RESIDENTIAL BUILDING ENERGY MANAGEMENT

This section describes the present state of energy management in residential buildings. It then describes ZCA Buildings Plan recommendations which include widespread use of smart electricity metering, web portals, in-home displays, and certain appliance controls. The application of these technologies is projected to reduce average annual energy consumption in Australian residences by 6.6% or approximately 3.7 TWh/annum.

The Problem: Limited Information and Limited Control

The ability of Australian homeowners and tenants to reduce energy consumption, especially at peak electricity demand times, is limited by a lack of information. Such information must indicate when, where, and how much energy is being consumed directly by the household. Some examples include residents being unaware of:

The cost of stand-by electricity being used in their home every day and night,

The cost of running an old and inefficient second refrigerator,

The cost of leaving appliances turned on when not in use -such as lighting, computers or televisions, The relative amounts of energy used by different electrical appliance technologies such as halogens versus LED lights, plasma versus LCD televisions, or heat pump versus radiant heaters,

The cost of running electricity-intensive appliances such as refrigerative air conditioners, pool pumps or clothes driers,

The cost savings possible by shifting electricity use to different periods of a day or week.

The disproportionately high cost of supplying electricity at peak demand times has been described by the Productivity Commission [132] who state, for example, that "around 25% of retail electricity bills reflect the cost of system [electricity network and supply] capacity that is used for less than 40 hours a year (or under 1% of the time)".

Even in instances where residents are aware of how much electricity an appliance uses, the ways that energy can be controlled is generally limited to:

- Manual intervention by the resident.
- The use of simple timers.
- Adjusting thermostats for room temperature control.
- Standby power controllers.

More sophisticated methods of controlling energy, based on real-time information, are not yet widely used in Australia.

However as described in the next section, trials have shown the value of applying currently-available residential building energy management technologies.

The Solutions: Zca Buildings Plan Recommendations

Technologies now exist that merge information and communication methods into residential building energy management systems [133, 134]. These can assist residents to reduce peak and average energy use.

As shown in Figure 3.25, these technologies include:

- "smart" electricity meters that transmit near real-time electricity consumption data,
- web portals displaying energy use information, as measured by the smart meter and transmitted to and recorded by the electricity supplier (typically for half-hourly or hourly intervals),
- in-home displays (IHDs) that show near-real-time energy consumption data received from the smart meter,
- controllable smart appliances and other demand-response-enabling devices (DREDs) that can be used to control discretionary high-energy-demand appliances such as pool pumps[133], air conditioners, water heaters, and electric car chargers,
- aspects of automated energy control via a home-area network (HAN).

As described in the following sections, this Plan recommends the installation of these technologies in Australian residential buildings.

Roll out of these technologies is also recommended in many respects by the Council of Australian Governments (COAG) [136] who, based on work done by the Australian Energy Market Commission [137] and Productivity Commission [132], voiced "a commitment to make it easier for retailers to offer innovative products to give consumers the choice to have such things as smart metering, in-home displays, and time-of-use-pricing so they may better manage their energy use and reduce costs". Even more comprehensive and sophisticated centralized home automation systems are under development and deployment globally [138, 139]. However because of the nascent state of those advanced systems, they are not recommended as part of this Plan.

Smart Electricity Metering

A key enabling technology for residential building energy management is the smart meter. This section describes the various types of electricity meters. (Smart metering can also be applied to other utilities such as water and gas.)

Traditional spinning-disk type accumulation meters record a cumulative amount of electricity energy. They can measure net electrical flow from-the-grid (importing) minus to-the-grid (exporting). Such bi-directional meters, as a minimum, are necessary when there is on-site generation such as rooftop solar photovoltaicsystems.

Traditional accumulation meters cannot give any indication of when electricity has been consumed or generated. On the other hand, most modern digital electricity meters go further and log electricity flows over fixed time intervals. These are known as interval meters. For example, if the designated measurement interval is 30 minutes and the billing period is every 90 days, then the account at each bill will be based on 4,320 intervals.

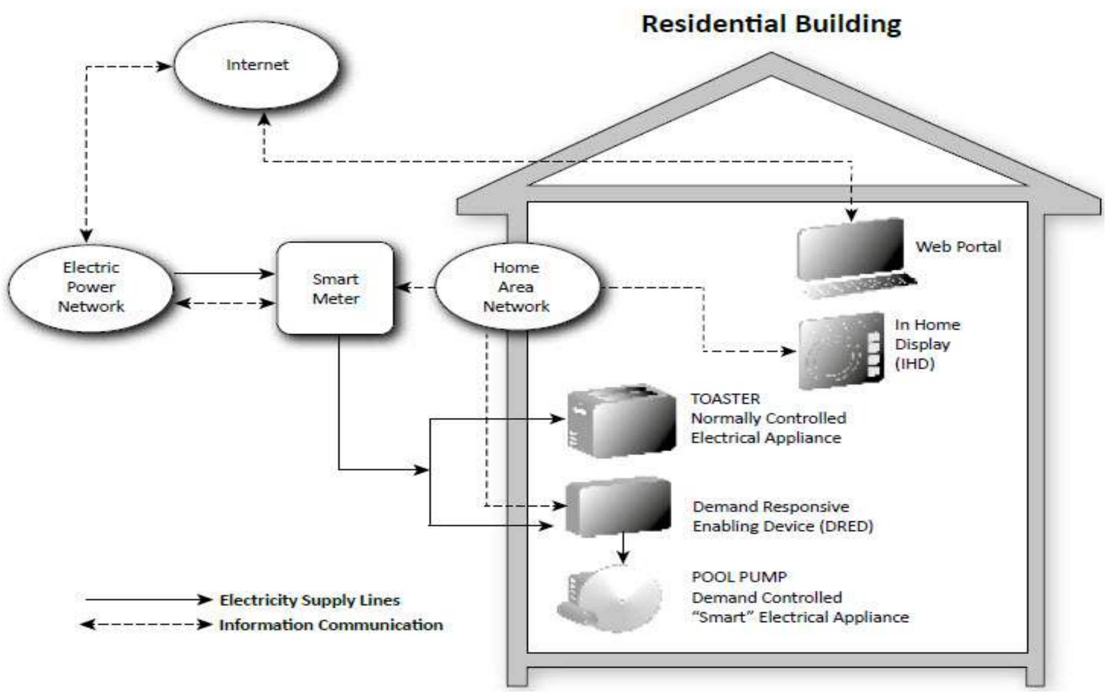

FIGURE 3.35
Recommended technologies for Residential Building Energy Management

Interval meters enable electricity to be sold at different prices (tariffs) for different blocks of time within the day (eg night versus day) or different days with the week (weekday versus weekend). This is known as time-of-use (TOU) pricing.

Smart meters are interval meters that can communicate with electricity supply companies and with in-home displays (IHDs).

Communication with electricity suppliers enables remote meter reading and remote control. Communication with in-home devices provides building residents with real-time information about electricity flows and also allows control of electrical appliances.

Smart meters have been installed as part of solar city trials in, for example, Perth [140] and Adelaide [141]. Victoria's roll out of smart meters for homes and businesses is due to be complete by the end of 2013 [142]. As recommended by COAG [136], the other Australian states and territories also intend to make smart meters more available to residential electricity consumers.

Web Portals

The interval data measured and transmitted by smart meters and recorded by electricity suppliers can be made available to home owners and tenants over the internet. This is known as a web portal [143]. Residents are assigned a login and password by their energy retailer and/or electricity distribution company. Residents can then log-on to the web portal which displays their electricity usage over time, as well as associated billing information [144].

Figure 3.38 shows how a web portal appears on a computer screen. The two bar charts show, for hourly periods, the amount of electricity imported to and exported from a home for two different days.

Advice about how to save electricity can be incorporated into the web portal, as well as comparative electricity used by neighbours in the same postcode area. This comparative analytical capability has been shown to help residents to change their behaviour [145].

In-home Displays (IHDs)

In-home displays (IHDs) are stand-alone devices that allow home owners and tenants to view their energy use in nearly real-time. Older technology current-clamp type IHDs have been available in Australia for some time; however, that type of IHD does not communicate directly with the electricity meter and has limited accuracy. State-of-the-art IHDs communicate wirelessly with smart meters, as shown schematically. Figure 3.37shows one commercially-available IHD with smart meter communication capability.

FIGURE 3.37
Commercially available in-home display. [Millennium Electronics Pty Ltd]

IHDs communicate with smart meters via a low-power, short-range wireless communications protocol known as the ZigBee Smart Energy Profile (SEP), a widely-used standard. A number of jurisdictions (eg France and the United Kingdom) are combining installation of IHDs with their smart meter programs. As of 1 March 2012Victoria included IHDs as a prescribed activity in the Victorian Energy Saver Incentive (ESI) scheme [146]. This effectively subsidises IHD purchases.

Some features of in-home displays that have been set as minimum specifications in the United Kingdom and Victorian schemes are listed below [147]:

- near real-time feedback (less than 30 seconds lag),
- at least 45 days of usage history,
- indicative cost data in cents per kilo-watt hour and accumulated cost,
- numerical and non-numerical displays,
- data communications security,
- power draw of no more than 0.6 watts,
- battery replacement not required within five years.

An additional feature of many mid to high-range IHDs is the ability to receive messages and alerts.

IHDs have the ability to assist energy consumers to understand their instantaneous whole-of-house electricity usage. Referring to an IHD, a resident can manually switch appliances on and off in order to understand electricity consumption. IHDs can also assist residents in becoming aware of standby power loads or the energy use of "forgotten" appliances.

IHDs can convert energy-use data into an indicative cost by applying the resident's electricity tariff. Tariff complexities such as different prices for different times of the day (known as "peak", "off-peak", or "shoulder") can make it difficult for consumers to understand how their energy use patterns impact their electricity bills. The design of an IHD aims to mitigate this problem by providing an easy-to-understand view of the resident's expected electricity bill.

FIGURE 3.38
Web portal. [T. Forcey]
Smart Appliances and Demand-Response-Enabling Devices (DREDs)

Given the high cost of supplying electricity at peak times [130], this Plan recommends the installation of technologies known as smart appliances or demand-response-enabled devices (DREDs).

Such appliances can be directly controlled by the energy supplier under agreed circumstances such as at times of peak electricity demand. This is known as Direct Load Control (DLC). In this situation, the electricity supplier might turn off, cycle, or adjust the electricity draw of the appliance. The electricity customer can be compensated via a rebate known as a critical peak rebate tariff.

Appliances can be controlled via smart plugs or via a wireless Home Area Network (described below). Smart plugs involve the appliance being directly wired into a specially-provided electrical socket that can be controlled by the electricity supplier.

Successful trials have been conducted into controlling devices such as pool pumps [135], and air conditioners[140]. For those appliances, and also for water heaters and electric vehicle charging, further investigation into the installation of these technologies is under-way [148] as recommended by COAG [136].

The Energy Supply Association of Australia was reported as expecting that a significant impact could be made on peak demand with as little as one-in-forty homes being involved with Direct Load Control devices. Residents might be invited to participate on an "opt-in" basis.

Automated Energy Control Via a Home Area Network (HAN)

A local area network (LAN) allows communication between digital devices deployed in the home such as computers and printers.

A home area network (HAN) extends that concept to smart meters, in-home displays, and smart appliances or DREDs.

Smart appliances, communicating via the wireless ZigBee protocol, can be programmed to automatically respond to signals sent from the energy supplier and potentially the resident. For example, the energy supplier might send a critical peak signal through to the HAN (via the smart meter) informing that a critical peak event is occurring. A smart appliance such as a pool pump could respond to that signal by stopping or reducing its electricity use during the critical period and returning to full operation later in the day.

Architectures that use HAN technology to reduce or time-shift electricity demand include "static" and "dynamic" home energy management. Static home energy management is set up by the resident in order to reduce their electricity bill by appropriately responding to a tariff structure. Dynamic home energy management is similar to static but can also respond to energy supplier requests.

Benefits

This section summarises the benefits in reducing average-annual and peak energy use that can be achieved by deploying the recommended residential building energy management technologies.

Reducing Average-Annual Energy Use

Global studies of energy-use-feedback technology trials found energy savings of 2% to 20% [149, 150, 151, 152]. Feedback that is more real-time and granular allows the greatest savings.

Figure 3.39 shows energy savings ranging from 3.8 to 12% depending on the type of feedback [150].

A recent study by Accenture [147] examined 76 global feedback trials (including seven Australian trials) and five other studies and found the following key trends particularly relating to IHDs:

- Consumers respond positively to ihds,
- Consumers measurably reduce energy consumption in response to feedback, ranging from two to 20%,
- Ihds drive energy consumption reduction in isolation from other feedback types,
- Dynamic (flexible) pricing tends to drive load-shifting behaviour, whereas feedback reduces overall energy use,
- On-going education has a negligible effect on the behaviour of ihd users,
- Energy saving behaviour persists over time. This is especially the case with IHDs which appear to have a stimulating effect on helping consumers to understand their consumption patterns and to lock-in new habits. The Accenture study concluded that for Victoria "IHDs could reasonably provide an average-annual energy

reduction of 6.6%" As a result the Buildings Plan conservatively assumes that the deployment of IHDs, along with the full suite of recommended residential building energy management technologies, will result in average-annual electricity savings of 6.6% throughout Australia.

Reducing peak energy demand

Flexible pricing alongside the provision of energy information, and even more so alongside automated response, enables the shifting of demand from peak times to other times. One study [149] reviewed the effect of different pricing schemes and associated feedback mechanisms on peak demand and found that peak demand in the home could be reduced by over 30% if flexible pricing schemes and automation of energy appliances were implemented. Smart meter infrastructure means it is also possible for smart appliances to be able to respond by varying their demand according to grid situation.

Costs and Economics of Plan Recommendations for Residential Building Energy Management

The expenditures required to realise the above average-annual energy savings are largely associated with the costs to install smart meters and IHDs.

In Victoria, the smart meter rollout is costing more than $700 per meter, with further ongoing operating costs of $20-30 per year. According to the Productivity Commission [132], the market for smart meters is maturing and prices are declining.

Smart meter installation involves safety checks. The overall cost of the roll out includes the incidental rectification of many safety issues. Hence there are indirect, but hard-to-quantify, benefits through avoided incidents such as electrical fires and electrocutions.

A mid-range IHD costs approximately $100.

Based on the recognised economy-wide benefits and broad government support [134], for the Plan-recommended residential energy management technologies, this Plan assumes that Smart Meters and IHDs will be common in Australia within ten years. Therefore their cost is considered a business-as-usual expense that is not factored into Plan costings.

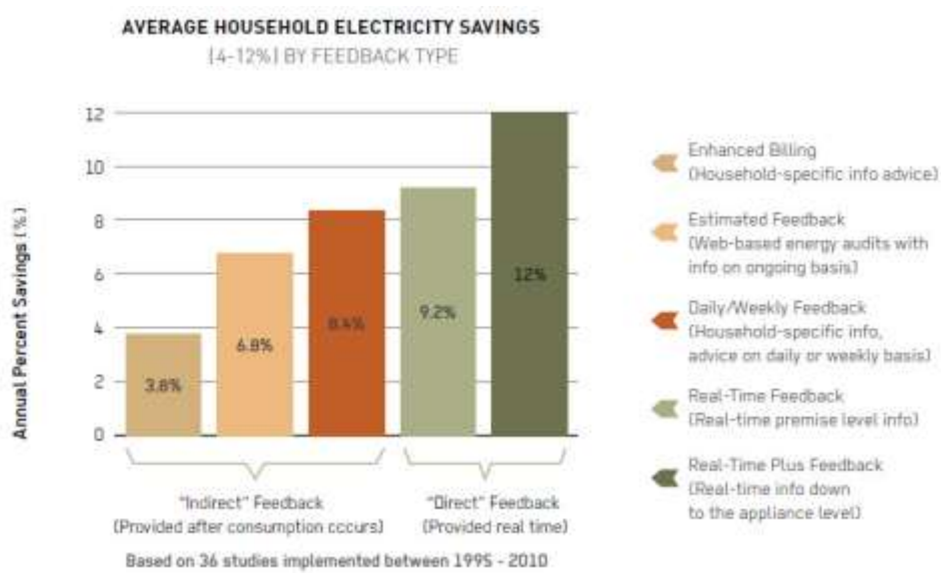

FIGURE 3.39
Average household electricity savings for different feedback types

Source: http://decarboni.se/publications/zero-carbon-australia-buildings-plan/6-residential-building-energy-management