BROADBAND COMMUNICATION ENABLES SUSTAINABLE ENERGY SERVICES

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Australia's electricity supply infrastructure requires investments exceeding $100b over the next 25 years to maintain quality of service to domestic users. Being careful to distinguish energy service needs from electricity delivery, the case is made for distributed energy services which offer improved sustainability outcomes to the traditional monolithic generation model. A key enabling technology for commercial success of the proposed paradigm is a broadband communication infrastructure. Broadband is essential in meeting the cost reduction and performance targets that would allow a distributed energy service model to succeed. Using broadband, a large number of novel business opportunities arise. A case study on solar water heaters is presented showing that a broadband enabled smart controller can realise 20% greenhouse gas savings for a conventional solar water heater and 75% savings for an electrical water heater.

INTRODUCTION

The focus of early broadband communications deployment in Australia since its recent inception has been for personal use featuring services such as entertainment, personal communication and Internet. As with the introduction of television in the 1950's, broadband has potential to fulfil other objectives such as enabling sustainable practices.

The term sustainability is often defined as *'the ability to provide for our current needs without compromising the ability of future generations to provide for themselves.'* Sustainable practices therefore encompass economic, environmental and social considerations and imply a long term vision.

This paper examines the status of residential energy service delivery in Australia with a focus on the electricity supply relationship between the electricity retailer and the residential customer. The current monolithic electricity generation and transmission structures are critically examined and an alternative paradigm is proposed which provides far greater opportunities for sustainability outcomes including employment, greenhouse gas emissions and cost savings to householders. This paradigm relies on a broadband communications infrastructure and would be readily applicable to both business and domestic use.

CURRENT STATE OF SUPPLY OF ELECTRICITY TO RESIDENCES IN AUSTRALIA

The National Electricity Marketing and Management Company (NEMMCO) operates the electricity market on the eastern and southern seaboard including Tasmania (NEMMCO 2005). They are responsible for setting the wholesale market price for electricity as determined by the current demand. The NEMMCO service model consists of energy suppliers (Generators), energy transporters (Network Operators), energy distributors (Retailers) and customers. The value of energy increases as it moves from generation to distribution to consumption (Figure 1).

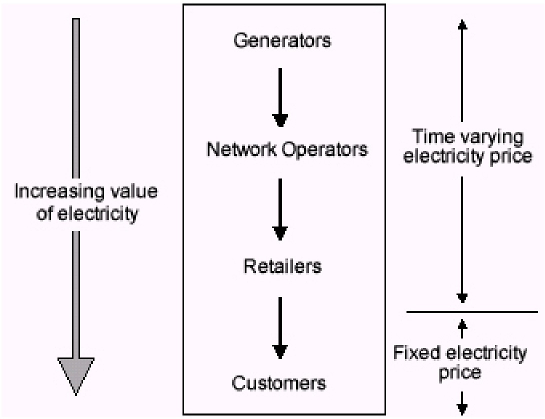

Figure 1 The structure of the national electricity market

The time-varying wholesale electricity price is the result of a supply and demand balance and is seen to change significantly over the course of a day and across a number of days (Figure 2). Australia has a dynamic electricity spot market, where prices can vary from minus \$1000 to positive \$10 000 per MWh of electricity on a half-hourly basis.

Energy retailers must supply electricity to customers with fixed tariff structures and thus carry significant exposure to the wholesale energy price fluctuation. Retailers offset this risk by maintaining a financial hedge position, usually with future price averaging contracts. Their exposure is also mitigated by inflating the connection and distribution charge to consumers while maintaining a fixed energy rate or by charging a time of use tariff.

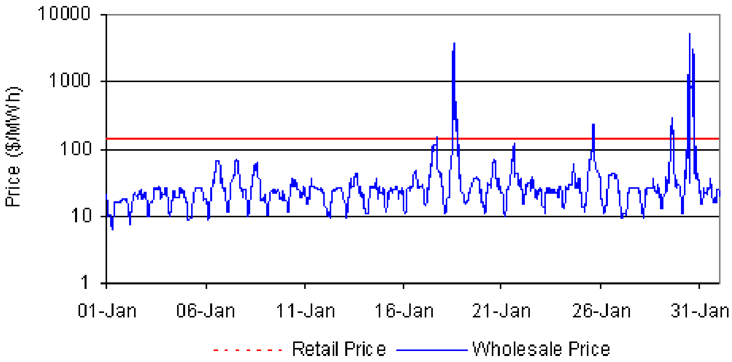

Figure 2 Electricity wholesale spot price for NSW compared to fixed retail price, Jan 2003
Data provided by *NEMMCO*

Apart from financial instruments, technologies that reduce the exposure of an energy retailer to peak wholesale energy costs are generally called demand side management (DSM) and comprise of two strategies:

1. *Peak shedding* - load reduction through end use energy efficiency
2. *Peak shifting* - load shifting in time through energy storage

It is not really to the retailer's advantage to promote either form of DSM under the current regulatory framework. Peak shedding represents a reduction of exposure to peak wholesale electricity prices at the cost of a sustained loss of income. Peak shifting is currently not feasible on a large scale. Furthermore, the retailer is often responsible for implementing government regulations such as the Mandatory Renewable Energy Targets (MRET) and Smart Electricity Metering.

Domestic electricity supply in Australia is at a crisis point. The Electricity Supply Association of Australia, representing the big electricity generators, reports that Australia needs to build $35b of *generation assets* in the next 25 years to meet the forecast 67% increase in electricity demand by 2030 (Energy Supply Association of Australia 2007). This cost could increase to $78b if carbon capture and sequestration is required and this is looking increasingly likely due to the implementation of emissions trading schemes. It should be noted that carbon sequestration technology is still in development and carries risks (Thomas et al. 2004; van der Hoek and Dennis 2004).

Furthermore, peak electricity demand is growing faster than baseload demand. Since the power output of large baseload fossil fuel power stations cannot easily be modulated, such generators are not capable of providing the complete solution to Australia's future electricity supply.

Electricity *transmission assets* will require $35b investment over the same period to maintain peak capacity of electricity delivery to our homes (Energy Supply Association of Australia 2007).The transmission peak capacity problem is largely (75%) attributed to the boom in residential air conditioner sales (Energy Retailers Association of Australia 2004). In effect, the households with no air conditioning cross subsidise those with air conditioning to the extent of $75/year (or about 1.5-2c/kWh) through increased grid connection charges.

Despite this immediate need for investment, infrastructure financiers are reluctant to invest in generation facilities due to uncertainty in future carbon pricing and reluctant to invest in network facilities due to low capacity factors (Figure 3). One NSW retailer estimates that the top 10% carrying capacity of its network is used to meet this peak load for less then 24 hours per year (Energy Australia 2006) and that they spent $525,000,000 on network assets in 2005/6. This represented about 25% of sales. A further $3.7b of investment in network augmentation is planned until 2009/10. This is money that utilities cannot easily claw back because of federally controlled retail pricing.

In recent times, the centralised electricity generation model has come under increased scrutiny for additional reasons:

- High greenhouse gas emissions from electricity supply due to the predominance of fossil fuels as the energy source and low electrical conversion efficiencies (The Australian Greenhouse Office 2007)
- High water consumption of power station cooling towers has become a serious concern. Each year, Australia's fossil fuel electrical generators consume the equivalent of over half of Sydney's annual water consumption (Rose 2006)[1]
- High transmission losses, in the order of 10% of electrical energy, is dissipated in the transmission grid (NEMMCO 2005)
- Security of supply issues
- Vulnerability to point failures

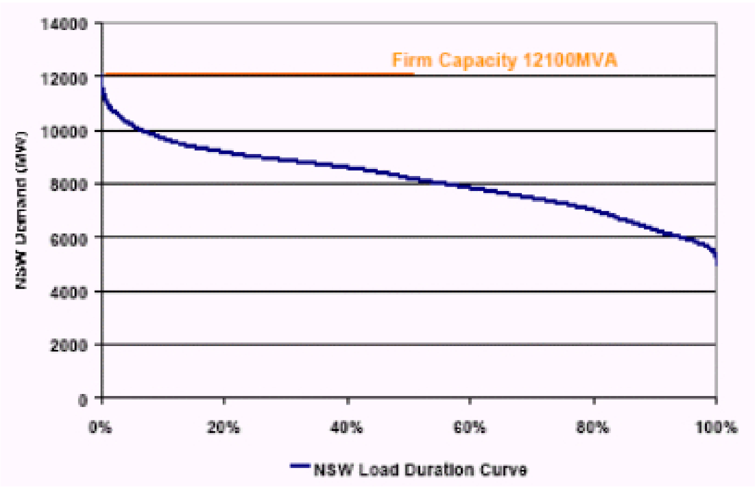

Figure 3 Low capacity factors do not reward large investments in electricity network augmentation. Data shown for NSW

Over the next 25 years, the total required electricity infrastructure investment previously mentioned is equivalent to about $14,000 per household. Given that there has been marked reluctance for private sector investment in electricity infrastructure in recent years, one must question whether centralised electricity generation, potentially risky carbon sequestration and bulk electricity transmission form the best uses of these funds.

ELECTRICITY OR ENERGY SERVICES?

Abbreviating energy services (what we actually need) to electricity (what form we think it should take) would be misleading. Around 70% of our household energy service needs are for household thermal processes such as water heating, space heating and cooling while only around 30% of household services such as appliances *require* electricity (Figure 4). Noting the sustainability implications of the electricity supply chain previously cited, careful consideration should be given to the means by which energy services are provided. Reduction of demand should always be a higher priority than capacity building in generation. By examining household energy service needs, it is easier to understand that renewable energy sources are able to offset much of the existing residential electricity demand.

Grid based wholesale renewable energy generators do help reduce greenhouse gas emissions but require subsidies to be competitive at wholesale electricity market rates. There are also perceived problems with dispatchability of the power for wind and solar sourced electricity. However, the chief shortcoming from grid-based renewables is that the energy is transmitted as electricity and it must be delivered through the electricity grid.

Given that the structure of the electricity market places distributed (household) energy services at the high value end of the energy infrastructure, perhaps there is greater potential to utilise renewable sources at a household level. Increased market penetration of renewable energy generation would help to meet our energy service needs in a more sustainable way.

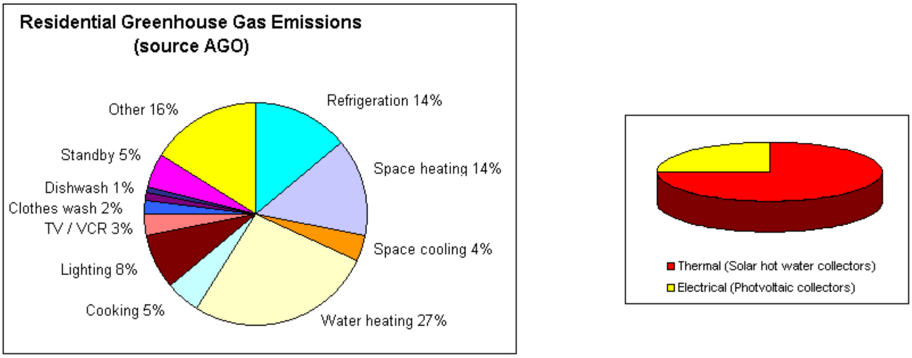

Figure 4 Residential energy demand grouped by energy application (left) and renewable energy source (right)(Australian Bureau of Statistics 2001)

DISTRIBUTED ENERGY SERVICES – AN ALTERNATIVE PARADIGM

In a wider context, the term *Energy Services* should be embellished to include energy storage and generation as well as the applications in which the energy is used. The notion that each household could both generate and consume energy services precipitates the term *Distributed Energy Services*. One of the primary aims of the distributed energy service model is that homes could become greenhouse gas emission neutral in operation or even net exporters of energy. That is, each household could act at both ends of the electricity supply spectrum, as generator and consumer. The retailer's role as master-in-charge would be coordinated via a broadband network.

The model promises far greater sustainability outcomes than centralised electricity generation can provide. In the narrative *Small is Profitable*, 207 distinct benefits of distributed energy services are declared (Datta et al. 2002). Fundamentally the benefits include:

- Vastly improved matching of energy source to energy service demand
- Very attractive financial environment (smaller investment steps, faster returns, volume deployment, lower risk)
- Greater ability of the householder to influence sustainability outcomes from supply of energy services
- A competitive energy service market
- Increased use of low greenhouse gas technologies such as renewables
- Greater opportunities for flow on energy service business
- Greater security of provision of energy services

There is evidence from Europe that distributed energy services do work. In Germany, the Renewable Energy Sources Act (2000) has resulted in an increase of renewable electricity generation from 6.3% to 12.0% over the last seven years (Federal Ministry for the Environment 2007). There have been considerable greenhouse gas savings and the resulting renewable energy industry now employs 214,000 people. During 2006 alone, there was over €9b privately invested in distributed electricity generation alone. Since its inception, the Act has cost €3.3b but estimated to provide €9.3b in benefits and is considered a huge success. This demonstrates the multiplicity of positive outcomes resulting from sustainable practices.

In parallel with energy policy directives, the key drivers that will trigger a change to distributed services are the enabling technologies. They include:

- Renewable energy generation technologies
- Household energy storage technologies
- Broadband connectivity

Each enabling technology is rapidly maturing in its own right, but the greatest benefits of the distributed energy services model comes from integrating the enabling technologies.

A typical house roof in Australia receives solar power at an average rate (over 24h) of about 20 kW. Annual statistics(Australian Bureau of Statistics 2001) indicate an average household energy expenditure of less than 2 kW. The cost of conventional electricity is rising quickly due to a looming network and generation investment surge and the cost of renewable technologies is decreasing with production capacity. Blakers (2005) predicts price convergence during the year 2015, at which time growth in photovoltaic technologies will be explosive. Many households would become net exporters of energy services.

Solar water and air heaters for residential application are commonly available now and work reasonably well. The authors present a case study which demonstrates that improved performance is possible if the enabling technologies are better integrated.

Broadband technology is now close enough to saturation point in many developed nations that it could be utilised to provide more sophisticated offerings for many common services. We foresee several possibilities for the utilisation of broadband technologies for energy service delivery. Broadband provides the communications technology that is necessary to realise the true flexibility offered by the distributed energy services model. It differentiates from other communication technologies by bringing high capacity, low latency, real-time communications to the household or business. Given that the distributed energy service model is largely market driven and thus asynchronous and real time, broadband communications become the method of choice to unlock the benefits of distributed energy services.

DISTRIBUTED ENERGY SERVICES BENEFITS THE ELECTRICITY RETAILER

The electricity retailer carries exposure to fluctuations in wholesale electricity pricing, the responsibility for implementing government regulations such as the Mandatory Renewable Energy Target (MRET) and the onus of managing customers. The integration of enabling energy service technologies combined with a distributed energy service model opens new opportunities for electricity retailers.

A key to enable a shift to an energy service environment is the ability to manage a large number of geographically and temporally distributed energy services. Currently, the balance of supply and demand must be centrally managed in real time since there is little ability to store electricity on a large scale. The snowy Mountains Hydro Scheme is the only significant example on Australia's electricity grid. Furthermore, distributed generation is seen only as a reduction in aggregated demand. With distributed services, localised generation, storage and demand services can interact in complex ways with enhanced sustainability outcomes.

Several states in Australia are implementing smart electricity metering.[2] The proposed agenda is to automate electricity meter reading and to collate half hourly consumption data on a daily basis. Narrowband communications would suffice for this purpose. Since the expensive process of rolling out new meters will not be repeated for some time, this would be an ideal opportunity to at least trial broadband communications with electricity metering.

High granularity knowledge of electricity demand in space and time combined with predictive pricing models and geographic information systems (GIS) allow electricity retailers to maximise supply margin and highlight potential distribution grid weakness. In such circumstances, the retailer might choose to offer a cluster of householders a discount for load shedding. By routinely reducing its exposure to high wholesale electricity pricing, electricity retailers are able to reduce their hedge position and thus realise a greater cost-price margin.

Broadband communications technologies allow far greater decision support capabilities for retailers. Performance and fault information can be gathered in real time over broadband to allow fault prediction and prevention. If a fault has occurred, detection and location of the fault can be expedited. Savings from this alone are substantial (Energy Australia 2006).

Mandated feed-in tariffs for domestic generation, chiefly photovoltaic panels, are providing small-scale distributed generation capabilities to householders. As the penetration of this kind of technology increases, the electricity retailer has a growing supply/demand management problem (opportunity). The combination of weather forecasts, high-resolution meter reading and generator location information will be essential to managing distributed generators on a macro and local scale.

Local clustering and distributed generation greatly strengthen security of electricity supply and can put off investment in grid augmentation. This is particularly true as small-scale energy storage becomes commonplace. Distributed energy generation and storage services allow expensive transmission network upgrades to be delayed or spread over a greater period of time. This is a large cost reduction to the network operator, which is mirrored by charges to the retailer. Only broadband would have the capacity to enable real time demand management for the electricity retailer.

Although transactions between the electricity retailer and the customer would be automated, there are communications implications for the control, metering feedback, billing and notification events associated with clustering and much of this would occur in real time over a number of clients on a potentially large scale.

DISTRIBTED ENERGY SERVICES BENEFITS THE HOUSEHOLDER

The energy services in modern households are rather disconnected from our needs and our desire for sustainable outcomes. Our lights don't come on when we need them and turn off when we don't. We don't know how much hot water we have left in the hot water tank. Our air conditioners don't understand that the transmission network is highly stressed on hot days. Presently, the only feedback paths on household energy consumption are the electricity meter and the electricity bill. Neither of these mechanisms is equipped with sufficient resolution or communication to allow the householder to negotiate the best sustainability outcomes (including financial) in real time. Studies show that visibility of electricity consumption information is vital to reducing greenhouse gas emissions (Oliphant 2003).

The distributed energy services model with broadband communications tightly integrated offers householders a number of possibilities including the ability to:

- Schedule energy related services
- Remotely control services
- Monitor energy consumption and cost
- Respond to price or other incentive signals from the retailer
- Aggregate generation or demand and negotiate services on that basis
- Negotiate transfer of energy services within a local cluster

Implementation would most likely be via all households being provided with a set-top box, similar to that used for digital television customers. The consumer's installation would be configured according to their needs (as determined by a questionnaire, say, or from just a standard choice of service 'plans'). The main part of the software would run at the electricity retailer and would allow for variable electricity pricing to consumers based on either time of use or network demand. The consumer's configuration could take into account maximum cost per unit of time (day/week/month) for financial budgeting purposes, and sustainability targets including greenhouse gas emissions, energy usage, energy storage, optimization of appliance usage (e.g. water heating) and generation to consumption targets. That is, each household could either draw from the grid or contribute to it, as is happening with some solar powered households already. With this broadband setup, householders could be rewarded for contributing to the grid based on demand, rather than the current flat rate (those who are able to generate more than they consume during peak times, for example very hot days when everyone has high power-consuming air-conditioners on, deserve some incentive and compensation!).

Another possibility is the formation of household *clusters*. Members of a cluster could be linked either via the main consumer/retailer link or possibly via a separate wireless broadband network. The idea of a separate network has the advantage of not being dependent on the main network being available, taking further advantage of distribution of the service with security and peak demand implications. Households within a cluster could negotiate amongst themselves with respect to power usage and distribution, minimizing transmission losses, for geographically based clusters, and lessening distribution complexity.

THE DOMESTIC GATEWAY

At present it is difficult for the householder to realise the benefits listed above. The household would benefit from the introduction of enabling energy service infrastructure. As mentioned above, an important new appliance requirement is a piece of household equipment that we denote the domestic broadband gateway, similar in function to a television set-top box but with additional functionality related to energy service provision.

The domestic gateway would have comprehensive interfacing and control capability within the house as well as communication portals to householders. It would have an open software structure to allow value adding applications such as smart irrigation and interfacing to a wide range of water and energy metering equipment. This would be the key device to drive sustainability outcomes. It provides the householder with the means to take affirmative action to drive sustainability outcomes in energy cost, energy consumption and greenhouse emissions.

Marketing of smart appliances that cooperate with each other and the domestic gateway is currently on hold pending a suitable standard definition. Manufacturers understand the technology that defines smart appliances and are motivated to explore market opportunities in this area.

Although there is no other technology impediment to the deployment of domestic gateways, the additional infrastructure has the potential to be expensive. If the expense is greater than the energy cost savings to the householder, there is likely to be little market penetration despite the environmental and convenience benefits. Thus there would need to be a push to thin clients and strong servers. That emphasises the requirement for a reliable and real time communications infrastructure. Broadband is the only practical means of achieving this.

The establishment and maturation of the domestic gateway hints that there might be emerging business opportunities from the distributed energy service model. These future businesses would manage the servers and the remote applications. They may also choose to broker energy services and the market would be highly competitive.

A VIEW TO THE FUTURE

There is now little doubt that the world is moving rapidly toward carbon constrained economies. Businesses will come to realise that products with associated carbon or other sustainability anchors will not compete in future markets.

The thin client model will also see the emergence of new database businesses that offer broadband connected sustainability services and high value applications. These businesses might offer clients automated optimal running of their energy services on behalf of the client or electricity retailer. They would be able to distribute the cost of very intelligent optimisation algorithms over a large number of clients. A leading application would be managing energy efficiency remotely and this will most likely be contracted out by the householders.

These new thinking companies will be rewarded for environmental outcomes over and above selling bulk energy as with the present energy retailer selling model. Companies that offer ‘own and operate’ energy services while allowing the householder to influence sustainability outcomes to suit their circumstances will be the survivors. The centralised generation model of the past will prove too expensive and too inflexible for their needs. These companies will necessarily require broadband connectivity to be competitive in a service-oriented business.

With distributed energy services, including storage, new energy trading markets emerge. It is possible for households or ad-hoc clusters of households to barter for energy services. Energy bartering would most likely be automated and requires real time communication. As an example of such a barter, the energy retailer might offer 10% of consumers clustered by timing of peak demand in one suburb a price incentive to shift or reduce peak electricity consumption. There could be similar negotiations between clusters for energy supply and storage; there could be green credit bartering.

Mandatory disclosure of product manufacturing embodied emissions would quickly move markets in favour of sustainability outcomes, probably faster than by regulations such as minimum energy performance standards (MEPS). The commercial building industry is rapidly moving to energy efficiency standards that far exceed minimum mandatory regulations *because* the market demands it.

The heightened awareness of sustainability will have far-reaching consequences for the household and it would seem logical that householders would like far greater control over energy service provision than they have had in the past in order to control energy service costs and control sustainability outcomes. Visibility of energy consumption in the home will be matched by a call for mandatory disclosure of greenhouse gas emissions associated with everyday purchases, including energy services. This has recently been introduced in the United Kingdom (Salt 2007).

There are outstanding research opportunities in the field of distributed energy service management. Renewable energy generation is moderately well invested, but two aspects require immediate attention. Firstly, a high degree of penetration of distributed energy services creates a potential control problem. This has been studied by CSIRO for some time (Taylor et al. 2005). The emerging conclusions are that there is no problem up till about 40% saturation of services, backed up by observations in California (US National Renewable Energy Laboratory 2005; Martin and Diesendorf 1982; Butler et al. 2005; Denniss et al. 2004) and that these potential problems can be controlled if the nature of these energy services is predictable. Broadband communications alone has the ability to collate the information necessary to support the prediction of supply, demand and storage of distributed energy services.

The second outstanding research opportunity lies with distributed energy storage. In the context of a household, this might constitute the storage of heat, cold or electricity. Thermal storage is already readily available in the form of hot water tanks and the fabric of buildings. Electricity storage is likely to merge with sustainable transport. For example, during the day our houses are generators and our cars are repositories for electricity, requiring only local network support. At night, our cars power our house with some proportion of renewable energy.

Within the home, we will see the emergence of smart appliances that are able to negotiate with the household gateway and each other to obtain the best outcomes as prioritised by the householder. The case study in this paper shows that a solar hot water system can be made to optimise generation of hot water to maximise solar heating and could potentially negotiate optimal timing for delivery to a load.

CASE STUDY: SMART PREDICTIVE CONTROL OF SOLAR WATER HEATERS USING BROADBAND

This case study outlines work recently completed at the Australian National University to demonstrate the effectiveness of solar water heaters with smart control strategies. Broadband communications are an important enabling technology.

SOLAR WATER HEATERS MARKET UPTAKE IS POOR

Domestic water heaters in Australia produce around 15 $MtCO_2$-e/yr (The Australian Greenhouse Office 1999). There is a clear imperative to move away from electric water heaters to gas and ultimately to solar (preferably with gas or greenpower as auxiliary). If all electric and gas storage water heaters were replaced by solar water heaters, there is potential mitigation of about 10 $MtCO_2$-e/yr (Wilkenfield 1998). However, only 5% of Australian households have solar water heaters and their uptake is largely correlated with rebate schemes due to their high capital costs (Business Council for Sustainable Energy 2007). Householders are being expected to pay for future energy savings up front and the water heater is not easily transportable should the family move house.

A lesser problem is the suitability of dwellings for the installation of a solar water heater. Nearly 25% of Australian households are tenanted and a further 12% are apartments with limited roof space (Australian Bureau of Statistics, *4130.0.55.001)*.

TECHNICAL PROBLEMS WITH CONVENTIONAL SOLAR WATER HEATERS

There are technical issues relating to energy consumption of solar water heaters that can be addressed by broadband connectivity.

Operation of a traditional hot water system is likened to a car without a fuel gauge. The car has an over-sized fuel tank that gets topped up regularly whether it needs it or not. The traditional hot water system is one of the few modern devices that does not provide an indication of its readiness for service.

The main impediment to performance is a simple thermally triggered mechanical switch called the thermostat. What's wrong with the good old thermostat?

- It is impatient. The thermostat acts reactively rather than predictively, thus heats the tank immediately after a load is drawn. This results in high tank heat loss and reduced solar contribution
- The thermostat switches a very powerful heater resulting in rapid (non-solar) temperature recovery
- It is fixed to one location in the storage tank, thus it usually heats more water than it needs to
- It has a fixed temperature setting
- The thermostat exercises no judgement on switching time and cannot benefit from flexible tariffs

Replacing the thermostat with smart control is a key imperative. The thermal losses from the studied solar water heater amount to about 25% of its energy consumption.

PREDICTIVE ENERGY BALANCE STRATEGY

The most energy efficient water heater would be a tankless design. That is, one that heats water when and where the hot water is required rather than storing it. However, a hot water energy store is a requirement to allow solar heating to be delivered after sunset and to take advantage of the variable price of auxiliary heating. Thus the smart control strategy is to mimic the action of an instantaneous heater as much as possible while maintaining the function of an energy store. This requires the strategy to understand future hot water demand, solar energy availability, system losses and energy pricing.

By observing household habits, the smart controller learns household water usage patterns and an appropriate safety margin. It is able to detect load flows very accurately and detect load types by the flow rate and duration characteristics. The controller uses its broadband connection to obtain a weather forecast from the Bureau of Meteorology and energy pricing from NEMMCO. The controller must balance the energy flows predictively (Figure 5) since the water cannot be heated instantaneously, particularly if sustainability outcomes are desired. By actively delaying auxiliary heating to the last possible moment, solar efficiency is maximised and standing losses from the store are reduced.

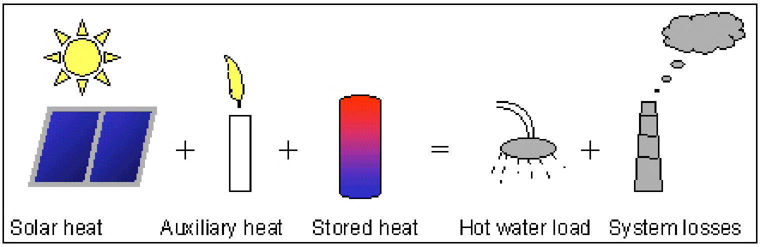

Figure 5 An energy balance for a *solar water heater*

Thus, the advanced control strategy is based upon predicting and controlling the energy content of the storage tank. The control strategy is energy tariff sensitive and may be set by the householder to behave in an energy efficient or cost effective manner. The combined scenario of distributed solar generation, distributed energy storage and smart control using broadband demonstrate that this is a path to desirable sustainability outcomes.

RESULTS

Modelling suggests that the thermal efficiency of the solar water heater can be further improved by 25%, primarily through reduction of tank standing losses, if the thermostat is replaced by a smart controller in this way. Auxiliary energy consumption, auxiliary energy costs and greenhouse gas emissions are reduced proportionally. This modelling is backed up by experimental evidence (Dennis 2004). Importantly, the optimal system produces less than 20% of the emissions of a conventional electric water heater.

DISTRIBUTED INTELLIGENCE – THE NEXT STEP

As previously mentioned, the thin client approach is likely to be more cost effective, and thus marketable, than an intelligent local controller. As part of the experimental work, a distributed intelligence strategy was trialled successfully at ANU. The aim was to mimic the management of a number of distributed solar water heaters with simple local control and a complex optimisation algorithm running on a central server. Communications between the devices was over a local area network.

Previous attempts at such optimisation have been traditional model based parameter optimisation (Ackermann 2002), with severe practical limitations including:

- Detailed parameterisation must be carried out for each individual system before meaningful modelling can begin. This is a costly and time intensive exercise.
- Model parameters are assumed constant over the life of the system
- Some parameters are difficult to quantify and model
- Some inputs are difficult to predict (eg timing and quantity of insolation, load demand) without active feedback
- Significant controller and sensing infrastructure is required at each installation with its associated expense

- There is no external visibility for the user
- There is no external visibility for the energy retailer

The central intelligent information server took care of high level tasks such as the gathering of a weather forecast, predicting solar input, obtaining load information from each local controller, performing an advanced load forecast, collecting reports from local controllers and performing online optimisations. The server would send an energy consumption plan to each household on a regular basis. The server had primitive capability to be managed in association with the energy providers with potential to alleviate peak network loading, particularly on marginal networks, by peak shedding or peak shifting.

A remote Internet interface to the server allowed pseudo-customers to logon and set their preferences for how their water heater should operate.

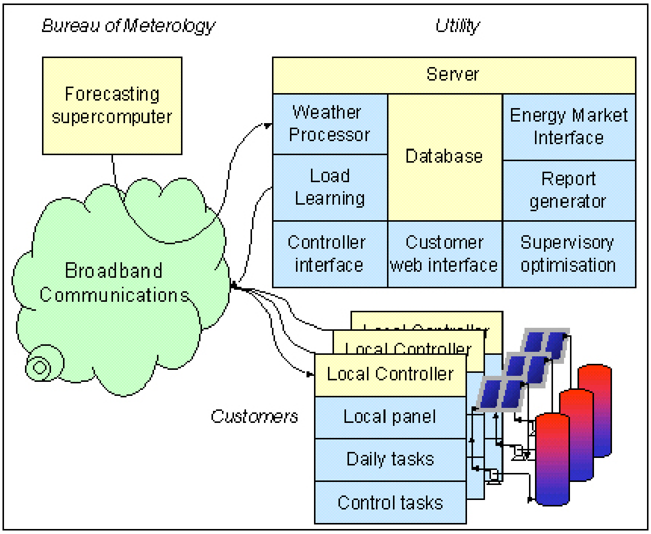

Figure 6 Distributed intelligence architecture for *domestic hot water systems*

A simple layered application was developed for the server. The application performed remote diagnostics based on performance monitoring over a number of days compared to the forecast performance. This application is representative of a number of value adding applications that emerging companies might offer clients to attract their business.

A simple local controller was also constructed. It had two buttons and a display (Figure 7). The controller was connected to the local area network and responded to requests from the server. The local controller allowed users to observe the behaviour of the energy service and override the server if required (useful for abnormal energy service demands).

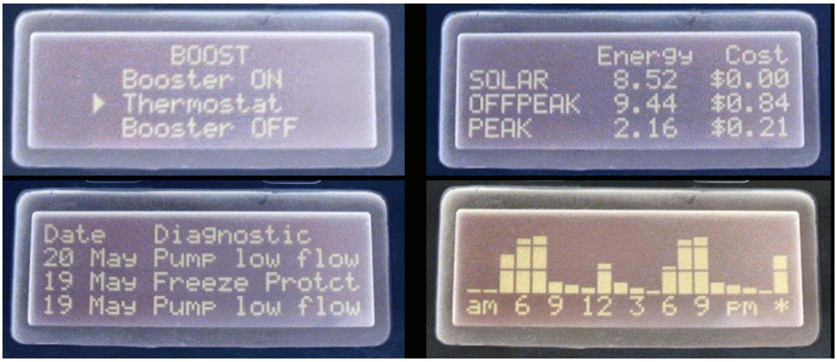

Figure 7 Four images of display options from the local controller

No intervention on the part of the user is necessary for the system to operate. Indeed it is configured to operate in a fail safe mode should communications with the server lapse. This infrastructure operated successfully over a period of four months during 2004.

This case study demonstrates that it is possible to integrate broadband communications into sustainable energy services and that there are a number of potential benefits from doing so. In this case study, the energy consumption of the solar water heater was reduced by 25% and the cost of the local controller was largely offset by the cost of the existing solar hot water controller it replaced. The client/server model was demonstrated and it is apparent that there might be benefits to the electricity retailer and the householder but these have not been substantiated in this study.

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ENDNOTES

1 Rose (2006) notes water consumption of 2L/kWh for coal based electricity generation, 2006.

2 CRA International. 'Advanced Interval Meter Communication', prepared for the Department of Primary Industries, Victoria. Available from: www.dpi.vic.gov.au/dpi/. Accessed September 2007. This site has comprehensive information of the proposed smart meter rollout in Victoria.

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