Smart appliances for smart grids: Flexibility in the face of uncertainty

George Wilkenfeld
George Wilkenfeld & Associates
POB 934, Newtown NSW 2042
geosanna@ozemail.com.au

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Abstract
A smart grid needs smart appliances. Unfortunately, there is no agreement on the meaning of either of these terms, and much of the investment in 'smart grids' could be stranded unless appliances can respond to utility load control signals or sense the condition of the grid.

There is no single global standard for communications between energy utilities and appliances. The existence of multiple pathways is itself a market barrier, because products that are compatible with one utility's system may not work in another's, and appliance manufacturers find it too risky to commit to a particular communications strategy that may have only limited takeup.

The ideal way to address these barriers is to develop open standards at the national and possibly the global level. Progress in this direction has been slow, so in the meantime Australian governments have developed a strategy based on flexibility and simplicity, that is compatible with existing systems such as Zigbee and Homeplug but allows for appliances to interact with different systems over time.

The strategy is based on Australian Standard AS4755, which defines a simple demand response interface for air conditioners, swimming pool pump controllers, water heaters using electricity (including heat pump and solar) and charge/discharge controllers for electric vehicles. Australian government are investigating the costs and benefits of making AS4755 interfaces mandatory for these appliances, perhaps as soon as 2011. Several global air conditioners suppliers participated in the development of AS4755 and are confident that they can supply complying products.

The priority appliances have been selected because of their present or projected contribution to peak demand, and their capacity to store energy during periods of low supply price or high availability of renewable generation. Unlike refrigerators or clothes dryers, they are fixed in place and do not move with the householder, so once a communication pathway is established it remains useful for the life of the appliance and the house.

This paper explains the AS4755 demand response interface, and how it interacts with a range of home area network protocols and with smart meters (for which Australia is also developing national standards). It also summarises the cost-benefit case for making the interface mandatory.

Introduction
Electricity demand in Australia is projected to increase at about 2.1 % per annum, or 0.7 % per annum per capita, over the next decade.[1] This stresses the supply infrastructure, which must accommodate high growth and at the same replace assets that have reached the end of their useful lives.

Much of the added supply capacity will only be used for a small part of the year, when demand on the system is at its maximum. This is largely due to household air conditioning: rising ownership, increasing average power and more use of cooling as summers become more extreme. It is projected that the proportion of Australian households with at least one refrigerative air conditioner (AC) will increase from about 56 % in 2010 to 70 % by 2020 (Figure 1).

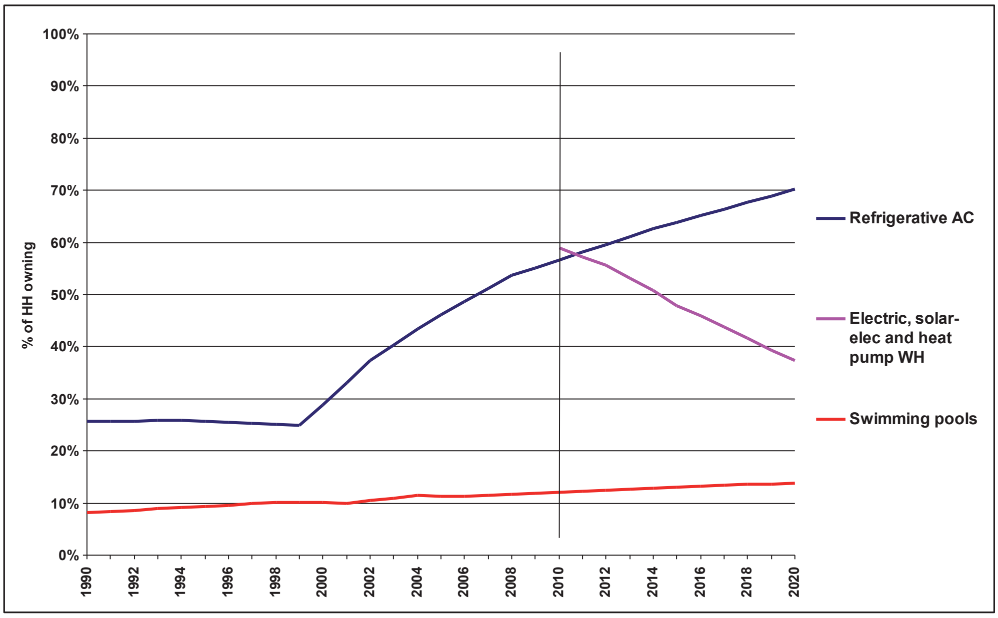


Figure 1 Penetration of selected fixed electrical appliances, Australian households.

Electricity blackouts caused by residential air conditioning in 2004 made Australian governments acutely aware of the peak load implications of household air conditioning. An analysis of policy options at the time concluded that increasing the energy efficiency of buildings and air conditioners would not have sufficient impact on peak load, given the projected rates of growth, and direct load control strategies were necessary. [2] Since then, the contribution of swimming pool pumps to summer maximum demand, and of electric water heaters to winter maximum demand, has also been analysed (Figure 1: the projected reduction in electric water heater ownership is due to a policy of phasing them out because of their high greenhouse intensity [3]). Electric vehicle charging has also been identified as a future peak load issue, although there are virtually no electric vehicles at present. Consequently, these products have been selected for coverage by demand response standard AS4755 (Table 1).

Many of the products which have been the focus of demand response interest in Europe [4] are not of great significance in Australia, where most system peaks occur in summer rather than winter. Even in winter peaking areas, some products that are common in Europe (eg heating circulation pumps) are rare, and appliances which can contribute to peaking in Europe (eg dryers, clothes washers) are less so in Australia, because of the relatively mild winters and the tendency to wash clothes in cold water.

In early 2005 the then Australian Greenhouse Office (AGO)[1] initiated the Australian Household Electricity Load-Management Platform (A-HELP) project, with aim building a large scale, reliable and low cost demand response capability in the household appliance stock. The author presented a paper on the A-HELP project at the 2006 Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL 2006).[5]. A-HELP was a focus for informal contacts between a number of organisations involved with aspects of peak load, including manufacturers and importers of air conditioners, the operators of electricity distribution networks, home automation system suppliers, professional organisations, university departments and research organisations.

In January 2006 Standards Australia formed a new committee (designated EL-054, Remote Demand Management of Electrical Products), which in April 2007 published AS 4755-2007, Framework for demand response capabilities and supporting technologies for electrical products. The standard adopts a three part framework, covering the 'Remote Agent' (which is usually the energy utility, but could be an intermediary such as a demand response aggregator), a 'Demand Response Enabling Device' (DRED) and the Electrical Product (EP). The DRED is actually a set of capabilities and functions, which may be located in a separate physical component, or incorporated into the Electrical Product itself, the electricity meter or some other device.

There are many possible pathways and protocols for communicating between the Remote Agent and the DRED, including wireless, power line carrier and internet-based options. There were (and still are) many views on which of several existing communications standards to adopt, or indeed whether it is necessary to adopt such standards at all, beyond specifying a core set of message requirements.

The Standards committee decided to disentangle these issues by first developing a simple physical interface between air conditioners and DREDs, so manufacturers could begin to sell demand response-capable products without waiting for resolution of the communications issues. This interface is defined in AS 4755 Part 3.1: *Interaction of demand response devices and electrical products – Operational instructions and connections for air conditioners.*[6] The author presented a paper on this approach at the 2009 Conference on Energy Efficiency in Domestic Appliances and Lighting (EEDAL 2009). [7].

1. In late 2007 the appliance energy efficiency and standards programs of the AGO were reorganised as part of the Commonwealth Department of the Environment, Water, Heritage and the Arts (DEWHA), and in early 2010 they were again reorganised as part of the Department of Climate Change and Energy Effciency (DCCEE).

'Smart Grids, smart metering, smart appliances' – Why is progress so slow?

Nearly seven years have passed since the AGO (now DCCEE) first identified the demand response problem and began working on a solution that suits Australia's circumstances and priorities. During that time, while work on AS4755 has continued, DCCEE has closely monitored international developments, to assess whether appliance manufacturers in Europe, Asia or the USA were likely to adopt a common approach to demand response. The published reports, while giving some indication of directions [7,8] are too general to form a basis for policy. The lack of focus has been confirmed through direct contacts with appliance manufacturers.

The issue has been given a boost by growing government and utility interest in 'smart grids'. Dynamic matching of supply and demand is one of the main benefits expected from the development of smart grids, which involve simultaneous changes in system 'hardware' (generation, distribution and end use technology) and 'software' (modes of management and control, contractual relations between energy suppliers and users, energy pricing and utility regulation).

It has been accepted in Australia that smart grid development will be largely driven by commercial forces, but governments have acknowledged that some guidance and intervention is necessary, given the scale of investment and the fact that much of it will be made by regulated monopolies, spending energy consumers' money.

However, progress on extending the principles of the smart grid all the way to the end point – the appliance – has been disappointingly slow. While smart meters and in-home displays are optional but useful elements of smart grids, smart appliances are essential. Without smart appliances even motivated energy users can eventually tire of monitoring energy prices and having to respond manually. Purchasing and enabling a smart appliance is a convenient way to ensure that user preferences are automatically carried out, just as purchasing an energy-efficient appliance locks in energy savings without users needing to think about their behaviour every time they use a product.

Despite the growing urgency, many of the discussions about appliances have an eerie familiarity from three, and even six years ago; the terminology has been rebadged (everything is now 'smart') but there is little evidence of concrete progress. The same few products seem to be rolled out at trade shows (the 'internet refrigerator', the Zigbee-enabled clothes washer) and there has been some useful work on communications protocols [9] but a true mass market roll-out seems to be as far away as ever. While international agencies such as the International Electro-technical Commission (IEC) have now become engaged in the issue [10], agreement on international standards could take many years, if it is possible at all.

One basic problem appears to be market failure through *positive externality*. Electricity users, electricity suppliers and other stakeholders would all benefit from the widespread availability and use of smart appliances, but no stakeholders can be assured of gaining enough of the benefit to take the steps necessary to bring this about.

Given the structure of the electricity supply industry, and the fact that smart grid technologies by their nature extend across both energy supply and energy use infrastructure, only governments have the capacity to address this form of market failure. Fortunately, Australian governments appear to be in a unique position to address this.

'Smart Enough' appliances – AS4755

There is no agreement on what makes an appliance 'smart', or indeed how smart an appliance needs to be. It is not possible to answer that without reference to the electricity grid and the pricing and regulatory environment where the appliance will be used – what we have called the grid 'hardware' and 'software'. A product that has sophisticated communications and response capabilities may be quite 'dumb' in a supply area that uses different communications protocols or where the electricity price regulator does not allow time of use (TOU) contracts.

AS4755 has deliberately reduced 'smart appliance' instructions to the simplest possible set of 'demand response modes' (DRMs) summarised in Table 1. DRMs may be initiated directly by the remote agent (i.e. Direct Load Control) or by the DRED itself, when pre-set electricity price or other threshold criteria set by the user are met. The physical interface between the DRED and the appliance is identical for all products covered by AS4755. It consists of either a set of screw terminals or a standard RJ45 plug. If the extra-low- voltage (32 V DC) circuit corresponding to DRM1 is completed by a relay closure in the DRED, the electrical product enters that mode and stays in it for as long as the circuit remains closed. Products switched on during an event (whether manually or by timer) must enter the required DRM immediately. Appliances may give a visual indication that they are in a DRM, but only limited user override functions may be provided (and on airconditioners, no over-rides at all).

To comply with standard AS4755, an electrical product must be capable of at least DRM1. This alone delivers nearly all of the economic value of demand response, through the ability to cycle the appliance during a peak event (typically 50 % on and 50 % off, but other sequences may be specified during the event or pre-programmed into the DRED), or to switch it off entirely during an emergency. AS4755 also describes how appliances must respond to the other DRMs, but appliance manufacturers would be free to make a commercial decision whether to provide those DRMs or not. However, if a supplier indicates that a capability is present, this must be verifiable by testing. DRM2 and DRM3 are intended to allow variable speed drive devices to provide a reduced service during an event. Utilities believe that this will give some users more confidence to participate in demand response programs than if they perceived a risk of appliance operation stopping completely. Thus DRM2 and DRM3 widen the market appeal for users, but creates no demand response benefit beyond what DRM1 delivers.

DRM4 is intended to make water heaters (electric, solar-electric and heap pump), pool pumps and electric vehicles operate as energy sinks during periods of low electricity price or high availability of renewable generation. For water heaters this means over-riding the normal thermostat settings and heating the stored water to a higher temperature (tempering valves are required for water heaters already, so this would not increase scalding risk, but if activated often, would fractionally reduce tank service life). For pool pumps, this would mean operating

Table 1. Demand Response Modes in AS4755.

Electrical Products	AS4755 part	Demand Response Modes (DRMs)			
		Minimum load/off	Reduced load	Load shift/ forced on	Discharge Energy
Air conditioners	3.1 (a)	DRM 1	DRM2,3	NA	NA
Pool pump controllers	3.2 (b)	DRM 1	DRM 2	DRM 4	NA
Electric storage water heaters	3.3 (b)	DRM 1	DRM 2	DRM 4	NA
Solar-electric water heaters	3.3 (b)	DRM 1	DRM 2	DRM 4	NA
Heat pump water heaters	3.3 (b)	DRM 1	DRM 2	DRM 4	NA
Electric Vehicle Rechargers	3.4 (c)	DRM 1	DRM 2	DRM 4	DRM 5

(a) Published part. (b) Advanced draft. (c) Drafting not yet commenced, so DRMs indicative only

for the duration of a DRM4 event, irrespective of the user timer settings. However, run time during a DRM4 event would have to be subtracted from the scheduled run time, so there would be no increase in daily operation. For electric vehicle chargers, DRM4 is a signal to absorb more energy (provided there is a vehicle connected to the charger, and the controller on the vehicle allows more charging). During a DRM5 event any available stored energy would be discharged to the grid (subject to over-ride by the vehicle's own controller).

AS4755 is unique in that it is the first standard of this kind published, and is already being used by some air conditioner manufacturers and electricity utilities in Australia. There are no comparable smart appliance interface standards available anywhere else in the world at present, so there is no possibility of conflict.

Activation of the interface

The demand response capabilities of an AS4755-compliant product are only latent until the interface is activated by connection to a DRED (which provides a physical pathway) and there is a contractual agreement between the remote agent and the user. The user may agree to direct load control (DLC) of the appliance under defined conditions, in return for some agreed benefit, or the remote agent may offer a TOU tariff under which the user can choose to program their own DREDs and manage their own appliances (or bear the cost penalty for not modifying their use).

The following diagrams, Figures 2–6, illustrate the range of activation pathways available. Figure 2 illustrates activation by DREDS which click on to the AS4755 interface, forming a simple home area network (HAN). The DREDs may be configured to receive control signals by whatever means the utility prefers – ripple control (popular in Australia, as a legacy of the large off-peak hot water load), mesh radio, FM radio (also used by some Australian utilities), the internet or any other means. Some local electronics companies have already designed DREDs capable of operating with both ripple control and local powerline carriers (ie Homeplug), with the mode selectable by the installer.

Figure 3 shows how a single DRED can replace separate units, with the advantage that it can be configured to switch appliances a pre-selected priority order during demand response events.

The electricity meter itself can function as a DRED. In 2008, at the instigation of Australian energy Ministers, utilities, government agencies, consumer representatives and other stakeholders started work on the development of uniform technical specifications for smart metering in Australia.[11] A rollout of smart meters will have several implications for the development of smart appliances:

- Smart meters could pass on DLC instructions, and so enable customers with smart appliances to participate in and benefit from utility DLC programs without necessarily enrolling in TOU tariffs or having to purchase additional equipment to set up a HAN; and
- Smart meters could transmit continuous energy price, CO_2-intensity or other information about the grid to customers who wish to pre-set their own DREDs so that their appliances respond according to their own preferences.

Ministers directed the metering working groups to consult DCCEE and Standards Australia, to ensure that the national smart meter standards support DLC and demand response. As a result, the Smart Meter Specifications published at the end of 2010 [12] require the meter to pass through the AS4755 DRM signals in Table 1, and also provide for two means of physically linking to AS4755 interfaces:

- Via a wireless HAN likely to be based on Zigbee and/or Homeplug standards (the installing utility would decide which). This would require corresponding Zigbee or Homeplug receivers (each with its own power supply or battery) to be clicked on to the AS4755 interfaces on the appliance at the site (Figure 6); or
- Via a 2 Amp rated voltage-free relay designed for direct cable connection to the AS4755 interface. The advantage of this pathway is that it would not require a receiver with a separate power supply, and would work in circumstances where power line or wireless signals are blocked (a situation that has been found to be all too frequent in trials so far). The disadvantage is that the relay could only operate one DRM on one appliance (Figure 4), unless it was connected to a DRED which multiplexed the signal (Figure 5), so introducing further cost and complexity.

However, the limitation of the relay to controlling a single DRM turns out to be relatively insignificant. Cost-benefit modelling shows that accessing DRM1 alone, and only on air conditioners, would deliver about 87 % of the total economic benefit of summer peak load reduction (pool pumps account for the other 13 % - the summer benefit from electric water heater DLC is small, but the winter benefit is greater).[13]

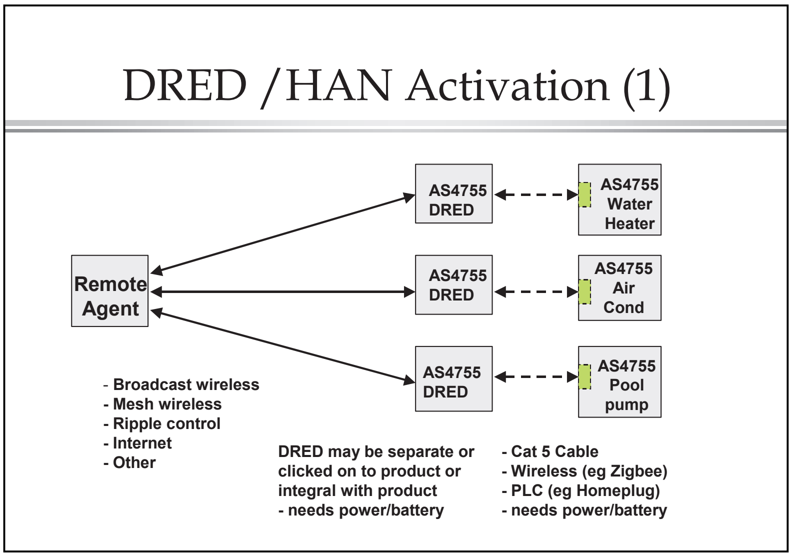


Figure 2. AS4755 Interfaces activated by separate DREDs.

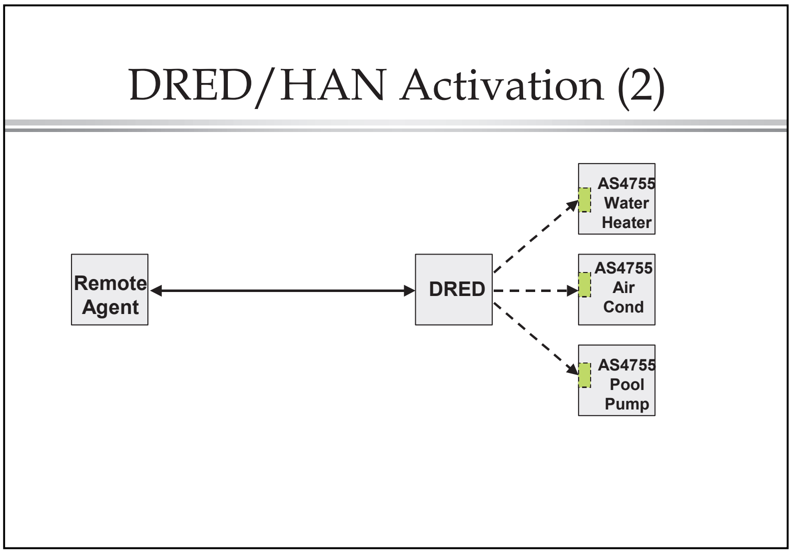


Figure 3. AS4755 interfaces activated by a single DRED.

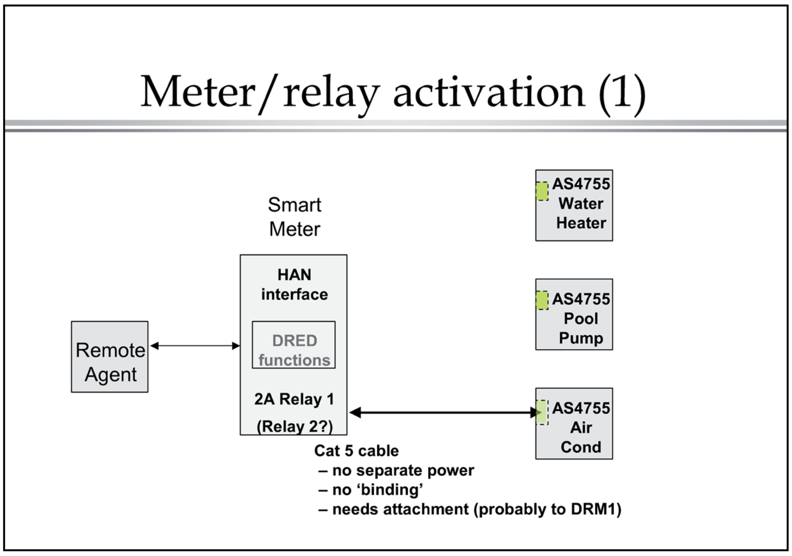


Figure 4. AS 4755 interface directly connected to 2A relay on Smart Meter by cable.

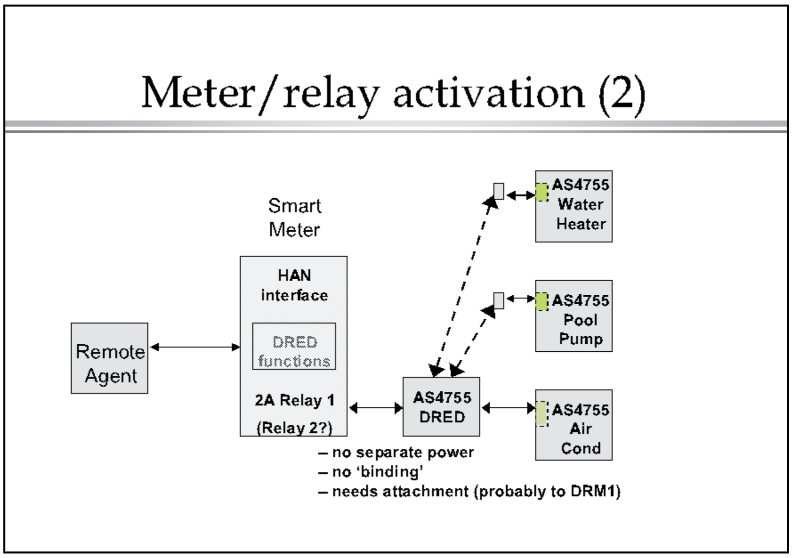


Figure 5. AS4755 interface indirectly connected to 2A relay on Smart Meter via DRED.

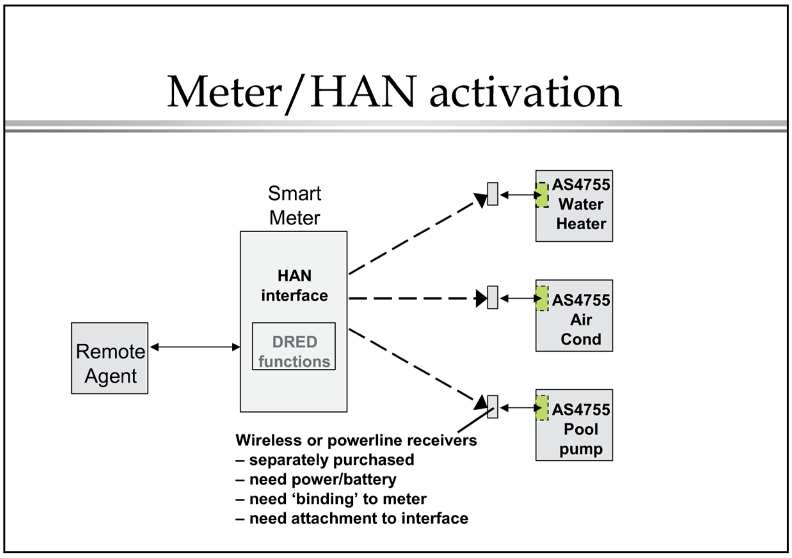


Figure 6. AS4755 interfaces connected to Smart Meter via wireless Home Area Network.

Flexibility and simplicity

The great advantages of this arrangement are flexibility and simplicity. Once an AS4755-compliant smart appliance is installed, it can accommodate any sequence of pathways. The physical changes required are as simple as substituting one DRED for another, or connecting or removing a cable. This would not be done by the householder– AS4755 specifies that the interfaces should be located under secure covers designed for access by an authorised person – but the extra-low-voltage system means that the authorised person need not be a certified electrician. This lowers the cost of large scale rollouts, making it possible for high-volume pay-TV and communications cabling companies to undertake AS-4755 activation work.

The arrangements also means that any AS4755 appliance can be substituted for any other. Indeed, the utility need not know what device is actually connected. If it propagates a DRM1 signal, for example, all DREDs receiving it (that have been enabled because the user has consented to participate in the DLC program) will close the DRM1 relay, and whether that relay is connected to an air conditioner or a pool pump, it will cease operating until the DRED received a signal to open the relay. More complex DLC strategies would be possible if the utility could address individual appliances at the user's site, and address distinct DRMs on each appliance. This would require logging of the appliance type and characteristics at the time of DRED installation.

Automatic logging of appliance type and capability, and reporting of the appliance's operating state to the DRED, are perhaps the only potentially useful features that this regime does not support. While the DRED could detect and report to the remote agent whether or not a current flows when a relay closes (although this would not necessarily prove the presence or absence of an appliance, or whether an appliance actually respond as intended), there is no provision for the appliance to communicate information to the DRED.

The value of two-way communication down to the appliance level was discussed at length during the development of AS4755. Ultimately, the electricity utility view was that DLC programs will always be based on probability. If the program is properly designed, most appliances will respond as expected. A few users will enrol in a DLC program to gain the monetary benefit and then deliberately disconnect the DRED so that their appliances are never interrupted (of course, if they are on a TOU tariff they may find the cost of defeating the DLC signal to be high). Another group will enrol in DLC programs in good faith, but will not have their appliances interrupted due to a failure somewhere along the communications pathway. (If they are on a TOU tariff they may eventually notice that they are missing out on savings, and bring the matter to the notice of the utility themselves). Yet another group will not reduce load during a DLC event simply because they are not home at the time or do not have the relevant appliances running. They should still be rewarded for making their appliances available for DLC, and if anything further rewarded for not contributing to the peak load problem at the time!

It would be difficult, expensive and ultimately unnecessary to directly determine the status and actual load reduction achieved by every appliance in every household during every DLC event. While the remote agent obviously needs to monitor the aggregate response to demand response events, and build up confidence in predicting load reductions, data can be collected at the meter, transformer or substation or level, through well-designed statistical trials. Ultimately, if the remote agent does not get the required load reduction through calling a DLC event in one suburb, it can call on more suburbs, or else start with a DRM2 signal (reduced load operation) and then proceed to a DRM1 signal (complete interruption) if there is still a load problem. As utilities accumulate experience over time, they will gain the confidence to bid amounts of demand reduction (or rapid energy absorption) capacity into the market based on their calculations of probable levels of response.

Making AS4755 mandatory in Australia – costs and benefits

Australian government are currently considering a proposal that all 'priority appliances' (ie those in Table 1) imported or sold after a target implementation date (either October 2011 or October 2012) must comply with AS4755. It is estimated that this would increase average appliance purchase price by about AUD 10. The benefits derive from the expectation that a proportion of appliance owners would use the AS4755 capabilities, or authorise the electricity utility or other intermediary to access those capabilities, in return for some incentive. Where householders choose to participate, there will be additional DRED, cabling and/or activation costs.

The main quantifiable benefit is the reduction and deferral of capital investment in networks and in generation capacity. Large scale demand response could also displace some spinning reserve, and act as an emergency grid management option. Benefits would accrue to all electricity users, including those that do not participate in DLC.

Cost-benefit modelling shows that the measure would be highly cost-effective, with a potential net benefit of about AUD 13,600 million for appliances installed up to 2025, at a benefit/cost ratio of over 9. (This compares with a projected net benefit of about AUD 32,000 million for the entire suite of mandatory appliance energy efficiency programs).[13] The projected savings are equivalent to a net present value of AUD 1,540 for every household in existence in 2010 (at a discount rate of 7 %). This could support an AUD 170 reduction in electricity bills per household in every year to 2025, if returned to households as tariff reductions. Benefits for New Zealand have also been calculated.

Direct Load Control programs for priority appliances could attain nearly 5,000 MW of controllable load during the summer peak by 2025, offsetting about a third of the projected growth in summer maximum demand in the central and eastern states (the 'National Electric Market' region, Figure 7). This is based on 50 % cycling (equal periods on and off) for participating air conditioners, and 100 % off-cycling for participating pool pumps, for not more than 30 hours per year. Nearly twice this load would be available during emergency events. Moderate participation rates are assumed – the maximum theoretical benefits from full participation by all priority appliances, if that were achievable, would be about three times as great.

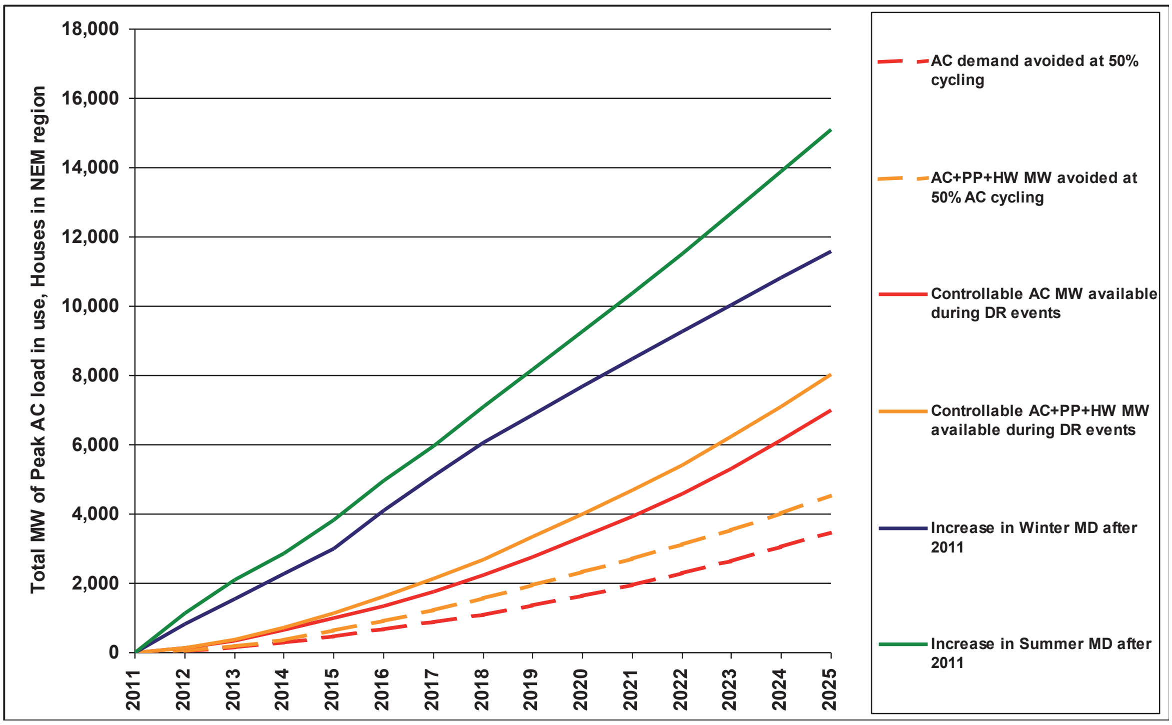
Sensitivity analysis indicates that the proposal would be highly cost-effective even under assumptions of higher costs, lower benefits and lower activation and participation rates. It would still be cost-effective if the lifetime of the measure were only 7 years. In other words, even if a global standard for appliance demand response takes effect from 2018, making AS4755 redundant (and there is no indication that this will happen), the measure would still be cost-effective as an interim strategy.

While the benefits of smart appliances can be realised independently of smart metering, in-home displays and TOU pricing, there are many areas where benefits can be mutually reinforcing. One such area is the inclusion of a means for smart meters to interface directly with AS4755 appliances via a 2 Amp voltage-free relay built in to every meter.

The value of the proposal is primarily in the reduction of energy supply infrastructure costs, not in energy savings or emissions reductions, although the energy use permanently foregone during demand response events would lead to some minor reduction in emissions. Energy labelling and minimum energy performance standards (MEPS) would remain the most effective strategies to increase appliance energy efficiency and reduce end-use emissions, just as they are today.

The potential for greenhouse reduction on the supply side depends on the amount of renewable energy that would otherwise be wasted, the share of water heaters and pool pumps capable of energy storage/time shifting (DRM4) and thereby displacing fossil fuel-generated energy, and the number of householders making their appliances' DRM4 capability available to DLC programs. As DRM4 capability would not be mandatory, it is not possible to estimate these values at present.

There may be small energy costs for adding DR capability to some appliances, because of the need to maintain an extra-low-voltage electrical potential across the control circuits. For appliances with electronic controls (as is the case with nearly all new air conditioners and pool pump controllers), there should be no additonal standby losses. However, most electric, solar-electric and heat pump water heaters use mains voltage controls at present, so adding a low-voltage capability could also require an additional internal power supply and add a new source of standby energy loss. If so, this would be held to less than 1W,



(Excludes Western Australia and Northern Territory)

Figure 7. Projected reduction in summer maximum demand, National Electricity Market area.

the global standby loss benchmark endorsed by Australian governments.[2]

However, the standby use of DR devices should be outweighed by the ability to make use of renewable generation that would otherwise be wasted during high wind/low demand periods. Wind generation capacity installed in Australia at the end of 2009 totalled 1,668 MW, producing 5,000 GWh of energy annually.[14] Another 558 MW was under construction. Increasing wind utilisation from all these projects by just 1 % would mean an additional 66 GWh displacement of fossil fuel generation each year, which would more than compensate for an extra standby losses.

Conclusions

If there were global standards for smart appliances and smart grids, and if the appliances that are priorities in Australia met those standards, there would be no need for AS4755 or for mandating AS4755. However, the Department of Climate Change and Energy Efficiency, which has closely monitored international developments in this area since 2004, through direct contact with relevant agencies, international organisations and appliance manufacturers, has formed the view that workable smart appliance standards, other than AS4755, are not likely for the foreseeable future.

It is recognised that the proposed regulatory action would places Australia (and New Zealand, if it participates) at the forefront of global regulatory action to support the development of smart appliances. On balance, this carries less risk than the failure to take regulatory action, especially as other decisions critical to the development of smart grids and smart metering in Australia will have to be taken over the coming year or two.

As long as there are competing technologies and lack of standardisation, neither appliance manufacturers nor energy utilities can risk committing to a single approach. However, if elements of the smart grid are put in place without any smart appliance strategy, there is a risk that the investments will be stranded. The AS4755 interface appears to offer a low risk option, by facilitating the development of smart appliances without precluding future developments in communications, metering or Home Area Networks.

After several years of years of considering that concerted international action was the best way forward on smart appliances, it now seems that only action and standardisation on a smaller scale – regional or national – can overcome the barriers to progress. However, that should not preclude global action, and Australian Government and Standards Australia are eager to work with other governments and international standards bodies towards that aim. However, Australia's growing peak demand problems and particular appliance preferences and load patterns make it urgent to implement a local solution, even as an interim one. In any case, it may be necessary to take these steps in order to stimulate the development of a global response, which otherwise may not occur.

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Glossary

AC	Air Conditioner
AGO	Australian Greenhouse Office
A-HELP	Australian Household Electricity Load-Management Platform
AS	Australian Standard
AUD	Australian dollar (at time of writing, 1 AUD = 1 USD, and 1 AUD = 0.75 Euro).
DCCEE	Department of Climate Change and Energy Efficiency
DLC	Direct load control
DRED	Demand Response Enabling Device
DRM	Demand Response Mode
EEDAL	Energy Efficiency in Domestic Appliances and Lighting (conferences)
EP	Electrical Product
Han	Home area network
IEC	International Electro-technical Commission
MEPS	Minimum energy performance standards
TOU	Time-of-use