

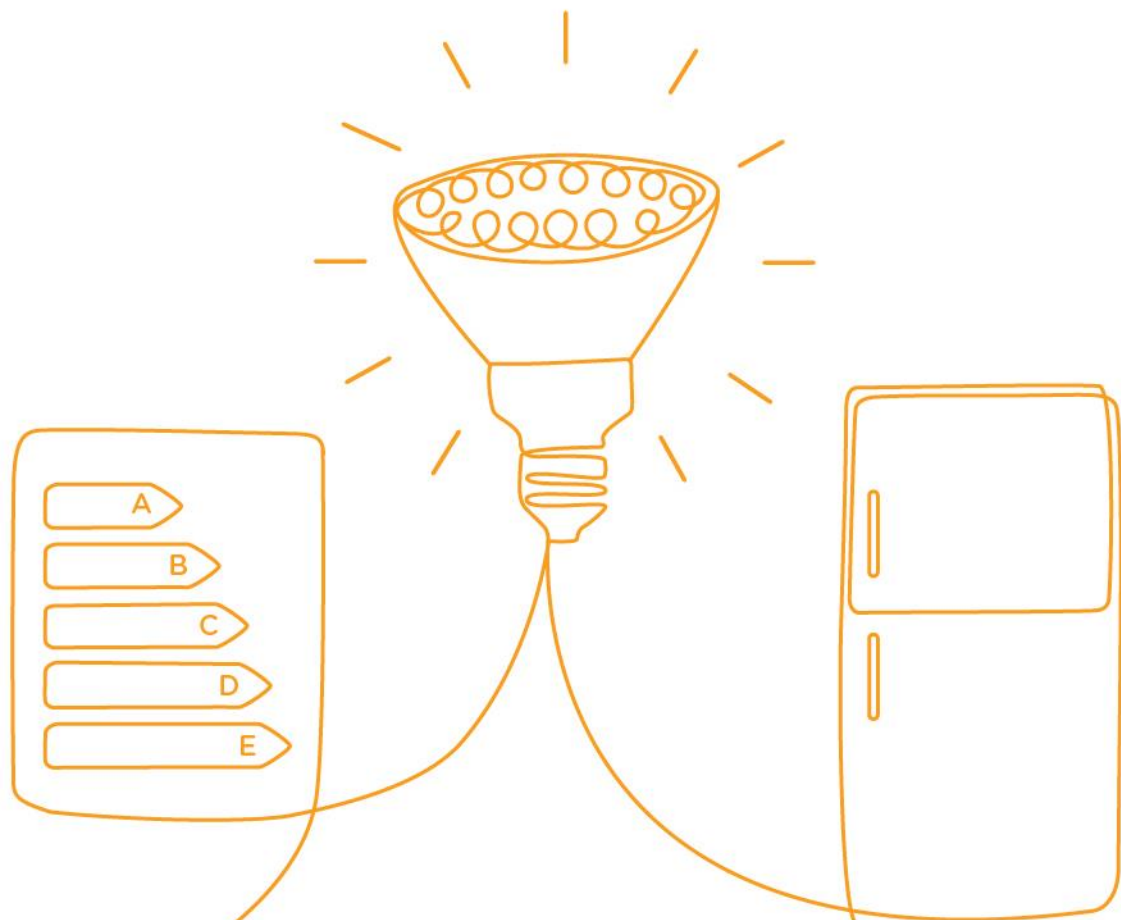


Appliances Get Smart:

But how and when?

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Summary

‘Smart’ is one of the most over-used marketing terms of our times. However, it needs considerable definition and qualification when used in relation to appliances. This paper reviews different types of appliance ‘smartness’, how their value can be realised, and the significance of standardisation in reducing market barriers to the adoption of such products.

The capabilities most commonly linked to ‘smartness’ are:

- The ability for the user to access the functions of an appliance and monitor its status and settings from off-site;
- The ability of the appliance to automatically adjust and optimise its operation based on information either deliberately input by the user (e.g. tariff data or user preferences), collected by observing the usage pattern over time, or both;
- The ability of the appliance to automatically adjust and optimise its operation based on information from sources other than the user - e.g. an electricity supplier or demand response aggregator. A distinct form of interaction is the ability to respond in a predictable way to direct load modification commands.
- Standardisation of inputs (the way the appliance interacts with the world) and of responses (what it does in response to common conditions or commands). Without standardisation a given product might only be assured of a market in areas with all the conditions necessary to its smart capabilities - the right communications pathways, the right tariff structures and perhaps the right type of smart meter.

The latent capabilities of smart appliances have to be activated before the benefits can be realised. There are many ways of achieving this - some with and some without time of use pricing or smart metering. Any system that can transmit or automatically generate five basic instructions - load off, reduce load, load on, store energy and discharge energy - is capable of realising the value of smartness in virtually any appliance. However, the mode of receiving these instructions and the required responses need to be set out in considerable detail before appliance manufacturers can know what to build.

At present there is a vast range in the possible pathways through which users, utilities or other agents can convey instructions, their form and information content (eg when to start and stop an altered mode of operation, the type and degree of alteration required).

There is also a wide range of design options regarding whether the appliance is limited to one specific communications system or can accommodate a range of systems with or without the use of add-on components.

The obvious place for defining these factors is in technical standards that can then be given legal force. The paper reviews smart appliance standardisation in Japan, the USA, Europe, Australia and China, and the development of relevant standards by the International Electrotechnical Commission (IEC). Given the diversity of approaches and requirements globally, a single common standard may well be impossible, and the best achievable objective may be a series of standards - hopefully limited in number and linked by some common elements - related to different ‘smart architectures.’

Finally, the paper considers the interactions between energy efficiency and smartness. Appliance smartness cannot be marketed or promoted in the same way as energy efficiency. When consumers compare the energy consumption and efficiency of different purchase options, they can assess the costs and benefits before buying, and a more efficient product will start to create value as soon as it is taken home and plugged in. The value of smartness, on the other hand, is largely contingent on the tariffs available, the time patterns of use and perhaps whether the product is compatible with the local utility’s smart meters or communications architecture.

Indeed, smartness could increase the overall energy use of the appliances themselves, by interrupting and extending operating cycles. Also, the infrastructure of routers, controllers, smart meters and other devices required to support communications with smart appliances will have its own energy load. While each device may have a modest power requirement, and be subject to national or international standby energy standards, there is a potential for hundreds of millions of new devices (several per home) that are on all the time.

Any increase in total energy use by smart appliances and their supporting devices may well be outweighed by raising the limits of the level of system-wide renewable generation that the grid can support. However, this remains to be determined - it cannot be assumed that smartness and energy efficiency are always aligned.

Hey, where's my smart appliance?

We seem to have been promised that smart appliances are just around the corner for many years. What happened to them? Or have they actually arrived but in a different form we have yet to recognise, like so many other technologies? What are 'smart appliances' anyway?

Because the definition is so vague, we could say that appliances exhibiting some form of smartness have been around for a generation. However, they have made barely any impact on the global appliance market, despite literally decades of innovation, promotion and expectation. Take-up has been restricted to small groups of consumers who value novelty (the 'early adopters' of any new technology) and those who place special value on selected attributes such as out-of-home remote control.

The first problem is that there is many claims that particular appliances are smart, but no single, accepted definition of a smart appliance. 'Smart' is one of the most over-used marketing term of our time. It has taken its place alongside equally vague terms such as 'sustainable' and 'eco-friendly'. This allows appliance manufacturers to define 'smartness' as any attribute that is unique to their product and that could increase its market appeal.

Some use the term 'smart' for any appliance with a wider range of settings or options than its competitors, or with touch controls and digital displays instead of switches and knobs. Others use it for products which make some use of information and communication technologies (ICT) or combine functions and technologies in new ways. For example, a refrigerator may have a bar code reader to scan items going in and out and a screen that can display an inventory of the contents. The screen could also function as a television and as an internet portal for the kitchen, through which the user (or the refrigerator's own software) could place grocery orders.

None of these functions is new, and many homes have computers, televisions, internet connections and even bar-code scanners that could do the same job, but the combination into one device may save space, increase convenience and create new possibilities for the user.

Another common use of the term 'smart' is for appliances that can provide better services or operate more efficiently based on what they learn about how and when they are being used. For example, the control processor of a water heater may be able to monitor the patterns of daily hot water demand and manage reheating to meet the expected load with the minimum heat loss. In addition, it may be able to match reheating times with varying energy price periods, to further reduce operating costs.

Other manufacturers equate smartness with the ability of users to control their appliances from outside the home, or to program sequences and combinations conveniently so that, for example, lights and appliances can be energised and de-energised with one command when the householder leaves home or returns, gets up or goes to bed - with different configurations for different situations.

This form of smartness has been promised, and partially realised in various forms, for at least a generation. It envisages the home as an integrated control system - a 'Smart House' in the terminology of the 1980s - encompassing all appliances and lights, as well as devices not currently electrified or automated, such as taps. These concepts were covered in the general press, including the New York Times:

'Forget about waiting in your bathrobe for the tub to fill or padding around at night to lock the doors and turn off the lights.

Think instead about calling up your appliances - the refrigerator, the hot tub, the alarms - from the car phone as you commute home from work. The refrigerator defrosts a pie and tells the oven to start the roast; the range signals the microwave

oven to heat the soufflé, and 102-degree water fills the bathtub. As you drive under the automatic garage door, the lights switch on, the heat fires up, the security system turns off and Andre Watts plays from a compact disk.

The house of the not-too-distant future is electronic, and you will be able to play it as you would a fugue. About a dozen companies in the United States, Japan and Europe are now making whole-house automation systems for both new and existing houses. The new levels of convenience, security and time-and-energy savings they provide promise to inspire a vast market and create a whole industry.' (Giovannini 1988).

The attractions of the smart house rested on communications (by the user and between appliances) and automation. Despite many efforts, the concept achieved only limited commercial traction. Indeed, the difficulty of creating a market has been a constant theme. In 2011 the journalist David Owen wrote, in relation to smart appliances (which are now often discussed in the context not of the smart *house* but the smart *grid*, another poorly defined concept):

'Sometimes it's hard to believe that the smart grid isn't partly a marketing scheme devised by manufacturers. At the 2011 Consumer Electronics Show, I attended a seminar on networked appliances and realized - as the panel's members described the wonders awaiting homeowners savvy enough to upgrade to smart refrigerators, dishwashers and clothes dryers - that I'd heard it all before, and not just once. On my smartphone I searched the New York Times online and found an article that closely tracked the discussion in the seminar room...That article, by Joseph Giovannini, was published in 1988.

...Because this was 2011, the main benefits for consumers were said to be energy savings, rather than Jetson-style convenience.¹ But the pitch was otherwise the same.' (Owen, 2012).

What has changed in the interim is that appliance manufacturers can now offer some of the benefits expected of the smart house without the need for fully integrated home automation. Once individual appliances such as televisions or air conditioners acquire remote controls, it is relatively straightforward to extend the geographic field of control outside the home.

Several manufacturers now offer appliances with downloadable applications software ('apps') that allow internet-connectable mobile telephones ('smart phones') to mimic all remote control functions and also to receive information on status and settings from the appliance. Products with these features include air conditioners (e.g. Samsung, Daikin, Panasonic)² refrigerators, dishwashers and clothes washer/dryers (e.g. Whirlpool)³ and ovens (e.g. GE).⁴ In some cases the final communications link to the appliance is made by the same WiFi router that connects many computers to the internet.

One advantage of these trends is the potential to combine of the remote control of multiple devices, from different suppliers, as apps on the single smart phone which many people now carry much of the time. Even so, how much extra 'smartness' does a remote control that works anywhere in the world represent, compared with just programming the timers and thermostats before leaving home?

¹ *The Jetsons* was an animated situation comedy program made for American television between 1962 and 1963. The Jetson family lived in a highly technological and automated home, set in 2056.

² See for example <http://www.samsung.com/au/air-conditioning/smart-zone/> and <http://panasonic.co.jp/corp/news/official.data/data.dir/2012/08/en120821-9/en120821-9.html> and <http://www.daikin.com.au/skyfi>

³ <http://www.abt.com/product/67607/Whirlpool-WRL767SIAM.html>

⁴ <http://www.geappliances.com/home-energy-manager/>

Finding enough commercial drivers has to build a worthwhile market has proven elusive so far. A new factor that could finally do it is interaction not just with the user, but with the grid.

Smart grid, smart appliance

Many of us will have heard the terms ‘smart grid’ and ‘smart meter’ as well as ‘smart appliance’. ‘Smart grid’ is often used to mean closer integration of the supply side and the demand side of the electricity system, through better communications and controls. Although there is no single accepted meaning, smart grid covers a range of emerging technologies and systems, as well as new relationships between electricity businesses and their customers.

Electricity cannot be easily stored on a large scale, so supply and demand have to be kept in constant balance. In the past this has meant matching supply to demand, by varying the output of power stations and making sure the network (the poles, wires and transformers) can meet the heaviest demands expected, even if those only occur for a few hours each year.⁵ This is proving increasingly expensive, and is one of the main factors driving growth in electricity prices in many countries.

Rising use of variable forms of renewable electricity generation such as wind and photovoltaics (PV) has also increased the difficulty of matching supply and demand and controlling voltage in some networks, even though it has helped reduce fossil fuel use.

One way to signal periods of abundance and periods of scarcity in the availability of electricity (as for any other goods or services) is through differential pricing, also called ‘time of use’ (TOU), ‘time-variant’ or ‘flexible’ pricing. The technologies of the smart grid are better able to support TOU pricing. If consumers are aware of price variations they can either adjust their energy use so that more of it takes place during low prices periods or make a conscious decision that it is worthwhile to pay more for energy when they really want it.

If the price response could be automated, then appliances could change their operation even when the householder is unaware of price changes or not at home. Some consumers may prefer to retain control of the decision, monitor price changes on their smartphone and exercise remote control over their major appliances wherever in the world they happen to be - a capability that some manufacturers are offering today - but many others, possibly the majority, may well prefer to make a ‘set and forget’ decision to allow automated response if that capability were available.

The principle of accepting some constraint on energy use in return for a lower tariff is already well established. This is the basis of ‘off-peak’ tariffs, where consumers consent to having limits placed on when water heaters or other devices can operate, in return for a cheaper tariff. The option slightly increases the risk that at some times of the year the household will run out of hot water during a period when reheat is unavailable, but suppliers have worked hard over the years to minimise and mitigate that risk through measures such as over-sizing tanks (bad for energy losses) or offering emergency over-ride switches on the expectation that they will rarely be used and will not be jammed on deliberately or through mechanical failure.

⁵ There are two main defining characteristics to virtually every element of an electricity network, from generators to wires to transformers to appliances: energy and power. Power (measured in kW) is the *rate* at which a network can deliver electrical energy. The *quantity* of electrical energy delivered is typically measured in kWh. If power flows at a rate of 1 kW for a period of 1 hour then 1 kWh of electricity is used. There are of course many other factors which must be managed in the planning and operation of power systems, including the maintenance of voltage, frequency and ‘power quality’ - ie managing the mutually distorting interactions of loads, frequency and voltage.

New metering technology allows electricity prices to vary not just between fixed ‘peak’ and ‘off-peak’ and ‘shoulder’ periods but at shorter intervals as well, up to the point where the change in price levels and time periods is more flexible and at shorter time steps, ie ‘dynamic’ Appliances can be designed to respond to these changes by automatically and quickly modifying their operation. If this capability is deployed on a large enough scale, and if it can be called on with sufficient reliability, then the total economic investment required to maintain a high-quality supply of electricity is significantly reduced, and the resilience of the network in the face of peak demands and emergencies is enhanced.

This is one of the chief benefits promised by the ‘smart grid’ concept. Of course, consumers would have to accept some constraints on their freedom to use electricity but with sufficient planning, explanation, marketing and design for risk mitigation there is every reason to expect this could be achieved, as it has been for off-peak water heating.

The emergence of smart grids provides a new and sharper context for defining smart appliances. Before the emergence of the concept of the smart grid and its supporting technologies (e.g. smart metering.)⁶ the value of smartness in appliances relied mainly on the promise of extra convenience and new functions. The smart grid enables forms of appliance smartness can create value for the electricity network as a whole, then all who use (and pay for) the network can benefit, not just those who own and use the smart appliances.

Linking smart appliances to the management of the network also means that the vast capital resources, revenues, pricing and marketing power of energy utilities can be brought to bear on promoting certain types of smart capabilities and so transforming the appliance market.

Some appliance manufacturers and industry associations have begun to make a distinction between ‘connected’ appliances, which are able to communicate with their owners or other appliances, and ‘smart’ appliances, which can also receive pricing or other information directly from or about the electricity network.⁷ However, these distinctions are also unclear.

The value of connected appliances is enhanced if the platform that the owner can use to communicate is universal and open, such as the GSM mobile phone system or the internet. However, electricity networks have a wider range of communication options available to them, including smart meters and power-line signalling systems such as ripple control, which may be just as effective for their purposes as GSM or internet. It is entirely possible to have an appliance that is ‘demand responsive’ but communicates via pathways not easily accessible to the owner.

The following definition of a smart appliance was proposed in 2011 by the US Association of Home Appliance Manufacturers (AHAM) and the American Council for an Energy-Efficient Economy (ACEEE):

‘The term “smart appliance” means a product that uses electricity for its main power source which has the capability to receive, interpret and act on a signal received from a utility, third party energy service provider or home energy management device, and automatically adjust its operation depending on both the signal’s contents and settings from the consumer.’ (AHAM, ACEEE et al 2011).

⁶ Interval meters can record energy use during different time periods for the purpose of differential pricing, but are not necessarily ‘smart’. While there is no standard definition, smart meters can generally: transmit the energy use data to the utility, so that meter readers are no longer required; receive and carry out commands such as disconnecting the supply when customers move out and reconnecting it when the next customer moves in; monitor the supply for faults and automatically advise the utility in case of problems; act as a ‘gateway’ or point of communications to the home for important information such as changes in price or notification of emergencies; and/or act as a two-way interface with the customer’s own appliances via what is called a ‘home energy network’ or HAN.

⁷ See for example <http://blog.bosch-si.com/appliances-in-a-smart-grid-12-the-north-american-perspective/>

This definition has been incorporated into the ‘Connected Product Criteria’ proposed for the US Energy Star Product Specification for Residential Refrigerators, Eligibility Criteria, Draft 3 Version 5.0 (EPA 2012), which are reproduced in Appendix 1 of the present document. However, the terminology is ‘connected’, not ‘smart’ appliance:

‘The [‘connected’] product shall be capable of receiving and responding to consumer authorized remote requests, via a communication link, similar to consumer controllable functions on the product. The product is not required to respond to remote requests that would compromise performance and/or product safety as determined by the product manufacturer.’

The Australian and New Zealand Standard AS4755 *Demand response capabilities and supporting technologies for electrical products*, first published in 2007, does not use the terms ‘connected’ or ‘smart’ but ‘demand response,’ which it defines as:

‘The automated alteration of an electrical product’s normal mode of operation in response to an initiating signal originating from or defined by a remote agent.’ (AS/NZS 4755).

Defining Smartness

From the preceding sections we can build up a picture of the capabilities commonly linked to smartness:

- The ability for the user to access the functions of an appliance and monitor its status and settings from off-site. Those settings may include the control of other smart capabilities;
- The ability of the appliance to automatically adjust and optimise its operation based on information either deliberately input by the user (e.g. tariff data or user preferences), on observing the usage pattern over time, or both.
- The ability of the appliance to automatically adjust and optimise its operation based on information from sources other than the user - e.g. an electricity supplier, aggregator or weather forecaster. A distinct form of interaction is the ability to respond in a predictable way to direct load modification commands.

At present there is a vast range in the possible pathways through which users or remote agents can convey instructions, their form and information content (eg when to start and stop an altered mode of operation, the type and degree of alteration required). There is also a wide range of design options regarding whether the appliance is limited to one specific communications system or can accommodate a range of systems with or without the use of add-on components.

This raises a key additional element of smartness - standardisation. Without standardisation of inputs (the way the appliance interacts with the world) and responses (what it does in response to common conditions or commands) the market for smart appliances will remain limited. Manufacturers can only be assured of a market in areas with all the conditions necessary to realise their product’s smart capabilities - the right communications pathways, the right tariff structures, perhaps the right type of smart meter.

The principal smart capabilities are summarised in Table 1. The examples are by no means exhaustive, but they illustrate a range, from not smart to appliances with the full range of capabilities: what might be called ‘maximum smartness’. Appliances which are able to receive information from both users and non-users will need to be some form of priority setting or protocols so that instructions do not conflict.

Without standardisation, the utilities that could gain the most benefit from smart operation may not be able to risk setting up the necessary platforms, if they have to accommodate appliances with vastly different inputs and unpredictable response patterns.

Appliance manufacturer themselves have recognised the importance of smart standards. In 2009 the Whirlpool Corporation, announced

“By 2015, Whirlpool Corporation will make all the electronically controlled appliances it produces – everywhere in the world – capable of receiving and responding to signals from smart grids” ...[Whirlpool] indicated that the company’s ability to successfully deliver on this commitment in this time frame was dependent on two important public-private partnerships:

- The development by the end of 2010 of an open, global standard for transmitting signals to and receiving signals from a home appliance; and
- Appropriate policies that reward consumers, manufacturers and utilities for using and adding these new peak demand reduction capabilities.⁸

In the event there still several competing standards for in-home communications with devices, including Zigbee and WiFi. For the range of smart appliances which Whirlpool introduced in 2013, it chose an internet-based platform, with users accessing the appliance via smartphone and WiFi, rather than Zigbee, which is more commonly used by smart meters.⁹ As long as there are competing standards, without full interoperability, the market for smart appliances will remain fragmented, and suppliers will have to decide which segments they want to concentrate on.

Table 1 Capabilities associated with smartness in appliances

Example	A. Remote inter- action by user	B. Auto-adjust in response to user- originated info		C. Auto-adjust in response to other- originated info		D. Interoperability and standardisation	
		1. Tariff, preference or other	2 Usage pattern	1. Monitor	2. Direct control	1. Inputs	2. Resp- ponses
Electronic Controls, extra functions	X	X	X	X	X	X	X
Learning from usage	X	X	✓	X	X	X	X
Smartphone access	✓	X	X	X	X	X	X
User inputs tariff data on appliance, which optimises operation	X	✓	✓	X	X	X	X
Tariff data downloads from smart meter,	X	X	✓	✓	X	X	X

⁸ <http://greeneconomypost.com/whirlpool-smart-appliances-2576.htm>

⁹ <http://www.greentechmedia.com/articles/read/whirlpool-launches-the-wi-fi-smart-appliance>

optimises operation							
User enters direct load control contract	X	X	X	X	✓	✓	✓
User sets operating parameters based on real-time tariffs	X	✓	✓	✓	X	✓	X
AHAM, ACEEE 2011	X	✓	X	✓	X	X	X
EPA 2012	X	✓	X	✓	X	X	X
AS/NZS 4755	X	X	X	X	✓	✓	✓
Maximum smartness	✓	✓	✓	✓	✓	✓	✓

✓ Indicates present or necessary X indicates absent or optional

The five commandments of appliance response

There are two aspects of standardisation - how the appliance communicates with the outside world and how it responds. As we have seen there are many competing methods and standards for external communication, but there has been less thought given to the modes of response. These become important in applications where smart appliances are used in direct load control (ie capability C2 in Table 1). The economic value of such arrangements is maximised if it is possible to predict how the participating appliance stock will react to specific commands.

In fact, it may be easier to standardise instructions and responses than modes of communications. All 'smart' commands, whether originated by the user, an automated controller or another authorised entity, boil down to the same set of basic instructions:

1. Turn off load, or go to least energy-intensive mode possible while maintaining essential ancillary services such as electronic controls or small fans and pumps;
2. Continue to provide the energy service which the product is designed to deliver, but at a reduced load or constrained level of operation;
3. Turn on load, even when the user, timer or other controls would not normally call for energy;
4. Export energy stored or generated electricity to the grid, even when the user, timer or other controls would not normally call for this; and
5. Do not export to the grid, even when the user, timer or other controls would normally call for this.

The first and second instructions can apply to any appliance in principle, although further definition is needed before appliance manufacturers know exactly what functions to build in and test laboratories know how to verify them. For example, Instruction 2 - reduce load - can

be expressed in a number of ways, depending upon the appliance the means chosen to reduce load:

- In relation to the full output capacity or maximum operating load of the product;
- In relation to the average power (or energy used) over a given period prior to the receipt of the instruction (e.g. the last 30 mins);
- As an absolute power level (e.g. no greater than 1 kW); or
- By prohibiting certain energy-intensive operations (e.g. defrosting in refrigerators or the use of resistance boosting elements in hybrid heat pump water heaters).

For products such as air conditioners or refrigerators the electric power input may be determined at conditions used for energy efficiency testing, but this 'reference level' will depend on the testing protocols used, and may not reflect well the actual usage of a specific appliance in a particular application. For other products the only stated power value is the maximum power rating for wiring purposes, which is usually so high that it is rarely reached in normal operation, so the only way to ensure a reduction in demand is to relate it to the actual operation when (or just before) the appliance receives the instruction.

The third basic instruction - turn on load - only applies to products capable of storing energy or providing useful energy services without the user present. Examples include water heating, swimming pool pumping or electric vehicle charging. This can be of significant value to the electricity grid when generation from variable renewable sources such as PV or wind is high. Switching on load at short notice may prevent the network having to 'dump' (i.e. disconnect) renewable generation sources, and so raise the share of renewable generation that can be absorbed by a given network over the cycle of the year. Of course, a 'load-on' capability must be used carefully so that it does not lead to wasteful energy use - e.g. cooling or lighting buildings that are unoccupied.¹⁰

The fourth and fifth basic instruction obviously apply only to products capable of generating or storing electricity: batteries (both stationary and mobile, i.e. electric vehicles), and small scale distributed generators. At various times the network may require energy support - hence instruction 4 - or there may be local safety or over-voltage problems - hence instruction 5.

Products only need to have one of these five basic functions to increase the overall smartness of the grid, but only when combined with the appropriate communications platforms, contractual arrangements and network management strategies. Without these, building smartness into the appliance is a cost without a benefit.

The architecture of smartness

All of the 'smart' capabilities so far offered by appliance manufacturers can be built up from the capabilities in Table 1 and the 5 commandments of appliance response. However the capabilities can interact in quite different ways, or different forms of 'smart architecture'

Let us analyse the common example of the delayed clothes wash cycle. The ability for users to load a clothes washer, select a wash cycle but delay the start by a specified period (or to a

¹⁰ The AS/NZS 4755 standard provides for a 'load-on' function for water heaters, swimming pool pump controllers and electric vehicle charge controllers, but not for air conditioners. As water heaters and electric vehicles store energy, the induced consumption displaces later consumption, so is not wasted. Where swimming pool pump operation is brought forward the controller must subtract the induced run time from the pre-programmed run time so there is no overall increase in pumping in any 24 hr period. As these limits do not usually apply to air conditioners it was considered that the risks of energy waste from switching them on remotely would exceed the benefits in terms of overall network management.

clock time) is already a common feature in products. The washer does not need to know the cause for the delay. It could be that the user does not want noise for a few hours, or wants to time the finish of the cycle so that they can hang out the clothes when they come home, or perhaps the home is on a TOU tariff and the user wants the washing to take place during a period when the user calculates - correctly or not - that the cost of energy is lower.

The operation becomes 'smart' if the user specifies (or has previously specified) that the cycle should take place at a time 'when electricity prices are at low'. If so the washer needs to know the energy price to calculate the costs saving from a delayed start. It could then display the information and let the user decide, or use it in a more complex way to overlay learned or expected cycle times (capability B2) to optimise cost saving in some way.

If the tariff happens to be low when the user presses start, the machine's logic controller allows the cycle to commence immediately. If not, then the controller effectively issues smart instruction 1 (turn off load) and later, when the clock time matches the 'low cost tariff' criterion, smart instruction 3 (turn on).¹¹

How does the machine know the electricity price at different times? The simplest way would be for the user to program the machine with the tariff time steps - either on the machine itself (capability B1) or remotely via a smartphone or other device (capability A). Most TOU tariffs have rigid time steps, so these only need to be entered once, but the actual price of energy at each time step will vary from year to year or even month to month. Therefore there is some advantage to making updates as convenient as possible for users, eg by giving them access to tariff websites. However, an appliance with B1 capability could access tariff websites directly, or to get price data from an on-site smart meter.¹²

Alternatively, the price monitoring functions and logic control could be located entirely outside the washer. They could reside in the software of a laptop or smartphone, a home area network, a smart meter or some other device. They could reside in the computers of the energy utility, the 'cloud' or a third party demand response aggregator. If so, the appliance may only need to respond to direct load control instructions (Capability C2).

One advantage of leaving the logic control outside the washer is that over time it could be redesigned to integrate a vast range of information - not just tariffs, but whether the baby is asleep, whether so many high power devices are in operation that the clothes washer load could trip the home's load limiter, a weather forecast for good line drying weather or any other factors the user considers important enough to program in or arrange to be sensed. Some users may wish to monitor and act on information that is not communicated through the energy price, such as the level of renewable energy available to the grid.

In the end the controller needs only to communicate the same two instructions to the clothes washer: instruction 1 (no load) when the criteria for washing are not satisfied, and instruction 3 (turn on) when they are. However, in this architecture, there would need to be a physical pathway for the washer to receive information from the external controller. As clothes washers are not generally designed to receive information from external sources, this pathway (or pathways) would need to be defined.

The washer needs to be compatible with a wider 'architecture of interoperability', or in other words, to meet a set of pre-determined technical standards. The standard needs to be about how the washer communicates with an 'upstream' device (eg a meter or a HAN) and what it does with information it receives so that:

¹¹ There may be a need for other considerations- e.g. a user who has just missed the lowest cost period may not want to wait for 12-16 hours before the next one, and may settle for the next 'shoulder' cost period.

¹² Miele has designed a clothes washer that can accept user-programmed tariff schedules and also has the capability to later be connected to a communications hub to receive the information directly from outside sources. This product is described, accurately, as 'smart grid ready' rather than smart. http://www.miele-project-business.com/international/en/project_business/products/miele-at-home.aspx

- The manufacturer knows what to build, without having to make guesses about every aspect of the smart grid;
- The buyer knows that the washer has the capabilities to function as a smart appliance in their particular situation, either as purchased or with the addition of known, identified elements (eg a router, a smart meter, or a special tariff offering).

This is in fact the architecture adopted in AS/NZS 4755 (although the range of appliances covered by that standard does not include clothes washers).

These examples represent two fundamentally different models of smart appliance architecture:

- Predetermined criteria for modifying product operation (in this case energy price, overlaid with cycle selection) and the logic for assessment of the criteria residing in the appliance (in this case a clothes washer); and
- No predetermined criteria, and the logic for assessment of criteria residing outside the appliance.

In fact there is a wide range in possible variations in architecture between these models. If some of the logic resides outside the appliance and some inside, this raises issues of communications protocols, message structures and priorities which require high levels of standardisation to resolve. This is not an insurmountable problem. It is analogous to the global standardisation which allows the internet to operate and for mobile phones to roam from one country to another.

However, it would require embedding information and communications technology (ICT) into appliances - perhaps to the point of assigning a distinct phone number and/or internet address to every product. While this is certainly possible, it may have a significant impact on the costs of appliances, especially if it forced lower-cost, lower-technology operators out of some markets. Alternatively, building a global smart appliance architecture on this basis may be of little value in developing countries, where the supporting ICT does not extend to every house while at the same time the urgency of acquiring some electricity load management capability is very high.

Ultimately, whatever the decision criteria, however they are communicated and wherever the processing takes place, all architectures come down to modifying the operation of the appliance with the same basic instruction set: off, part load, on, discharge energy, do not discharge.

Who's in control?

The functional outcomes of automated response should be the same whatever the architecture and wherever the decision processing takes place. However, there are legitimate concerns regarding the ability of owners to influence the process, and the risk that unauthorised persons or entities could exercise control over the operation of smart appliances or somehow exploit the information gained from their operation.

One point of view is that users should always have the freedom to over-ride a demand response event. If the clothes washer does not start because it has been pre-set to wait for a lower price period, but the user wants the clothes washed straight away and does not mind paying more for the privilege, that is obviously their right.

This makes very little difference for clothes washing, where load diversity is high and each load is moderate. Different households do their washing at different times of the day. The power of washer motors is relatively low, and electricity use for water heating could range from high - where the user selects a hot wash and the water is heated in the machine - to nil, where the user selects a cold wash.

It is estimated that about 38% of washes globally are done in cold water.¹³ A survey of clothes washer use in the five largest European countries found that the share of loads washed at less than 40°C ranged from 4% in the UK and Germany to 87% in Spain. The share of loads washed at 60°C or greater ranged from 30% in France and Italy to 3% in Spain (Ecolabelling Denmark 2011). Over 72% of Australian householders indicate that their preferred wash temperature is 'cold' (ABS 2011). Also, many clothes washers take their hot water from the house supply, and if this is heated by gas, heat pump, solar or off-peak electric (where reheat can only take place in specified time periods), the link between hot water washing and electricity load is further weakened or broken entirely.

These differences, based on cultural factors and washer type preferences as well as prevailing cold water temperatures, mean that the value to the network of deferring a wash cycle from the peak load period can vary from moderate to negligible. In some markets it will not matter very much if individual users with smart clothes washer will want to over-ride from time to time. At the same time, the economic value of adding smartness to clothes washers in those markets in the first place will be questionable.

Other appliances have very different characteristics. In Australia, the largest single contributor to electricity network peak demand is household air conditioning (PC 2012). In most areas the last 20% of network capacity is used for less than 2.5% of the time, and the last 10% of capacity is used for less than 0.5% of the time, or about 40 hrs per year. If air conditioner load could be reliably reduced during those peaks, it would save billions of dollar of annual investment in the network - costs which have to be borne by all network users, whether they contribute to the problem or not.

Australia has long had energy efficiency labelling and standards for new air conditioners and new buildings, but this has had limited impact on the growth in peak demand. Where air conditioners are installed, there is a 70% probability that they will be switched on during extreme peak periods, and most will be operating at maximum output without getting down to the thermostat set point. The preferred air conditioner types are split units with internal thermostats, which makes it difficult to break into the control circuitry with after-market devices. Demand response strategies such as raising the set point of programmable communicating thermostats - which suits US air conditioner types and patterns of use, for example - are ineffective.

¹³ http://www.nytimes.com/2011/09/17/business/cold-water-detergents-get-a-chilly-reception.html?pagewanted=all&_r=0

Nevertheless, trials have proven that even in the hottest conditions, customers will accept a reduction of up to 50% in the output of their air conditioner (ie basic instruction 2) provided the fan keeps operating and the period of output constraint is limited to about 2 hours. There will obviously be costs - room temperatures will be slightly higher during the control period than otherwise - but this is offset against enormous economic benefits.

It is estimated that in Australia the electricity networks need to invest an average of about A\$3,500 of capital to provide a firm kW of capacity during summer peak periods. The average electrical load per installed air conditioner is about 2.1 kW during peak periods (even allowing for the fact that 30% of units will be off). Therefore contracting with users for the right to restrict their air conditioner load by 50% for no more than 40 hrs per year would avoid building about 1 kW of peak demand per air conditioner, worth A\$3,500 to the network.

This provides a lot of potential value to be shared between the network operators, the owners of the participating air conditioners (who may receive cash payments or lower tariffs) and with other network users. The value will only be realised if users modify the way they use air conditioners. This could occur in three ways:

- If the price of using the air conditioner during peak periods is signalled to users at the time, they can make a decision about manually turning it on or off or setting it down. However, this requires both a time-variable price and a means of reinforcing the user's awareness of it at the right time. Time-variable prices have been available for many years but customers show an understandable reluctance to adopt them unless they are forced to.¹⁴ If they do adopt TOU prices, in-home displays could amplify the price signal. None of this requires a smart appliance.
- Customers on TOU pricing who tire of having to respond manually could take advantage of the smart capabilities by programming their air conditioner to respond automatically when the price reaches a certain level. This is called 'price-driven demand response'. Users can decide to over-ride the response at any time, provided they are aware of when it occurs and are at home or able to control the product remotely. Any smart appliance should be capable of being used in this way, (although if the price information is programmed in by the user rather than conveyed directly from the outside world the arrangement would not meet the first criterion of smartness: the ability to receive instructions from sources other than the user).
- Customers could authorize their electricity utility or a demand response aggregator to control the cycling under agreed conditions. This is called 'direct load control'. The crucial difference is that no TOU pricing is necessary. Direct load control can work equally well under flat tariffs. The user's reward comes in the form of an up-front cash payment or a bill rebate, not (or not only) as a saving in energy costs during high price periods. This allows the network to initiate demand response at times when the economic value to the network is greatest, which may be outside the pre-determined TOU price periods.¹⁵

In principle, smart appliance architectures should allow for either price-driven response or for direct load control, and for switching between them. However, the realisation of the economic benefit to the grid depends on the reliability of the demand response. In price-driven demand response, the network operators may not know in advance how many users

¹⁴ One estimate is that by mid 2012 about 1% of US households had adopted TOU tariffs, despite almost every utility offering the option. <http://blog.bosch-si.com/appliances-in-a-smart-grid-12-the-north-american-perspective/>

¹⁵ A more targeted form of TOU pricing is Critical Peak Pricing (CPP), in which the utility sends advance notice of a very high price periods (possibly several times the higher the highest step of the TOU tariff). These get a higher manual response rate than TOU prices alone, but represent risks for both the utility and the customer. As a high share of annual revenue is collected in a short time, small miscalculations in price levels by the utility and in the response by the user can result in disproportionate losses or gains. Indeed, a rational user would only enter such an arrangement with the protection of automated response or, better still, direct load control.

have smart appliance capabilities, how many have programmed them to respond to price signals and how many will actually over-ride them during peak periods. Therefore the expected response will be heavily discounted and the potential to offer participation incentives will be limited.

In direct load control arrangements the network operator (or aggregator) has very good information on the number of households signed up and the operating characteristics of each connected air conditioner. If there is no over-ride button, users cannot easily opt out during a demand response event. The costs per controllable kW acquired may be higher than in the price-driven response model- not necessarily in extra equipment, since much of that would be required simply to communicate prices - but in marketing, incentive payments, call centres and data management. On the other hand, the economic benefits would also be higher, because direct load control could achieve a greater level of demand response, large enough and predictable enough to factor into infrastructure planning.

Alternatively, smart products could be designed to monitor the voltage and frequency of the grid (another form of capability B1), and respond automatically without the need for a direct load control signal. Again, the magnitude and reliability of the aggregate response will be affected by the ability of users to over-ride such events.

Whatever the model of demand response in smart appliances, consumers are ultimately in control. They can always choose not to purchase a smart appliance, or not to activate its capabilities, and if they do, to manage the response themselves rather than enter a direct load control contract.

If they elect for a direct load control or automated response arrangement they would do so on the basis of their own weighting of the risks (constraints on appliance use) and rewards (electricity bill savings or other incentives). Most countries have consumer protection legislation that require full disclosure of the conditions and which protect the vulnerable from being coerced into such arrangements. The elderly and households with members who are more sensitive to extreme temperatures could be advised not to sign up.

Customers who did sign up would have to be made aware that they could not over-ride an air conditioner demand response event simply by pressing a button - they would have to call a centre, and possibly withdraw from the arrangement permanently and forego the remainder of their benefits.

Smart appliances allow for a wider range of energy service business models and a wider range of pricing and contractual relationships between energy suppliers and their customers. If no customers want to take advantage of those possibilities, that is their right. But then, all users would have to incur the costs of higher electricity prices flowing from lack of demand response.

An inconvenient truth about energy efficiency

Many advocates of smart appliances claim increasing efficiency of energy use as one of the benefits. It is difficult to see why smartness (in the sense defined in this paper) is necessary to increase energy efficiency, or why it would be more effective than the many energy efficiency programs and measures that have been in place for many years, such as energy labelling and minimum energy performance standards.

A truly energy-efficient appliance should perform its main service (heating, cooling, washing or whatever) with the minimum of energy use whenever it is required to do so, and should waste as little energy as possible (preferably none) when it is in standby.

An energy-efficient appliance might be smart to the extent that it can monitor its own usage to further reduce its energy consumption (Capability B2 in Table 1). However, once the capability is used to shift or modify operation in response to electricity prices or the condition of the electricity grid, it may save its user more money, but not raise its level of energy efficiency and further.

In fact, shifting the time of operation could actually reduce energy efficiency. If a clothes washing or drying cycle is delayed or interrupted it may be necessary to add additional rinses or tumbles to achieve the same quality of washing and the same finished condition of the clothes as if the cycle had proceeded as usual. Furthermore, extra energy may be required to support communications and processing capabilities, compared with non-smart appliances of equal energy-efficiency.

Some manufacturers claim that their smart clothes washers will default to a low energy wash cycle during high-electricity-price periods as a way of saving money. Other manufacturers design their clothes washers to automatically use the least possible amount of energy and water for every load, irrespective of the time or the energy price. In this example one could conclude that smartness does not actually increase energy efficiency but reduces it, because it allows (and assumes) that outside demand response periods the washing can be done at higher-energy modes. The link between smartness and energy-efficiency is further weakened if there is an over-ride button on a product that allows it to revert to a higher-energy mode even during demand response.

There are other fundamental differences between energy-efficiency and smartness. Buyers who select a more efficient appliance in preference to a less efficient one will gain some benefit as soon as they take the appliance home and plug it in, irrespective of what tariff they are on. By contrast, a buyer of a smart appliance will, at the very least, need to be on a TOU tariff, program this information into the appliance and set the appliance to modify its behaviour in response, before gaining any benefit at all.

If the appliance needs to communicate with the user or with the outside world, then additional hardware and effort will be needed,. Admittedly, some of this process can be streamlined (the ICT and home entertainment industries have made considerable efforts to develop 'plug and play' systems which work most of the time) but it is an additional level of complexity, cost and source of on-going energy consumption. The rising energy standby costs of 'always-on' products were addressed in study for the International Energy Agency (EES et al 2010):

'A critical component [of energy efficiency] is power management across all modes - shutting down unnecessary capacity or functions when they are not required while meeting all relevant user needs. Another element is to ensure that the power required for all functions is as low as possible, especially in low power modes' (EES et al 2010).

Although the findings were framed in relation to ICT equipment, they apply equally to smart appliances (Xergy 2013).

Those who wish to have their smart appliances participate in direct load control programs could only do so if these were available, and the process of signing up and being connected would involve further costs and delays. Again, utilities are working on streamlining this process by advising consumers and offering incentives at the point of sale for the purchase of products with the appropriate characteristics.¹⁶

While the benefits of energy efficient appliances are assured and easy to obtain, the benefits of smart appliances are, at present, contingent and uncertain. This means that few customers can assess the value of paying more for an appliance with smart capabilities, even if they are in the habit of routinely assessing the value of paying more for a product with a higher level of energy efficiency. This makes it difficult to rely on measures such as energy labelling alone to create market demand for smart appliances, so others means and strategies are necessary).

The lack of impact on end-use energy efficiency does not weaken the case for smart appliances, which is based on other major benefits:

- the scope for increasing the overall economic efficiency of the capital invested in the electricity supply system, by enabling the optimisation of supply side and demand side investment; and
- the scope for reducing the fossil fuel-intensity of electricity supply, by making better use of variable renewable sources of electricity. This could be at the household level (eg by delaying clothes washing until solar collector has had a chance to heat the water) or at the system level (eg by bringing forward swimming pool pumping to a period when wind generators would otherwise have to be disconnected for lack of load).

These objectives can sometimes be in conflict with one another. For example, the Australian and New Zealand demand response standard AS/NZS 4755 provides for electric-boosted solar water heaters to have smart instruction 3 (which switches on the booster element) as well as 1 (no boost) and 2 (can boost, but at reduced load). This is to allow the utilities to pre-heat solar water heaters on winter mornings, when they know that the solar contribution will not be enough to prevent the boosters coming on during the evening peak period. This reduces the solar contribution for that day, but gains the much greater economic value of liberating peak load capacity.

This example also illustrates one advantage of direct load control. For price-driven demand response to achieve similar outcomes, the smart appliance (or its consumer-managed controller) would have to be aware of a forward price signal indicating expected network congestion that evening and would need to initiate preheat, not just avoid preheat during the actual high price period and so risk running out of hot water. All of this is feasible - some electricity systems set prices a day ahead - but requires the presence of a logic capability in the water heater, which is not necessary for direct load control. In direct local control the smartness resides in the system, not just in the appliance.

Direct load control also allows costs and benefits to be assessed on an aggregate level, and conflicts between different stakeholders resolved. The network operator may wish to call demand response events at times of network congestion, while the retailer may want to do so at times of high wholesale generation costs. These periods may or may not coincide. If the customer is on a contract with the retailer that limits demand response to a maximum of, say, 10 events and 40 hrs total in any one year, the retailer could on-sell some of that

¹⁶ <http://www.energex.com.au/sustainability/rewards-for-air-conditioning-pools-and-hot-water/energy-conservation-communities-ecc/whats-involved>

capability to the network, so optimising the economic value without the customer even being aware of it (except that their cash payments may be higher).

In theory, these benefits could be achieved by autonomous smart appliances which are capable of exchanging information about their current and projected operation between themselves or with a central controller. Some researchers are already working on the mathematics of such arrangements.¹⁷ However, this level of complexity would rely on a critical mass of appliances with this high-level capability, all operating on common standards and algorithms. This is not likely in the first stage of smart appliance development, in which the main problem is still to create a viable market.

Therefore appliance smartness cannot be marketed or promoted in the same way as energy efficiency, and indeed could increase the overall energy use of the appliances themselves. Finally, the new infrastructure of routers, controllers, smart meters and other devices required to support communications with smart appliances will have its own energy load. While each device may have a modest power requirement, and be subject to national or international standby energy standards¹⁸ there is potential for hundreds of millions of new devices (several per home) that are on all the time.

Any increase in total energy use by smart appliances and their supporting devices may well be outweighed by raising the limits of the level of system-wide renewable generation that the grid can support. However, this remains to be determined - it cannot be assumed that smartness and energy efficiency are always aligned.

¹⁷ See for example A Parisi and K Christensen Integrating Demand Response Capability into Smart Appliances: Design and Evaluation of Distributed Scheduling (2011)

<http://www.eedal.dk/Conference/Programme%20and%20Presentations.aspx>

¹⁸ For example, the 0.5-1W maximum recommended by the IEA

Creating markets through standards

The main barrier to the spread of smart appliances is not a lack of technology but the lack of a market. In fact the abundance of technological options is itself a market barrier, because users are not able to compare the advantages of different approaches - all vigorously promoted by their suppliers - and decide what is the best for them, or indeed if it has any value at all given their current electricity tariffs and arrangements.

This is analogous to the situation with regard to energy efficiency claims in the period before governments mandated that all products of a given type had to be tested in the same way and the information reported in a common format - the legal basis of the existing energy labelling and standards regimes now in use in many countries.

This process is more complex for smartness, because the value of a given smart technology may be contingent on the availability of compatible supporting technologies (eg particular types of smart meters or home area networks), time of use tariffs or direct load control contract offerings from the local utility. A product which is smart (or can be made smart) in one utility service area may be just an ordinary product in the neighbouring area.

These uncertainties make it very risky for appliance manufacturers to build smart capabilities into their appliances, unless they know there will be a market demand, at least in some parts of the world.

In fact, attempts are being made to create the conditions for smart appliance markets in several parts of the world. Up to now these attempts have been largely independent of one another, but the first steps are being taken toward some level of global convergence.

Japan

Perhaps the earliest initiative with a smart appliance aspect is the Japanese Echonet (Energy Conservation and Home Care Network), which was established in 1997. The Chairman of Echonet states:

In the ECHONET Consortium, we have promoted the development of basic software and hardware for home networks that can be used for remote control or monitoring of home appliances. We have also established basic technology for the ECHONET Specifications. The aim in doing so has been to reduce CO2 emissions while responding to the increasing sophistication of home security and home healthcare. The ECHONET Specifications are universal communication standards for linking home appliances made by different manufacturers and providing various services using easily installed transmission media, in both new and existing homes. They have also been recognized as international standards.¹⁹

The first Echonet specification was published in 2000, and has been revised several times since. An Echonet Lite specification was published in 2011. The interest in using the Echonet standard to enable inter-operation between products from different appliance, home area networks systems and smart meter manufacturers has increased significantly since the earthquake and tsunami of March 2011 created long term disruptions in energy supply. A new Echonet Certification Centre was opened in November 2012. There has been no use of Echonet outside Japan so far, although as a result of participation in Echonet many Japanese appliance manufacturers have included basic demand response capabilities in some globally traded products, notably air conditioners.

¹⁹ <http://www.echonet.gr.jp/english/index.htm> The appliance manufacturers supporting Echonet include Toshiba, Panasonic, Hitachi, Mitsubishi Electric and Sharp.

Australia and New Zealand

Another initiative for the smart appliance architecture is that embodied in Australian and New Zealand Standard AS4755 *Demand response capabilities and supporting technologies for electrical products*. The *Framework* part of the standard was published in 2007. A part for air conditioners was published in 2008 and revised in 2012. A part for swimming pool pump controllers was published in 2012 and parts for water heaters and electric vehicle charge/discharge controllers are due to be published in 2013.

The aim of the standards is to give manufacturers all the information they need to build complying products and to testing laboratories how compliance with the standard will be verified. The standards specify how an appliance should respond when it receives any of the five basic demand response instructions described earlier. They specify a common physical and electrical interface (an RJ45 plug or a set of screw terminals) for connection of the product to an external demand response enabling device. This could be a smart meter, a Zigbee receiver, a ripple control receiver, an internet-connected device or any other: the appliance manufacturer does not have to know which.

The architecture was deliberately designed so that the smart capabilities of the appliances could be used with virtually any communications device, either in a price-driven demand response environment where the user has sole control or under direct load control arrangements.

By August 2012 some 53 of the 1,160 air conditioner models registered for sale in Australia had an AS/NZS 4755 interface built in, and a further 178 models could comply with the addition of a standard interface card.²⁰ This included both imported and locally made models. The Department of Climate Change and Energy Efficiency, which manages the national appliance standards and labelling program, has indicated the intention to mandate compliance with AS/NZS 4755, so that all new air conditioners and other covered products sold after a date yet to be determined must have an interface, subject to a national cost-benefit analysis and regulation impact assessment.²¹

Although it is expected that most appliances will never have their interfaces activated, the measure is still justified if the net community benefit is high enough and the benefits are widely distributed through lower network charges for all. This is the principle on which many countries have mandated energy labelling. The presence of the label gives appliance buyers the option to make a purchase decision based on the label and all consumers benefit from the increase in appliance efficiency stimulated by labelling.

United States

In the USA, interest in demand response and smart appliances was stimulated by the Energy Independence and Security Act of 2007 and by the American Recovery and Reinvestment Act of 2009, which contained about US\$3.5 billion in funding for smart grid projects, including some that test and deploy smart appliances (McMahon 2011).

In 2011 the Association of Home Appliance Manufacturers and the American Council for an Energy-Efficient Economy petitioned the Environmental Protection Authority to request 'a five percent credit to the energy performance level required to meet Energy Star eligibility criteria for smart-grid enabled appliances' (AHAM, ACEEE et al 2011 - see extract in the Appendix). In other words, appliances with this capability were to qualify for the Energy Star

²⁰Some of these models are listed <http://www.energex.com.au/sustainability/sustainability-rewards-programs/households/energy-conservation-communities-ecc/whats-involved?a=76902>

²¹<http://www.aemc.gov.au/Media/docs/Department%20of%20Climate%20Change%20and%20Energy%20Efficiency-6063cf28-84be-4c1b-84a6-b55f04e79d9e-0.pdf>

endorsement despite using up to 5% more energy than would be required for ‘non-smart’ products of the same type.

The EPA agreed to this proposal and developed criteria for what it calls ‘connected’ appliances in the *Program Requirements: Product Specification for Residential Refrigerators, Eligibility Criteria, Draft 3 Version 5.0* (see relevant extract in Appendix). The proposed implementation date is currently March 2014. EPA has also started work on connected appliance criteria for air conditioners, but these are not yet complete and no start date has been announced.²²

The EPA has indicated that it is including this allowance as a way of ‘helping to “jump start” the market for refrigerators with smart grid capabilities’, and definitions and rules for connected appliances could change over time (EPA 2012).

It is understood that there is no plan to have a special version of the Energy Star label for appliances that meet the ‘connected’ criteria. This will create at least five categories of products:

1. Those that do not meet Energy Star levels of energy efficiency and have no connected capabilities;
2. Those that do not meet Energy Star levels of energy efficiency but have connected capabilities;
3. Those that meet Energy Star levels of energy efficiency and have no connected capabilities;
4. Those that only meet Energy Star levels of energy efficiency because they invoke the allowance for connected capabilities;
5. Those that would meet Energy Star levels of energy efficiency without the allowance, but also have connected capabilities.

Customers who may actively seek a product with connected capabilities would not be able to identify those from the Energy Star label, although they may get some assistance if they download the list of qualified products from the Energy Star website (assuming that the connected status of products is included in the list). Energy Star can give no help to identify products in Category 2 above. As some manufacturer have pointed out, the arrangements would give negligible market advantage to suppliers of products which are *both* energy efficient *and* connected (Category 5 above).²³

European Union

- The European effort on smart grids is led by the three organisations CEN (the European Committee for Standardisation), CENELEC (the European Committee for Electrotechnical Standardization) and ETSI (the European Telecommunications Standards Institute). The aim is an integrated set of standards for smart grids, smart houses and smart appliances although the preferred term for ‘smartness’ in appliances is ‘demand response’ (CEN/CENELEC/ETSI 2011).

CENELEC has published a Roadmap for ‘SmartHouse and related systems’ which states that:

The technical requirements for the Roadmap that follow from the project’s purposes are:

²² <https://www.energystar.gov/products/specs/node/170>

²³ See BSH comments at <https://energystar.gov/products/specs/node/125>

- Help manufacturers from industries to ship their products to a consumers home where they will be interoperable and provide services sharing resources by recommending a limited and helpful set of international (European) standards
- Advise consumers who want to access services in- and outside the home on appropriate standards
- Recommend a minimum of (existing) standards and specifications that fit in a common architecture providing seamless communication in and outside the home
- Assure that standards reach a higher level of interoperability instead of the whole market having to move to one particular standard' (CENELEC 2011)

As there are as yet no European standards for appliances which meet the criteria, there are none on the market, although some European manufacturers are offering products that they term 'smart-grid-ready'.

IEC

The European standardisation effort is also closely linked with the International Electro-Technical Commission (IEC), which has set up a large number of committees related to smart grid standards. The most relevant to smart appliances are:

- PC 118 *Smart Grid User Interface* (set up at the request of the China National Standards Committee, first met in February 2012)
- TC 57 *Power systems management and associated information exchange*
- TC59 Working Group 15 *Connection of household appliances to smart grids and appliances interaction* (first met in October 2012). This is the IEC body with the most direct responsibility for developing a global set of standards for smart appliances. It has representation from the National Standards Committees of Italy, Germany, Japan, China, Turkey, Mexico, the USA and Australia.

China

To date, China has not developed its own smart appliance standards, preferring instead to take part in the IEC process. Some Chinese appliance manufacturers use the term 'smart' in their marketing, but the products so described often lack any of the capabilities identified in Table 1.

Legally smart

To date, no country in the world has succeeded in creating a market for smart appliances, but the ones most advanced are the USA, Australia and Japan. While they are using different technical and policy approaches, they share a critical principle -definitions of 'smartness' that are specific, testable and hence legally enforceable. The countries of the European Union and the IEC are also working towards that objective.

As it happens, none use the term 'smart' in the documents that define smartness. The US EPA uses the term 'connected', the AS/NZS standards use the term 'demand response' and Echonet specifies command structures for changing appliance operating status. As the attributes of 'smartness' are analysed and restated to the level of precision required for standards, more precise terms become necessary.

The ideal basis for developing a global market for smart appliances would be an accepted international standard. Governments could then restrict the right to claim an appliance as 'smart' (or any other agreed term) only if it complies with the standard in question. This is analogous to the common requirement that statements about appliance energy efficiency be made in relation to a specified energy test.

However, the benefits of a smart appliance can only be realised once it becomes part of a system of technical elements that allows it to receive information from or about the outside world, and part of commercial arrangements which reward the user for allowing the appliance to modify its operation in some circumstances. The linking technologies (e.g. home area networks, connectors, smart meters) would also need to be compatible with the appliance standards, and labelled as such.

An over-arching set of standards that covers all possible elements of such a complex system may well be impossible. The best achievable outcome may be agreement on the capabilities that define smartness (e.g. Table 1) and a set of smart appliance standards covering a limited number of generic technical categories, for example:

- Products that have internal communications capabilities and those that do not;
- Products capable of two-way communications and those restricted to one-way communications (ie receiving instructions but without confirming receipt or action);
- Products that require the presence of specific elements such as smart meters (themselves complying with standards yet to be defined) and those which do not;
- Products that are capable of being controlled only by the user (and hence have smart value only in the context of TOU tariffs) and those capable of participating in direct load control arrangements.

The main drivers of demand for smart appliances are likely to be electricity utilities - indirectly through tariff design or directly through demand response services - and related service providers such as demand response aggregators.

Communications pathways and commercial contracts are likely to differ significantly between countries, businesses, network regions and service areas. While it may be difficult or impossible to achieve universal standardisation, it will be of great value to the development of demand response programs if utilities can refer to legally verifiable published standards when offering customers or manufacturers incentives for the promotion of smart appliances in their areas.

Conclusions

‘Smart’ is one of the most over-used marketing terms of our times. However, it needs considerable definition and qualification before it can be usefully applied to appliances.

The capabilities most commonly linked to ‘smartness’ are:

- The ability for the user to access the functions of an appliance and monitor its status and settings from off-site. Those settings may include the control of other smart capabilities;
- The ability of the appliance to automatically adjust and optimise its operation based on information either deliberately input by the user (e.g. tariff data or user preferences), on observing the usage pattern over time, or both.
- The ability of the appliance to automatically adjust and optimise its operation based on information from sources other than the user - e.g. an electricity supplier, aggregator or weather forecaster. A distinct form of interaction is the ability to respond in a predictable way to direct load modification commands.
- Standardisation of inputs (the way the appliance interacts with the world) and of responses (what it does in response to common conditions or commands). Without standardisation a given product might only be assured of a market in areas with all the conditions necessary to its smart capabilities - the right communications pathways, the right tariff structures, perhaps the right type of smart meter.

The latent capabilities of smart appliances have to be activated before the benefits can be realised. There is a huge range in the possible pathways through which instructions may be received, their form and information content (e.g. when to start and stop the altered mode of operation, the type and degree of alteration required). There is also a wide range of design options regarding whether the appliance is limited to one specific communications system or can accommodate a range of systems with or without the use of add-on components.

There are many ways of achieving smart operation in appliances which do not depend on time of use pricing or on smart metering. Any system or arrangement that can transmit five basic instructions - load off, reduce load, load on, store energy and discharge energy - is capable of realising the value of smartness in virtually any appliance. However, the mode of receiving these instructions and the required responses need to be set out in considerable detail before appliance manufacturers can know what to build.

The obvious place for this is in standards. However, given the diversity of approaches and requirements globally, a single common standard may well be impossible, and the best achievable objective may be a series of standards - hopefully limited in number and linked by some common elements - related to different ‘smart architectures.’

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Note: Readers of a certain age may notice allusions to selected television programs and films in the title of this paper and some of the subheadings. No great significance should be attached to this.

Appendix - selected definitions of smart appliances

AHAM and ACEEE

From Joint Petition to Energy Star to Adopt Joint Stakeholder Agreement as it Relates to Smart Appliances (ACEEE and AHAM 2011)

<http://www.aham.org/ht/a/GetDocumentAction/i/51594>

The Joint Petitioners propose the following provisional definitions related to smart appliances. Any smart appliance must meet the definition of “smart appliance” and the product specific requirements below.

The term “smart appliance” means a product that uses electricity for its main power source which has the capability to receive, interpret and act on a signal received from a utility, third party energy service provider or home energy management device, and automatically adjust its operation depending on both the signal’s contents and settings from the consumer. The product will be sold with this capability, which can be built-in or added through an external device that easily connects to the appliance. The costs of such devices shall be included in the product purchase price.²⁴

These signals must include (but are not limited to) appliance delay load, time-based pricing and notifications for load-shedding to meet spinning reserve requirements. Any appliance operation settings or modes shall be easy for an average, non-technical consumer to activate or implement. Additionally, a smart appliance or added device may or may not have the capability to provide alerts and information to consumers via either visual or audible means. The appliance may not be shipped with pre-set time duration limits that are less than those listed below, but may allow consumer-set time duration limits on smart operating modes, and will also allow consumers to override any specific mode (e.g. override a delay to allow immediate operation, limit delays to no more than a certain number of hours, or maintain a set room temperature).

The term “delay load capability” refers to the capability of an appliance to respond to a signal that demands a response intended to meet peak load deferral requirements, but which also could be used to respond to a sudden maintenance issue at another time of day.

The term “spinning reserve capability” means the capability of an appliance to respond to a signal that demands a response intended to temporarily reduce load by a short-term, specified amount, usually 10 minutes.

We further recommend product-specific definitions as provided below. Each of the following definitions includes a response to a “delay load signal” and a response to reduce load to provide spinning reserve services. A smart appliance needs to have the capability to meet both of these requirements, but not simultaneously.

²⁴ If additional requirements are needed to activate the product’s “smart” capabilities as purchased, then prominent labels and instructions must be displayed at the point of purchase and in product literature on what specifically consumers or utilities need to do to achieve these capabilities (e.g. “This product requires snapping in the compatible network module and utility installation of a smart meter or other device for use of capabilities that earned the ENERGY STAR label”).

a) Refrigerator/Freezers: a smart refrigerator/freezer must have the following minimum capabilities -

i) Delay load capability - upon receipt of a signal requesting a delay of load for a time duration not exceeding 4 hours, the product must shift defrost cycles beyond the delay period and do one of the following --

(1) shift ice maker cycles beyond the delay period, or

(2) reduce average wattage during the delay period by at least 9.6 watts relative to average load over a 24 hour period, and may shift this wattage beyond the delay period", and

ii) Spinning reserve capability - upon receipt of a signal requesting the start of a reduced load period for a time duration not exceeding 10 minutes, the product must restrict its average energy consumption during this time period to a maximum of 50 percent of the average load over a 24 hour period (unless there is a consumer initiated function, such as door opening or ice or water dispensing).

b) Clothes Washers: a clothes washer must have the following minimum capabilities -

i) Delay load capability - upon receipt of a signal requesting a delay of load for a time duration not exceeding either 4 hours or such other period that the consumer may select, the product must automatically delay the start of the operating cycle beyond the delay period, and

ii) Spinning reserve capability - upon receipt of a signal requesting the start of a reduced load period for a time duration not exceeding 10 minutes, the product must automatically reduce its average wattage during this time period by at least 50 percent relative to average wattage during this period in the operating cycle under DOE test conditions.

c) Clothes Dryers: a clothes dryer must have the following minimum capabilities -

i) Delay load capability - upon receipt of a signal requesting a delay of load for a time duration not exceeding 3 hours, the product must automatically delay the start of the operating cycle beyond the delay period, and

ii) Spinning reserve capability - upon receipt of a signal requesting the start of a reduced load period for a time duration not exceeding 10 minutes, the product must automatically reduce its average wattage during this period by at least 80 percent relative to average wattage during this period in the operating cycle under the DOE test conditions.

d) Room Air Conditioners: a room air conditioner must have the following minimum capabilities -

i) Delay load capability - upon receipt of a signal requesting a delay of load for a time duration not exceeding either 4 hours or such other period that the consumer may select, the product must automatically reduce its average wattage during this period by at least 25 percent relative to average wattage during this period in the operating cycle under the DOE test conditions, and

ii) Spinning reserve capability - upon receipt of a signal requesting the start of a reduced load period for a time duration not exceeding 10 minutes, the product must automatically reduce its average wattage during this period by at least 80 percent relative to average wattage during this period in the operating cycle under during the DOE test conditions.

e) Dishwashers: a dishwasher must have the following minimum capabilities

i) Delay load capability - upon receipt of a signal requesting a delay of load for a time duration not exceeding either 4 hours or such other period that the consumer may select, the product must automatically delay the start of the operating cycle beyond the delay period, and

ii) Spinning reserve capability - upon receipt of a signal requesting the start of a reduced load period for a time duration not exceeding 10 minutes, the product must automatically reduce its average wattage during this period by at least 50 percent relative to average wattage during this period in the operating cycle under the DOE test conditions.

Energy Star

From ENERGY STAR® Program Requirements: Product Specification for Residential Refrigerators, Eligibility Criteria, Draft 3 Version 5.0

<https://energystar.gov/products/specs/node/125>

Connected Product Criteria

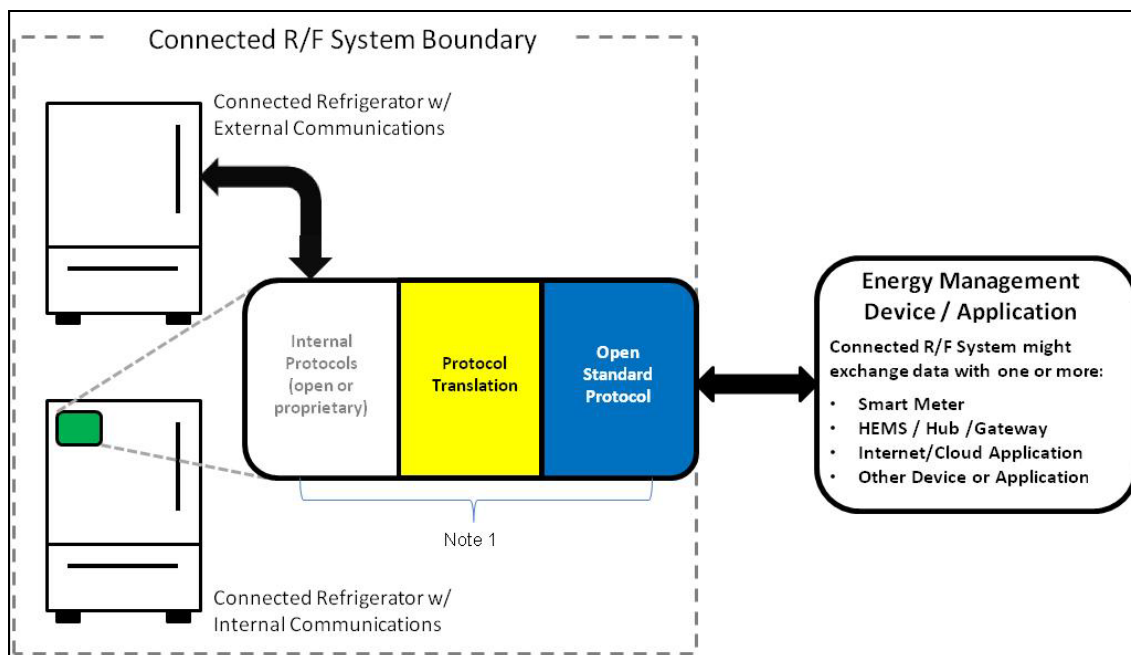
A. Connected Refrigerator-Freezer System

To be recognized as connected and to be eligible for the connected allowance, a “connected refrigerator or refrigerator-freezer system” (Connected R/F System, as shown in Figure 1) shall include the base refrigerator or refrigerator-freezer plus all elements (hardware, software) required to enable communication in response to consumer-authorized energy related commands. These elements may be resident inside or outside of the base appliance. This capability shall be supported through one or more means, as identified in section 4B2.

The specific design and implementation of the Connected R/F System is at the manufacturer’s discretion provided it meets the communication requirements in section 4B and includes at least one supported configuration that is capable of receiving and directly responding to open standards-based energy related commands on the consumer’s premises.

The product must continue to comply with the applicable product safety standards - the addition of the functionality described below shall not override existing safety protections and functions. The appliance must meet manufacturer’s internal minimum performance guidelines, e.g., food preservation

Figure 1 Connected Refrigerator/Freezer System Boundary - Illustrative Example



Note 1: Communication device(s), link(s) and/or processing that enables open standards-based communication between the Connected R/F System and Energy Management Device/Application(s). These elements could be within the base appliance, and/or an external communication module, a hub/gateway, or in the Internet/cloud.

B. Communications

1. Open Standards - Communication with entities outside the R/F System that enables connected functionality (sections 4D through 4H) must use, for all communication layers, standards:

- Included in the Smart Grid Interoperability Panel (SGIP) Catalog of Standards,¹ and/or
- Included in the NIST Smart Grid framework Tables 4.1 and 4.2, and/or
- Adopted by the American National Standards Institute (ANSI) or another well-established international standards organization such as the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), International Telecommunication Union (ITU), Institute of Electrical and Electronics Engineers (IEEE), or Internet Engineering Task Force (IETF).

2. Communications Hardware Architecture - Communication with entities outside the Connected R/F System that enables connected functionality (sections 4D through 4H) shall be enabled by any of the following means, according to the manufacturer's preference:

- a. Built-in communication technology
- b. Manufacturer-specific external communication module(s) and/or device(s)
- c. Open standards-based communication port on the appliance combined with open standards based communications module
- d. Open standards-based communication port(s) on the appliance in addition to a, b or c, above

If option b or c is used, the communication module/device(s) must be easy for a consumer to install and shipped with the appliance, provided to the consumer at the time of sale, or provided to the consumer in a reasonable amount of time after the sale.

C. Open Access

To enable interconnection with the product, an interface specification, API or similar documentation shall be made available to interested parties that at a minimum, allows transmission, reception and interpretation of the following information:

- Energy Consumption Reporting specified in section 4D (must include accuracy, units and measurement interval);
- Remote Management specified in section 4E;
- Operational Status, User Settings & Messages specified in section 4F (if transmitted via a communication link);
- Communications required to enable Delay Defrost Capability specified in section 4G; and
- Demand Response specified in section 4H.

D. Energy Consumption Reporting

In order to enable simple, actionable energy use feedback to consumers and consumer authorized energy use reporting to 3rd parties, the product shall be capable of transmitting energy consumption data via a communication link to energy management systems and other consumer authorized devices, services or applications. This data shall be representative of the product's interval energy consumption. It is recommended that data be reported in watt-hours for intervals of 15 minutes or less, however, representative data may also be reported in alternate units and intervals as specified in the product manufacturer's interface specification or API detailed in section 4C.

The product may also provide energy use feedback to the consumer on the product itself. On-product feedback, if provided, may be in units and format chosen by the manufacturer (e.g., \$/month).

E. Remote Management

The product shall be capable of receiving and responding to consumer authorized remote requests, via a communication link, similar to consumer controllable functions on the product. The product is not required to respond to remote requests that would compromise performance and/or product safety as determined by the product manufacturer.

F. Operational Status, User Settings & Messages

1. The product shall be capable of providing the following information to energy management systems and other consumer authorized devices, services or applications via a communication link:
 - Demand Response (DR) status (e.g., normal operation, delay appliance load, temporary appliance load reduction).

2. The product shall be capable of providing the following information on the product and/or to energy management systems and other consumer authorized devices, services or applications via communication link:
 - At least two types of messages relevant to the energy consumption of the product. For example, messages for refrigerators, refrigerator-freezers and freezers, might address: door left open notification, a notification that product lost power, a reminder to clean refrigerator coils, or report of energy consumption that is outside the product's normal range.

G. Delay Defrost Capability

When interconnected with an energy management system or other consumer authorized device, service or application via a communication link, products with automatic defrost shall have a delay defrost capability active by default, where the consumer can input or the product itself shall identify, the time of day, and the product shall automatically move the defrost function outside of a 4-hour deferral period. The deferral period is seasonal and has been defined to align with both summer and winter peak energy demand periods, as follows:

- 6am to 10am - November 1 through April 30
- 3pm to 7pm - May 1 through October 31

The product shall provide an option for the consumer and/or consumer authorized 3rd party to modify scheduling and functional status of this capability in order to, for example: respond to a short term request from the utility, align defrost avoidance periods with on-peak periods for their utility or enable/disable the capability.

In the event of a power outage, after power is restored the product shall not require any interaction from the consumer to maintain this defrost deferral feature with the same settings as prior to the power outage.

Exceptions:

- Once the consumer enrolls in a program that sends consumer-authorized signals to the R/F System, the Delay Defrost capability, as defined in this section, shall be disabled. The product may include an optional transition period of up to 24-hours after enrollment, during which the R/F System is not required to provide either Delay Defrost capability or DR capability as defined in Section 4H.
- A refrigerator, refrigerator-freezer or freezer with manual defrost or partial automatic defrost is not required to provide Delay Defrost Capability.

H. Demand Response

A connected refrigerator, freezer or refrigerator-freezer shall have the capability to receive, interpret and act upon consumer-authorized signals by automatically adjusting its operation depending on both the signal's contents and settings from consumers. At a minimum, the product shall be capable of providing the following:

1. *Delay Appliance Load Capability*: The capability of the product to respond to a signal by providing a moderate load reduction for the duration of a delay period.
 - a. Upon receipt of signal and in accordance with consumer settings, except as permitted below, the product shall:

- i. Shift its defrost cycle(s) beyond the delay period, and
- ii. Either shift ice maker cycles beyond the delay period or reduce its average power draw during the delay period by at least 13% relative to the average power draw drawn during an average load over a 24-hour period as defined by the Baseline Test in the Test Method to Validate Demand Response.

b. Exceptions:

- i. The product is not required to respond to a delay appliance load request if the signal requests the delay load period to begin while the product is defrosting.
- ii. The product is not required to provide the 4H1(a)(ii) response if the delay appliance load signal requests the delay load period to begin while the product is in an ice-maker harvest/refill cycle.

c. Default settings -The product shall ship with default settings that enable a response in accordance with 4H1(a) for at least 4 hours.

d. Consumer override - The consumer shall be able to override the product's Delay Appliance Load response before or during a delay period.

e. The product shall be able to provide at least one Delay Appliance Load response in a rolling 24-hour period.

2. Temporary Appliance Load Reduction Capability: The capability of the product to respond to a signal by providing an aggressive load reduction for a short time period, typically 10 minutes.

- a. Upon receipt of signal and in accordance with consumer settings, except as permitted below, the product shall restrict its average power draw during the load reduction period to no more than 50% of the average power draw during an average load over a 24-hour period as defined by the Baseline Test in the Test Method to Validate Demand Response.
- b. Exceptions - Under the following conditions, the product is not required to provide a response in accordance with 4H2(a):
 - i. If a signal is received during a defrost cycle, that defrost cycle may finish. However, no additional defrost cycle(s) shall occur during the time period, and/or
 - ii. If there is a consumer-initiated function such as a door opening or ice/water dispensing during the load reduction period.
- c. Default settings - The product shall ship with default settings that enable a response in accordance with 4H2(a) for a time period of least 10 minutes.
- d. Consumer override - The consumer shall be able to override the product's Temporary Appliance Load Reduction response before or during a load reduction period.
- e. The product shall be able to provide at least one Temporary Appliance Load Reduction response in a rolling 24-hour period.

I. Information to Consumers

If additional modules, devices, services and/or infrastructure are part of the configuration required to activate the product's communications capabilities, prominent labels or other forms of consumer notifications with instructions shall be displayed at the point of purchase and in the product literature. These shall provide specific information on what consumers must do to activate these capabilities (e.g. "This product has Wi-Fi capability and requires Internet connectivity and a wireless router to enable interconnection with an Energy Management System, and/or with other external devices, systems or applications.").

Australian and New Zealand Standard AS/NZS 4755.3.1

Key definitions from AS4755.3.1:2012 Demand response capabilities and supporting technologies for electrical products. Part 3.1: Interaction of demand response enabling devices and electrical products-Operational instructions and connections for airconditioners Standards Australia

<http://infostore.saiglobal.com/store/Details.aspx?ProductID=1528196>

Demand response (DR)

The automated alteration of an electrical product's normal mode of operation in response to an initiating signal originating from or defined by a remote agent.

Demand response capability

The ability of an electrical product to provide demand response.

Note: The capability may reside in the electrical product itself, or in the combination of the product and a separate demand response enabling device (see Figure 2).

Demand response capable air conditioner

An air conditioner that is supplied with the necessary interface, circuitry and components to fully comply with this Standard.

Air conditioners that are assembled from components on site are demand response capable if all components necessary to make the assembly demand response capable are supplied with every unit, and the installation instructions require all components to be assembled.

Demand response enabling device (DRED)

A device that provides the functionalities and capabilities to achieve demand response.

This Standard applies to electrical products that do not contain a DRED, and have a demand response interface intended to connect with a DRED that will be provided by others.

Demand response event

The period between the initiation and termination of an operational instruction.

Demand response interface

The physical connections and associated functions that enable an electrical product to receive operational instructions from a DRED, or the physical connections and associated functions that enable a DRED to convey operational instructions to an electrical product.

Demand response mode (DRM)

A mode of operation within specified conditions, constraints or parameters during a demand response event (see Table 1).

Figure 2 Demand response architecture embodied in the AS/NZS 4755 standards

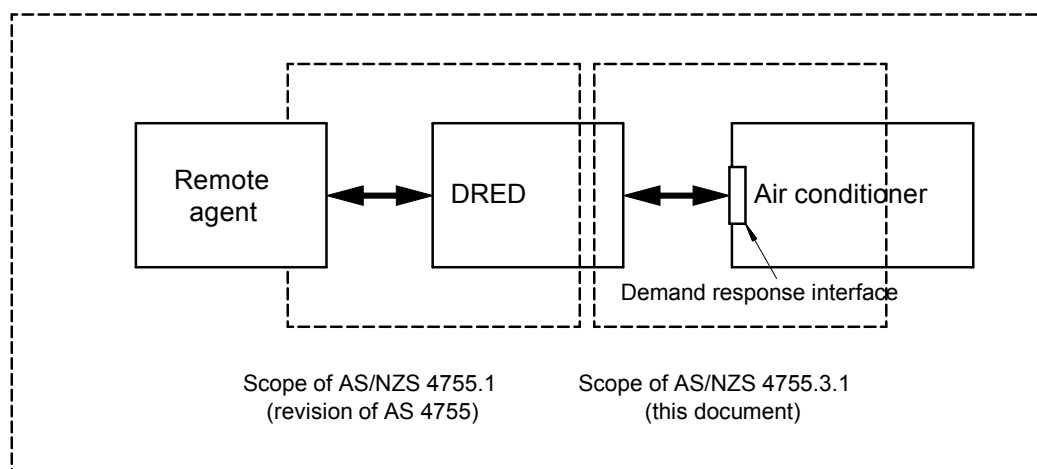


Table 2 Air Conditioner Demand Response Modes

Operational instruction (OI)	Demand response mode (DRM)*	Description of operation in this mode	Mandatory for compliance with this Standard (AS/NZS 4755.3.1)
OI 1	DRM 1	Compressor off	Yes
OI 2	DRM 2	The air conditioner continues to cool or heat during the demand response event, but the electrical energy consumed by the air conditioner in a half hour period is not more than 50% of the total electrical energy that would be consumed if operating at the rated capacity in a half hour period.	No
OI 3	DRM 3	The air conditioner continues to cool or heat during the demand response event, but the electrical energy consumed by the air conditioner in a half hour period is not more than 75% of the total electrical energy that would be consumed if operating at the rated capacity in a half hour period.	No

* Other electrical products may have additional demand response modes beyond those included in this Table.