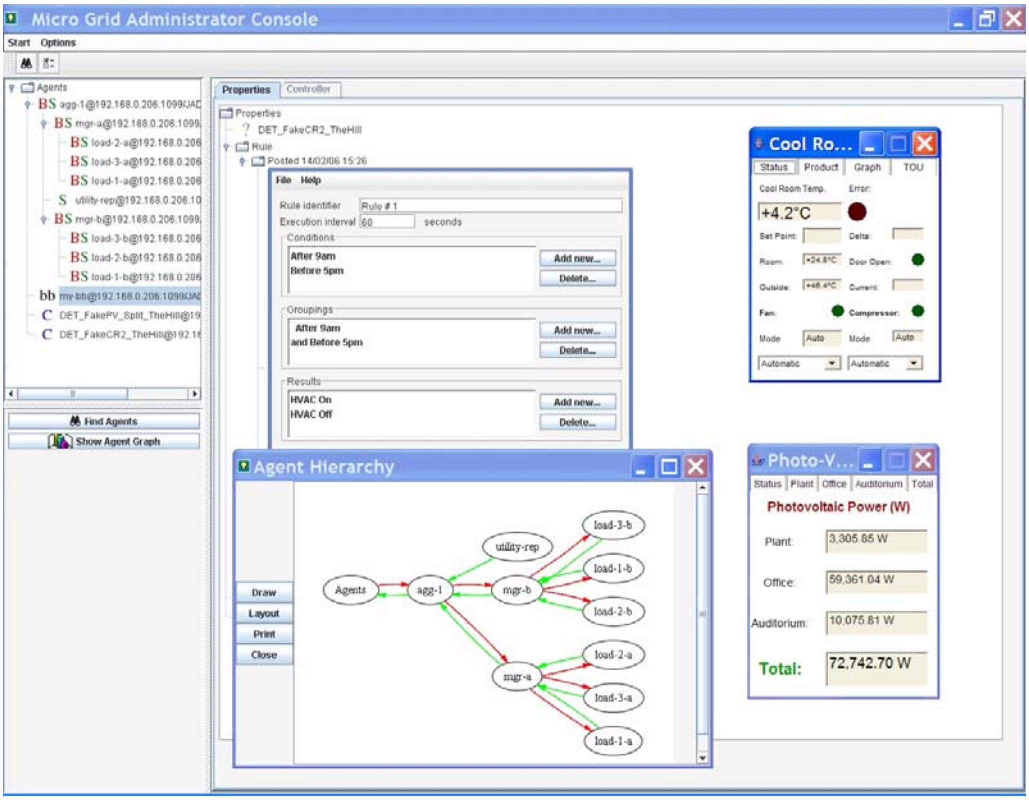

Figure A.22 Web-based Management Console for the CSIRO GridAgents

The system includes very intelligent algorithms that enable aggregation of thousands of disparate loads and generators across the whole electricity distribution network into one aggregated response, with system wide benefits, whilst still considering the local constraints of those loads and generators. The aim is to provide a firm demand response, whilst still incorporating user preferences.

System-wide benefits include:

- the ability to aggregate supply and demand from groups of customers to flatten out peak demand; and
- the formation of intelligent islands or mini-grids that can survive supply disconnections and that continue to provide services during contingencies on the main network.

Deployment: Working with US-based software developer Infotility, CSIRO has completed the first release of the GridAgents software framework. CSIRO is building a demonstration system at the CSIRO Energy Centre in Newcastle (Figure A.23, page 85), putting a gas micro-turbine, photovoltaic arrays, and a wind generator under agent control, along with two cool rooms and a zone of a building climate system. This will form a mini-grid coordinating supply and demand and reacting intelligently to electricity market or retail contract price signals. CSIRO has also trialled the system with a major Australian electricity business, and is looking for partners to work together on a large-scale trial of this technology.

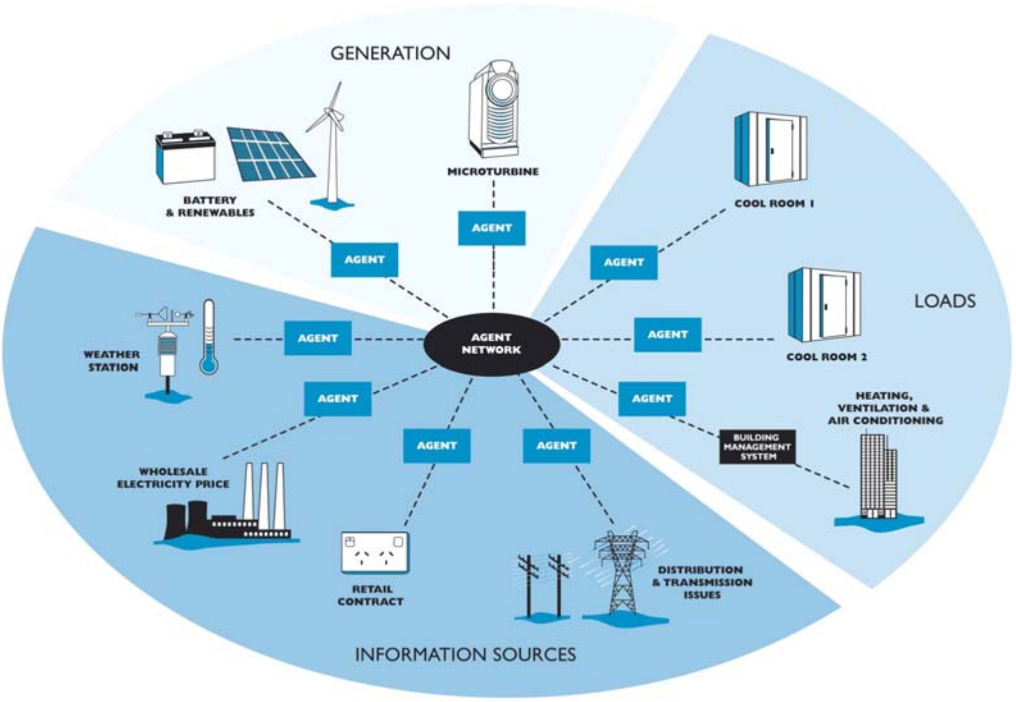

Figure A.23 Demonstration GridAgent System at the CSIRO Energy Centre

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A4.6 Wattwatcher Smart Monitoring System

Developer: Wattwatchers Pty Ltd

Manufacturer: Wattwatchers Pty Ltd

Distributor: Wattwatchers Pty Ltd

Country of origin: Australia

Function: Real time monitoring and measurement of energy consumption; remote switching of appliances and equipment

Communications: Mesh radio

Type of metering required: Metering not required but can interface with interval meters

Description: The Wattwatcher Smart Monitoring System is designed to deliver to the mass market for a very low cost most of the functionalities and benefits of a home automation and energy management system.

The Wattwatcher system includes:

- electronic devices that provide householders with easy access to real-time detailed data on their electricity use, and the resulting financial costs and carbon emissions; and
- software applications that enable householders to gain a deep understanding about how they are using electricity at home; to use interactive software programs to make energy savings; and to become participants in on-line forums and communities focussed on saving energy.

System Configuration

The operation of the Wattwatcher Smart Monitoring System is shown in Figure A.24.

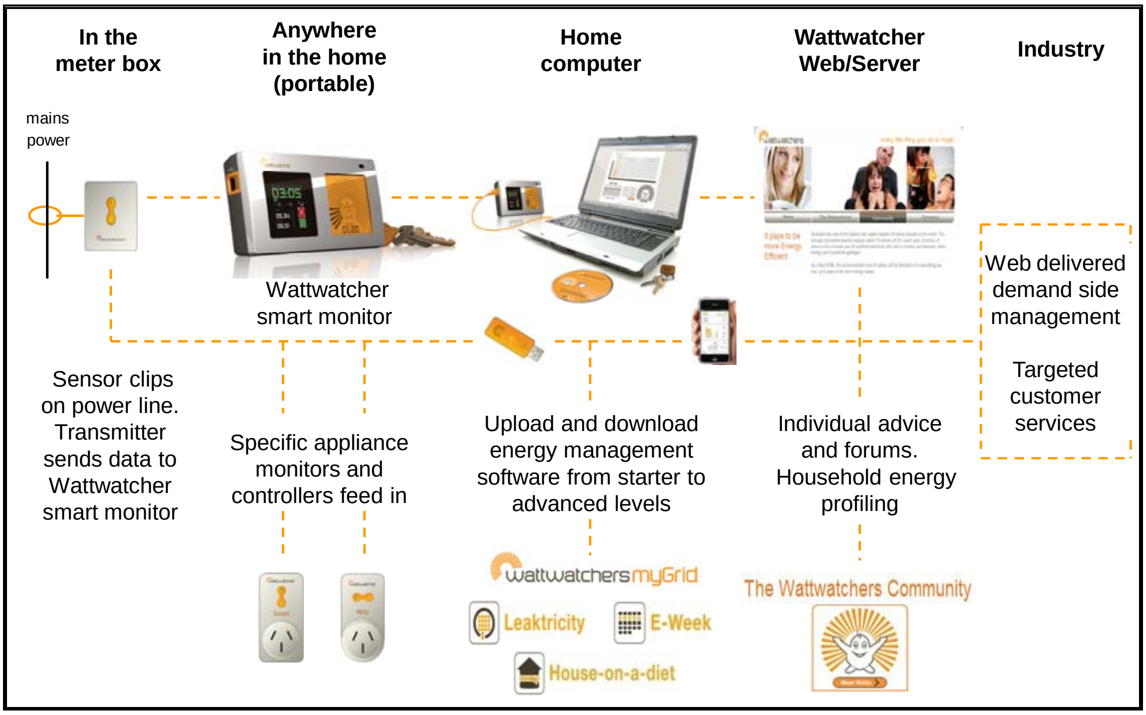

Figure A.24 Components of the Wattwatcher System

An electronic sensor (current transformer) is clipped around the incoming power line in the meter box. This sensor accurately and continuously measures the total quantity of electricity being used by the household and is connected to a transmitter that conveys this information by radio to a portable electronic smart monitor. The smart monitor can be located anywhere in the home and can be moved to different locations as required.

The smart monitor records the electricity consumption data and displays a range of continuously updated measurements on a colour graphics screen, including:

- the household's electricity consumption (kWh), electricity cost ($) and greenhouse gas emissions (tCO2 e) over a range of time intervals, such as the last hour, day, week, month or year;
- the household's power consumption (kW) at any one point in time;

- the time (am or pm);
- the time-of-use electricity tariff currently in operation; and
- the outside temperature.

Wattwatcher Electronic Devices

The Wattwatcher electronic devices are shown in Figure A.25.

Figure A.25 Wattwatcher Electronic Devices

The smart monitor is currently being developed in three different formats:

- the **Wattwatcher Duo**, a two screen device that includes all the interactive, remote control and monitoring functionalities of the Wattwatcher system;
- the **Wattwatcher Ono**, a low cost single screen device with a simplified range of functionalities designed for less sophisticated households;
- the **Wattwatcher Smart**, a low cost single screen device similar to the Ono which also includes a bar code reader designed for disadvantaged households. The reader enables householders without a home computer or internet connection to download information (eg electricity retailer pricing and billing information) and software and firmware updates from printed media or public internet facilities, eg in public libraries.

The Wattwatcher system also includes three other electronic devices:

- the **Wattwatcher Spy**, a sensor that can be attached to any power point to measure and record the electricity used by individual appliances and transmit this information by radio to the smart monitor;
- the **Wattwatcher Toad**, a switching device that can be attached to any power point and receives radio signals that remotely switch appliances off and on; and
- the **Wattwatcher USB Dongle** that enables householders to use computers and always-on internet connections to carry out remote control of home appliances and monitoring of Wattwatcher devices.

Software Applications

All Wattwatcher smart monitors (except for the Wattwatcher Smart) can be attached to a personal computer to download and store the energy consumption data for further analysis. A set of integrated software applications supplied with the Wattwatcher system enables householders to:

- use the **myGrid** program (see Figure A.26, page 89) to break down the total household energy use into different time bands and end-uses in the home, eg refrigeration, water heating, lighting, cooking, air conditioning, room heating, other appliances;
- engage with an easy, multi-level, interactive games style program called **Leaktricity** that takes householders through simple discovery steps, shows how much appliances cost to run, then provides awards for identifying why and how the household 'leaks' so much electricity;
- operate the **E-Week** program that helps households set up an 'Energy Week' to see what energy savings are possible, and establishes a benchmark showing the potential for energy savings by the household;
- implement the **House-on-a-Diet** program, a simple planning and goal-setting tool which takes into account the individual household's lifestyle profile, and shows how to establish and maintain the energy-saving habits that really make a difference;

- access the internet to obtain energy saving advice tailored to the particular household profile and participate in on-line discussion forums and communities dedicated to saving energy in the home.

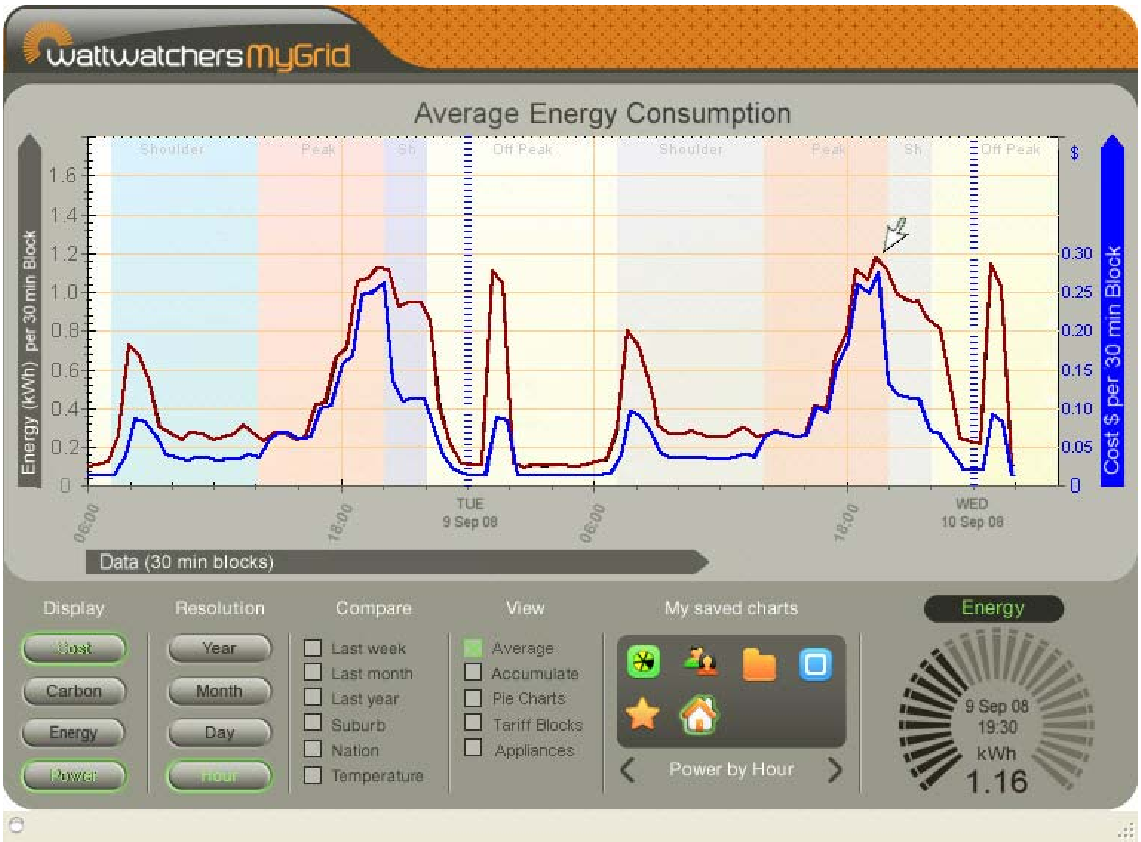

Figure A.26 Consumer Interface for the Wattwatcher myGrid Software

Deployment: The Wattwatcher Smart Monitoring System is currently under development. Deployment on a large scale is expected in the second half of 2009.

Further information: http://www.wattwatchers.com.au

A4.7 Lightchek Advanced Street Light Controller

Developer: Secure Meters Limited

Manufacturer: Secure Meters Limited

Distributor: Secure Meters Limited

Country of origin: India

Function: Real time monitoring, measurement and load control of the energy consumption of street lights

Communications: GSM mobile phone network

Type of metering required: Interval metering

Description: The Lightchek Advanced Street Light Controller provides centralised control of street lighting systems (see Figures A.27 and A.28).

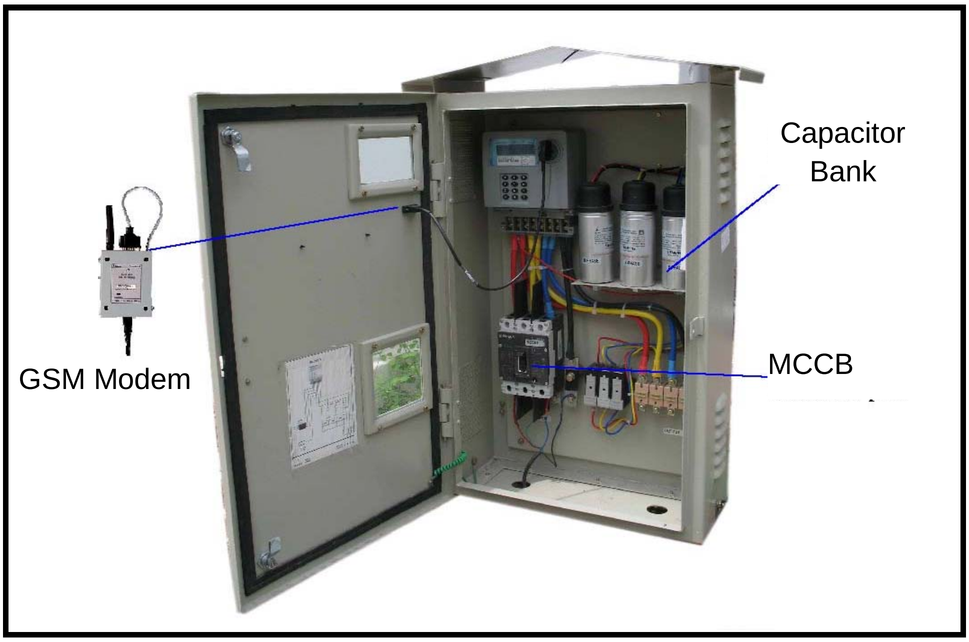

Figure A.27 Components of the Lightchek System

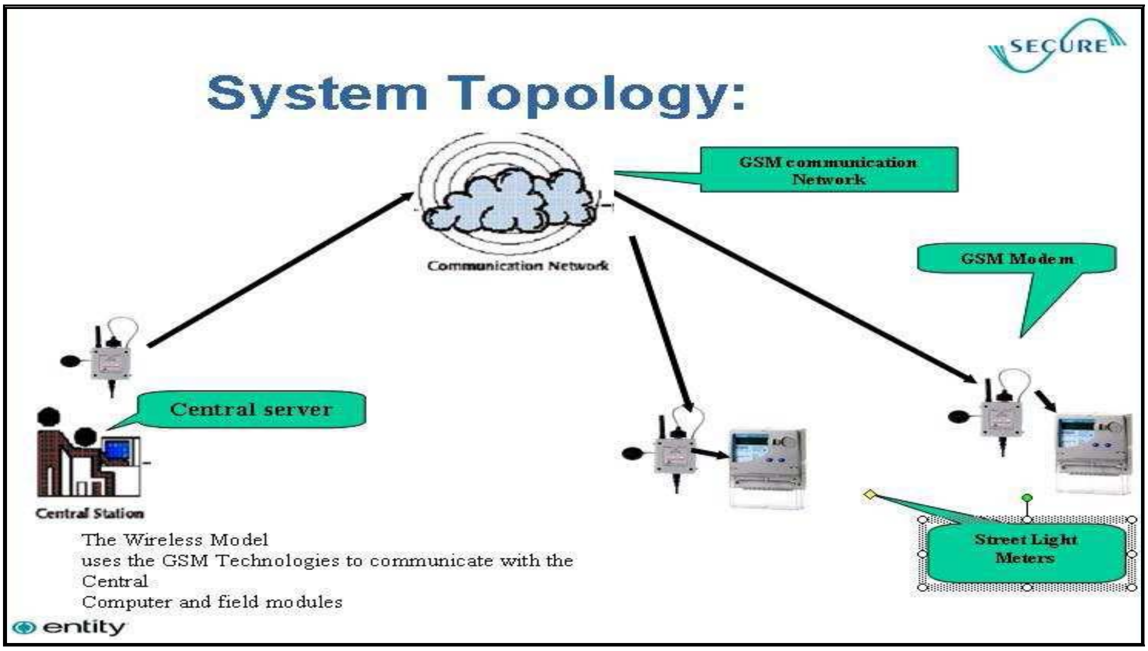

Figure A.28 Lightchek System Topology

Remote switching of street lights can be accomplished in four ways:

- through manual entry using a keypad;
- through a meter reading instrument;
- by SMS via a mobile phone or base computer software supplied with the system (see Figure A.29);
- by automated time-based switching using an astronomical real-time clock which can be programmed for sunrise and sunset times up to a year in advance.

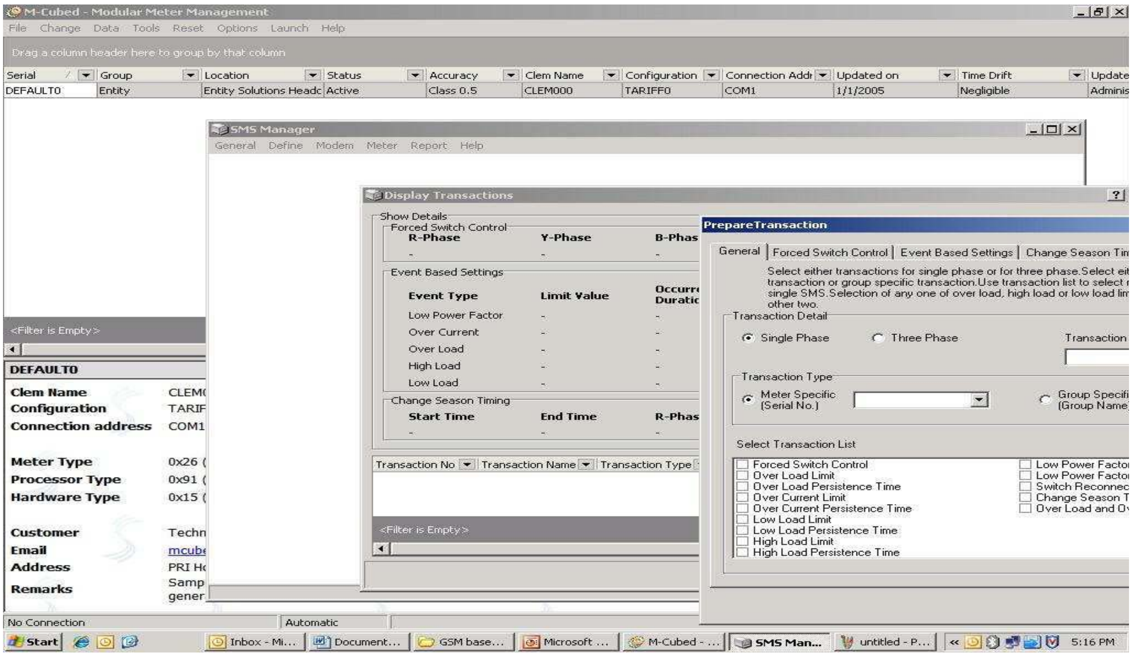

Figure A.29 Lightchek Base Software

The Lightchek system records energy consumption and reactive power used by the streetlighting system. Measurement data and event logs can be downloaded from Lightchek using GSM communication for reports, audits, energy tracking and planning.

The system has independent control of the three phases and can send alerts to the user's control station and/or mobile phones for faults or events.

The system includes a capacitor bank that can be used for power factor correction and also includes a moulded case circuit breaker (MCCB) for protection from surges and overloads.

Deployment: The Lightchek system has been deployed in New Delhi and Kolkata in India.

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A4.8 Saab Direct Load Control System

Developer: Saab Systems Pty Ltd

Manufacturer: Saab Systems Pty Ltd

Distributor: Saab Systems Pty Ltd

Country of origin: Australia

Function: Remote switching of consumer air conditioning and other loads

Communications: Public FM radio

Type of metering required: No metering required

Description: The Saab Direct Load Control System provides direct load control of consumer air conditioning and other loads.

On instruction, the system turns off the requested electrical loads at the targeted properties. This can occur on a variable cycling basis with a range of cycling profiles, eg all at once, section by section, individually, by load factor, etc. Alternatively, the system can distribute the load cycling on a rotational basis, eg 25% of participating loads every 15 minutes.

The components of the system are shown in Figure A.30.

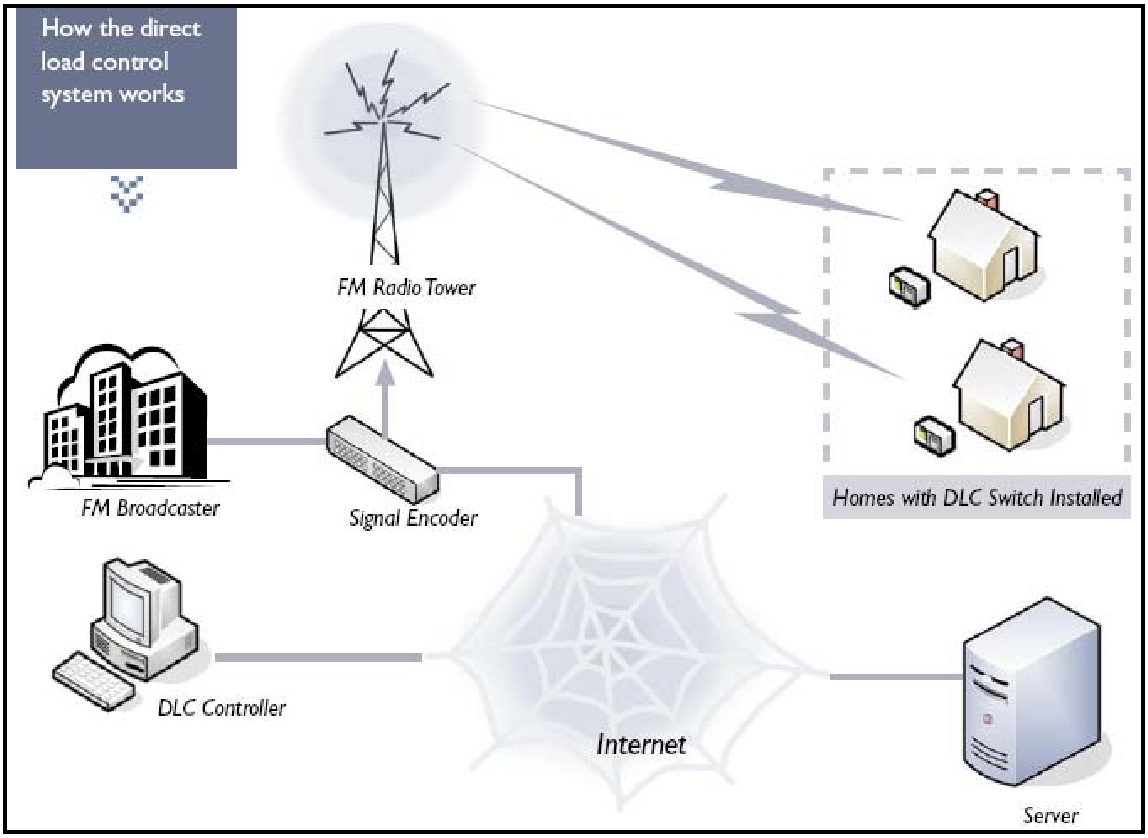

Figure A.30 Components of the Saab Direct Load Control System

The system utilises existing communications infrastructure. A web based user interface dispatches signal transmissions through public FM broadcasting stations to control small inexpensive load switching devices that switch electrical devices on or off during peak demand periods.

The system's server presents load cycling options and prepares commands for transmission via the signal encoder. The server contains the database of all DLC switches, recording their location and loads controlled. The signal encoder receives the commands from the server, modulates and transmits them via the transmitting station. The decoder receives the modulated commands from the transmitter, decodes them and acts in accordance with the instructions embedded in the commands to cycle appropriate loads.

The system does not require expensive direct connections such as phone line, GSM or GPRS. Household and commercial discretionary loads require a simple one-off hardware installation of a passive, low cost Direct Load Control (DLC) switch called the "Peakbreaker" (see Figure A.31).

Figure A.31 The Peak Breaker Direct Load Control Switch

Simultaneous operation of multiple DLC switches allows rapid load reductions.

Flexible switch identification (segmentation) allows sharing of load cycling across suburbs, substations or individual users to ensure fast rotation of load reductions during peak demand periods. Only targeted non-essential, high load appliances, such as air conditioners, are candidates for load cycling, to ensure essential appliances are not affected.

There is a range of installations of the Saab Direct Load Control System to suit most applications:

- a four-relay switchboard mounted DLC switch controls single or multi phase loads which enables control over any commercial or household load;
- a single-relay DLC switch for air conditioners interrupts the compressor leaving the fan operational during power shedding;
- a single-relay power point DLC switch controls any appliance connected to a mains power point.

Deployment: The Saab Direct Load Control System has been deployed in trials of air conditioner cycling in Adelaide, South Australia.

Further information:

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