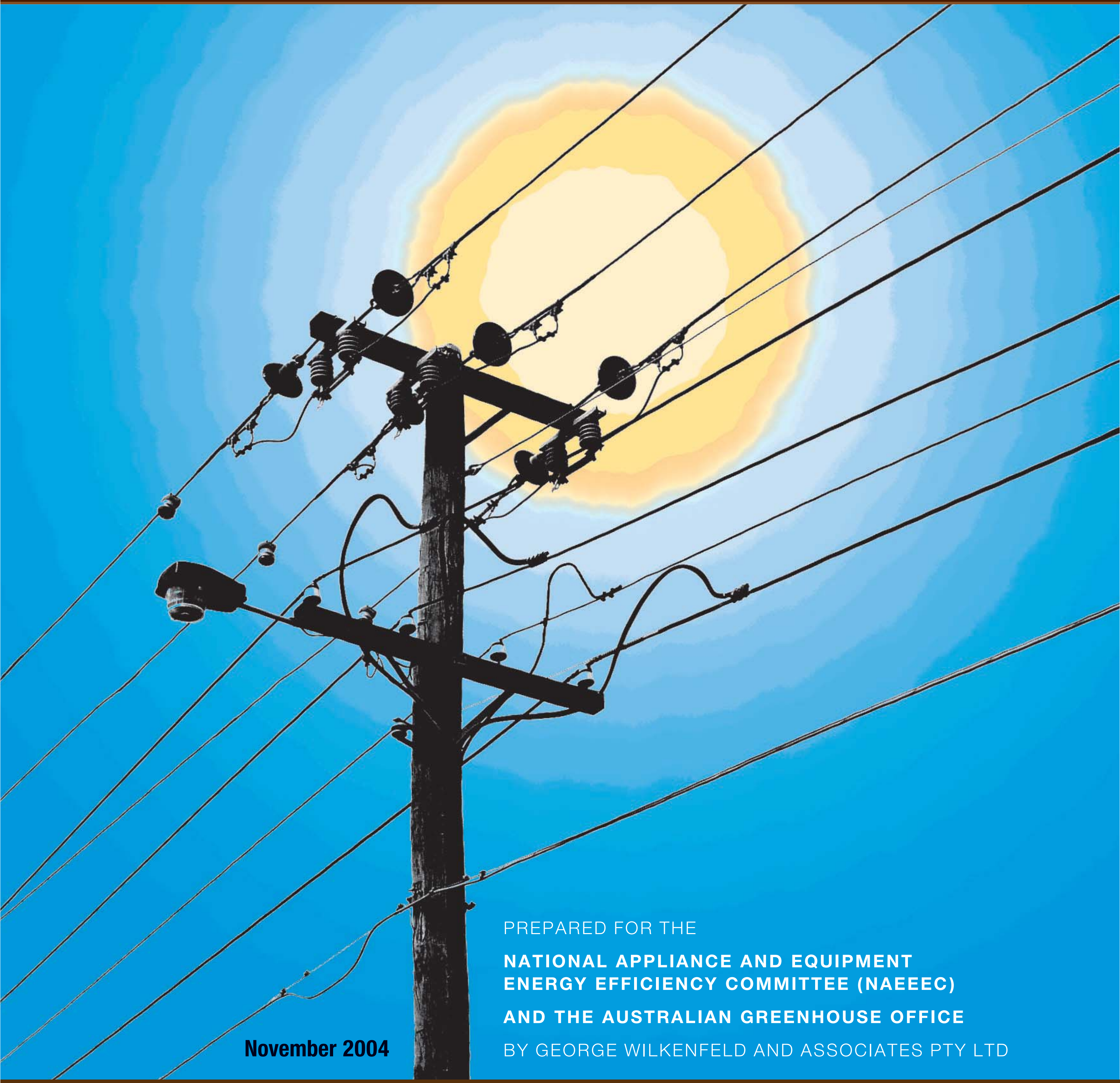
A National Demand Management Strategy for Small Airconditioners:

REPORT NO 2004/22

The role of the National Appliance and Equipment Energy Efficiency Program (NAEEEP)



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Summary

Air conditioner peak demand is one of the major factors driving capital investment in the National Electricity Market, as well as a mechanism for cross-subsidy between AC users and non-users. If no action is taken, both energy and peak demand are projected to increase rapidly in the coming years. This paper reviews a range of measures potentially impacting on the energy use and contribution to summer day peak demand of domestic and small business air conditioning in Australia.

Typically about 30-40% of commercial sector demand and 40%-50% of residential sector demand on system peak summer days is now due to air conditioning, and the two loads are of similar magnitude.

The load factor of commercial sector air conditioning use is similar to that of other commercial sector uses, whereas the load factor of residential sector air conditioning is very low – ie its share of annual energy use is far lower than its contribution to peak demand.

Much of commercial sector electricity consumption is metered by time of use, so the costs of air conditioning energy and peak load can be signalled and recovered. However, there are no ready means available at present to signal or recover the costs which air conditioner-owning households or small businesses place on the system, so there is a large and growing cross-subsidy from non-air conditioning households (including those with evaporative coolers) to those with air conditioners. The value of this cross-subsidy is estimated at $300-500 million per annum in the National Electricity Market area alone.

The incidence of air conditioning in larger commercial buildings has been fairly high for some time, so the growth in use is largely associated with growth in the building stock. However, the rate of growth in air conditioning use in the residential sector is much greater rate than the rate of growth in the housing stock. Air conditioners were formerly installed some time after construction of new dwellings, but are now being installed in a rising proportion of dwellings at the time of construction, a trend that appears not to have been affected by increasing building thermal performance standards. The rate of takeup by existing households is also rising.

The drivers for the increasing takeup of residential air conditioners include:

- A real decline in the costs of air conditioners (as for other appliances) with the growth of manufacture in China and other Asian countries;
- Rising disposable income;
- A masking of the real costs of domestic air conditioner operation through tariff cross subsidies;
- The long-term promotion (including by financing and concessional tariffs) of air conditioning by some electricity suppliers through the 1990s;
- The increase in the type of housing forms, site densities and urban environmental factors that make reliance on natural ventilation more difficult;
- The lack of significant improvement in building shell efficiency in recent years.

Domestic air conditioning energy consumption and peak load could potentially grow even more rapidly than the rate of growth in air conditioner numbers, because of increasing average dwelling size, the tendency to cool the entire house rather than just one or two rooms, longer hours of operation, and increasing average outside temperature and more frequent days of extreme high temperature due to global warming.

Given the combination of high growth rates in ownership and increasing use per air conditioner, it is conceivable that the energy consumption and peak demand of air conditioning in the residential sector could double in the next 10 years.

Energy Efficiency Responses

This paper considers the contribution that energy efficiency programs for buildings and air conditioners could make to containing the growth in air conditioning energy use and peak demand.

Measures targeting the air conditioners themselves are likely to have a more rapid impact: well over 90% of the housing that will be in use in 2010 has already been built, but over 90% of the air conditioners that will be in use in 2010 are still to be made.

The strongest link between building thermal performance and air conditioning demand occurs with continuous whole-building air conditioning, which is the typical mode of operation in the commercial sector. Provided the air conditioning plant is correctly sized and the controls are responsive, the cooling energy and the peak demand should fall as the building thermal performance improves.

However, with the intermittent mode of operation typical in households the link between building thermal performance and air conditioning demand is relatively weak. Improvements in shading, orientation and insulation will have only limited impact on energy consumption and even less on peak load.

The most effective contribution that higher building thermal performance standards could make to reducing domestic air conditioning would be through increasing summer thermal comfort to the point where air conditioning was not required. Once an air conditioner is installed there is a high probability that it will be operating at near full capacity during peak periods, although it may be able to achieve more comfortable internal conditions and reduce output more rapidly after the peak period in buildings with better shading and orientation.

Another approach to reducing energy consumption for air conditioning, with some benefits for peak demand, is to increase the average energy-efficiency of the air conditioner stock compared with Business as Usual (BAU). This is the objective of mandatory energy labelling for single-phase air conditioners, in place since 1987 (now part of the NAEEEP) and of MEPS for three-phase packaged air conditioners, which was introduced in 1999. MEPS levels for three-phase units are due to be raised in 2004, and MEPS are to be introduced for single-phase units in three stages, in 2004, 2006 and 2007, with the final stage to match world's best regulatory practice.

A MEPS or labelling-induced increase in the average energy efficiency of new air conditioners is more likely to achieve an increase in average cooling capacities than a reduction in average motor power. Either way, this should translate into a reduction in energy consumption and in peak load where cooling is more or less continuous and covers a large part of the house. However, where operation is intermittent and/or limited to one space, it is more likely that an increase in efficiency will lead to somewhat cooler internal conditions but have little effect on peak load.

Given the high incidence of intermittent cooling in the residential sector, it is therefore likely that the reduction in peak demand associated with labelling and MEPS-induced increases in the average efficiency of single-phase air conditioners will be significantly less than the reduction in energy consumption. This would lead to a further reduction in the load factor of the domestic air conditioning load.

Demand Management Responses

Table S1 summarise the characteristics and impacts of the types of measure considered in this study. The most effective approaches to containing peak load are those which act directly on the air conditioner during the peak load period, rather than measures which target the building shell or the energy efficiency of the air conditioner.

The incidence of the peak can be signalled in real time as a change in price, or communicated directly by the electricity retailer or distributor. The decision on whether and how to respond to the peak signal can be left to the user or to the microprocessor controls in the AC itself (in which case the user is generally able to over-ride the response if desired.)

The Table S1 Medium term impacts of measures targeting household and small business air conditioning

Measure		**Impact on buildings targeted**		**Impact on entire air conditioner load**		
		Energy reduction	**Peak load reduction**	**Energy reduction**	**Peak load reduction**	**Load factor**
Improve new building thermal performance only	Avoid AC	V.High	V.High	Medium	Medium	No change
	With AC	Medium	Low	Low	V. Low	Reduce
Improve new AC efficiency only		Medium	Low	Medium	Low	Reduce
Improve building thermal performance and improve AC efficiency		High	Medium	Medium	Medium	Reduce
Time of use pricing only	Customer response	Medium	Low	Medium	Low	Reduce
	Auto AC response	Medium	High	Medium	High	Increase
Direct load control only		Low	High	Low	High	Increase
All measures together		V.High	V.High	V.High	V.High	Increase

There are many possible ways to structure, recruit participants for and operate load control programs, involving a range of financial incentives, communications channels and response options. A given air conditioning unit not be immediately compatible with a given LC approach, for range of technical reasons. If so, the LC operator can either compensate with its own equipment and systems – thereby raising the program cost – or exclude the unit from the LC program , so reducing the potential benefit.

The more standardised the elements of load control systems, the more likely that AC suppliers will ensure that their products are compatible, and hence the lower the overall costs of implementing load control programs.

It is neither necessary nor practical to make every AC unit compatible with every possible approach LC, but there would be considerable benefit in standardising at, say, discrete levels of compatibility, for example:

- Basic load control compatibility: the AC is able to cycle the compressor off without affecting fan operation, can restart automatically, has user over-ride, is equipped for at least one mode of communications (eg power-line signals, internet)

- Advanced load control compatibility: the AC is equipped for at least one mode of communications (eg power-line signals, internet), and is able to optimise operation within a preset kVA limit (say 0.5 kVA for a period of 1 hour), balancing compressor run time and fan operation. Inverter units would be well suited for this.

- Smart meter load control compatibility: as for advanced, plus ability to program responses to real-time price signals received via a smart meter interface.

Increasing the availability and sales of LC-compatible air conditioners would lower the costs of implementing load control programs, but would not of itself compel utilities to offer such programs or motivate consumers to participate. However, introducing LC factors into the AC purchase process would facilitate other potential measures, eg:

- Requiring AC buyers to install smart metering and to go on time of use tariffs;

- Alternatively, including a 'demand management bond' (say $500-$1,000) in the purchase price, to be forwarded to a publicly-administered fund and to be redeemable after a specified period of participation in a utility LC program.

Measures such as these are justified on equity grounds, to ensure that new AC users do not add to the cross-subsidy burden on non-AC users, and on the grounds of increasing the security of electricity supply in a period where one of the highest risks of supply disruption is from air conditioner load. They should also have the benefit of increasing the competitiveness of demand-side responses in the national electricity market, by enabling the cost-effective aggregation and block demand bidding of AC loads.

State government agencies and local government would be well placed to develop and administer programs such as these.

The role of air conditioner technology

It would be feasible to incorporate elements and features into the design of air conditioners specifically to facilitate participation in DM programs. The aim would be to reduce the costs and risks to both DM sponsors and to AC users, so increasing the likelihood that the former will develop and offer AC DM programs, and that the latter will participate.

Customers will be more willing to participate in AC DM programs if:

- They can be assured that interrupted operation will not harm the AC system
- the AC fans continue to operate during interruptions
- the customer can over-ride a load control signal if necessary
- the AC unit responds automatically to price signals or interrupts, without requiring decision-making by the user
- the AC unit can anticipate periods of interruption and perhaps over-cool ahead of time (ie limited time-shifting).

Electricity suppliers (distributors and retailers) will be more willing to implement AC DM programs if:

- they can easily identify AC-owning households and businesses
- they know that the AC units already incorporate the features necessary to facilitate user participation
- the costs of establishing communications and signalling with ACs are low, because standard features built into new ACs contain many of the system elements which suppliers would otherwise have to provide themselves. (This is particularly important for retailer commitment to DM, because retailers are less assured of long-term retention of customers than are distributors).

Clearly, these conditions will not be met without a significant degree of co-ordination and standardisation with regard to:

- The technical specifications for DM communications and signalling;
- The interface between ACs and interval meters (if installed – although the general standards should not presuppose the present of interval metering); and
- The specifications for air conditioner DM response features.

Opportunities to develop a co-ordinated response

Present circumstances are uniquely conducive to the development of standardisation in these areas. One of the contributing factors is the common realisation by all State government energy agencies of the difficulties caused by summer peak demand, and air conditioning in particular. Another is the convergence of State-based electricity regulation, which raises the possibility of the development of a common regulatory approach to DM and LC programs, which would in turn allow a common technical approach.

In December 2003 the Ministerial Council on Energy (MCE) announced a program for major reforms to the Australian energy market to be implemented in the period 2004 to 2006, with the intention of strengthening competition and encouraging investment in the Australian energy market. One of the elements of the package is the establishment of a new Australian Energy Regulator (AER) to be responsible for economic regulation and market rule enforcement.

The primary objective of the AER will be to 'promote the long term interests of consumers of electricity with respect to price, quality and reliability of electricity services and economically efficient investment and innovation. In seeking to achieve this primary objective, the AER will be required to have regard to the following objectives:… [among other matters] the operation and use of, and investment in, infrastructure in the electricity industry (including transmission and distribution services) should be economically efficient'.

As the lack of price signals for air conditioner use is one of the main factors driving investment in transmission and distribution services, and is patently economically inefficient, it would appear that early attention to the matter fits squarely with the AER's objectives. If consistency of approach can be achieved through the NEM as a whole, the scope for cost-effective DM initiatives should greatly increase.

Role of the NAEEEP

The NAEEEP offers a ready made framework for developing standards for air conditioner demand management technologies. The NAEEEP already invokes (via State and Territory legislation) a number of Australian and New Zealand standards for the testing, performance, energy efficiency and labelling of air conditioners, largely based on international ISO standards.

If criteria for DM capability were developed, it would be relatively straightforward to incorporate them into the existing standards. At the very least, AC suppliers could choose to state whether their products were DM-compatible, and buyers who wished to participate in their utility's DM program could identify those products.

The next level of response may be to require disclosure of DM-capability (or possibly the level of capability) on the energy label. A suitable opportunity to do this may be at the introduction of the second stage MEPS for single phase air conditioners in early 2006. Ultimately, meeting a certain minimum level of DM-capability should become a mandatory requirement, like meeting a minimum level of energy-efficiency. A suitable opportunity to do this may be at the introduction of the third stage MEPS for single phase air conditioners in late 2007.

Any mandatory requirements would of course be subject to formal benefit-cost analysis and regulation impact assessment.

Conclusions and Recommendations

The development of a national strategy to directly address the peak load effects of air conditioners is becoming increasingly urgent. Air conditioning use is growing rapidly in homes and small businesses, and could conceivably double within 10 years.

This rate of growth in peak demand from air conditioners is likely to outstrip the countervailing effects of energy efficiency programs, which have a limited, indirect and uncertain effect on peak load, and even of programs which seek to reduce the demand of larger users at times of summer peak demand.

The development of direct load control, more efficient means of signalling prices and other demand management measures targeting air conditioners has been relatively slow because of high supplier costs, differences of approach by State regulators and a lack of technical standardisation.

These barriers can and should be addressed, and a wide range of stakeholders has already indicated their willingness to do so. The Australian Greenhouse Office and the National Appliance and Equipment Energy Efficiency Program can play an important role in the process.

It is recommended that:

1. The Ministerial Council on Energy ensure that the development of uniform Demand Management rules, particularly those concerning load control programs for air conditioners, is placed on the agenda of the new Australian Energy Market Commission (AEMC) and the Australian Energy Regulator (AER).

2. The Ministerial Council on Energy should direct the Energy Efficiency Working Group to convene an Air Conditioner Load Management Task Force to address regulatory, pricing and technological barriers to the development of air conditioner load control.

3. The Task Force should develop a National Demand Management Strategy for Small Airconditioners covering the next 10 years, with the early phase of the plan recognising and working with the existing framework of State-based electricity legislation and regulation, and the latter phase recognising the transition to a national framework.

4. As part of developing the 10-year plan the Task Force should consult with:

    - air conditioner importers, manufacturers and standards bodies
    - electricity distributors and retailers
    - State, Territory and Commonwealth electricity regulators (economic and technical)
    - State and Territory energy agencies
    - State and local government agencies responsible for planning and building.

5. The MCE commission modelling of the costs and benefits of a range of approaches to demand management for small airconditioners (including avoidance of air conditioner installation in new dwellings and promotion of evaporative cooling) using local case studies; and

6. MCE explore ways of funding trails and programs, including use of public sector funds as well as market or consumer levies.

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Contents

Glossary

AC	Air Conditioner: a device that controls the temperature, humidity, cleanliness and flow of air within a building
APEC	Asia-Pacific Economic Cooperation
AREMA	Air Conditioning and Refrigeration Equipment Manufacturers Association of Australia
Cooler	A device that reduces sensible or latent heat, but is not an air conditioner
DM, DSM	Demand Management, or Demand Side Management: the management of the pattern of demand on the electricity system, with the emphasis on time of demand rather than on total energy consumption
ESC	Essential Services Commission (Victoria)
ESCOSA	Essential Services Commission of South Australia
Evaporative cooler	A device that cools by humidifying and directing a flow of air
HERS	Home Energy Rating Scheme: a system of rating the insulation and other aspects of thermal performance of dwellings. Variations include *NatHERS* (national), *ACTHERS* (ACT) and *FirstRate* (Victoria)
kVA	kilovolt-ampere; commonly used rating the instantaneous load that electrical equipment places on the supply system. The power rating of a device in kW is the product of the kVA rating and the power factor. Electricity supply almost always deviates from the ideal power factor of 1, due to the characteristics of the end user devices connected to the supply system
LC, DLC	Load Control, Direct Load Control: direct intervention in a specified load or group of loads to remove or reduce their demand on the electricity system at the time when the LC intervention is exercised
MCE	Ministerial Council on Energy
MEPS	Minimum Energy Performance Standards
NAEEEC	National Appliance and Equipment Energy Efficiency Committee
NAEEEP	National Appliance and Equipment Energy Efficiency Program
NEM	National Electricity Market - covers all of Australia except WA and NT
SEAV	Sustainable Energy Authority of Victoria
single phase supply	A two-wire supply having one wire connected to a phase conductor and the other to the neutral conductor of a three phase system. In Australia the single phase supply voltage is 230 V
three phase supply	A system of supply having three related voltages with phase differences of one third of a cycle. In Australia the three phase supply voltage is 400 V

1. Background

1.1 Air Conditioner Sales and Ownership

Categories of air conditioning

'Air conditioning' generally means the close control of the temperature, humidity, cleanliness and circulation of air in the interior of a building. This definition excludes evaporative cooling, where temperature and humidity are not independently controlled. However, evaporative coolers compete with air conditioners for the cooling market in some parts of Australia, and will also covered to some extent in this paper.

It is possible to segment the air conditioner market in a number of ways, including:

- By type and capacity of equipment: there is a natural divide between the categories of product subject to energy labelling and MEPS – 'packaged' (ie factory-made) refrigerative units up to 65 kW cooling capacity – and other types, including larger packaged units and purpose-built systems using cooling towers;

- By sector of end use: residential, commercial and other. 'Commercial' generally covers retail, office, educational, health, catering, accommodation, recreation and other non-residential facilities, with many different typical building types and hours of occupancy, and hence different daily and seasonal patterns of air conditioning use;

- By the tariff, metering and control arrangements under which electricity is supplied to the air conditioner – whether the tariff is energy only or time of use, whether there are provisions for load interruption or load control, and if so the respective roles of the user, the electricity supplier and the air conditioner itself in responses to price and control signals.

In general, air conditioners installed in dwellings are smaller (up to about 10 kW cooling capacity, about the maximum for single-phase supply) and metered under energy-only tariffs, whereas those installed in commercial buildings tend to use three-phase supply and are often metered under time of use tariffs.

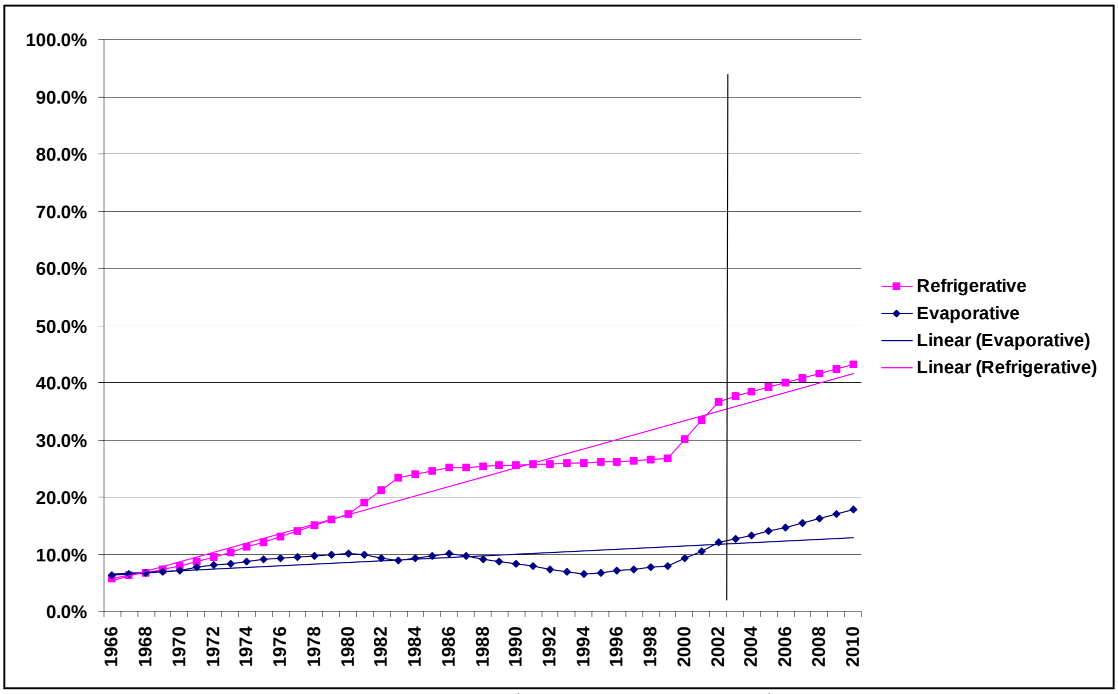
Air conditioners are also sometimes categorised by whether they are capable of heating as well as cooling ('reverse cycle'), whether the unit discharges air into ducts or directly into the spaces being served and by the physical arrangement of components such as compressors, condensers, evaporators and fans. These may be in a single unit ('window-wall') or 'split' between several units (see Table 1). Although such categories are often the main focus of ABS and other statistics, they are secondary for the purposes of this paper, since they have little impact on peak demand in cooling mode or on demand response strategies. In this respect the critical characteristic of an air conditioner is the demand it places on the system at the time of peak load. In the residential sector this is typically in the range 3 to 4 kVA for smaller units and up 6 to 8 kVA for larger whole-house units (IE 2003). This compares with less than 1 kVA for even a large evaporative cooler.

Ownership

The use of air conditioning is growing rapidly in Australia, especially in residential and small commercial buildings. While there is some uncertainty about the penetration rate of household air conditioning, there is little doubt that it has been increasing, and that the rate of growth has accelerated sharply in the past few years.[1] Some of the uncertainty in the statistics stems from a failure to distinguish between air conditioning and evaporative cooling, and from what appear to be anomalous ABS data for 1999.[2]

It is estimated that in 2004 the penetration of household air conditioning in Australia as a whole was about 38%, and that it will continue to increase as shown in Figure 1. The rapid increase between 1999 and 2002 is partly a real effect, consistent with an observed growth in sales, and partly an artefact of an apparent data anomaly for 1999. The penetration of evaporative cooling in 2004 was about 13%.

Figure 1 Share of Australian households with air conditioning or evaporative cooling – historical and projected



Source: EES (Private communication)

The States and Territories have different levels of penetration, largely because of their differing climates (Figure 2, Figure 3). The hotter, dryer states (SA, WA and Victoria) have high levels of ownership for both air conditioners and evaporative coolers, whereas the more humid States (NSW and Queensland) have lower air conditioner

[1] The penetration rate is the proportion of households possessing at least one unit of that appliance, and cannot be higher than 100%. The ownership rate is the average number of appliances held by owning households, and cannot be lower than 1.

[2] The latest ABS State and Territory data on air conditioner ownership in the residential sector, covering the years 1994, 1999 and 2002, come from ABS publication series 4602.0 *Environmental Issues*. The 1999 data indicate an actual decline in penetration rates in some States between 1994 and 1999, which is unlikely. However, the 2002 data appear to be more consistent with the longer term growth trend.

penetration and very low levels of evaporative cooler use. Air conditioner penetration is projected to increase in all States except SA, where it may be near saturation.

Figure 2 Share of State and Territory households with air conditioning – historical and projected

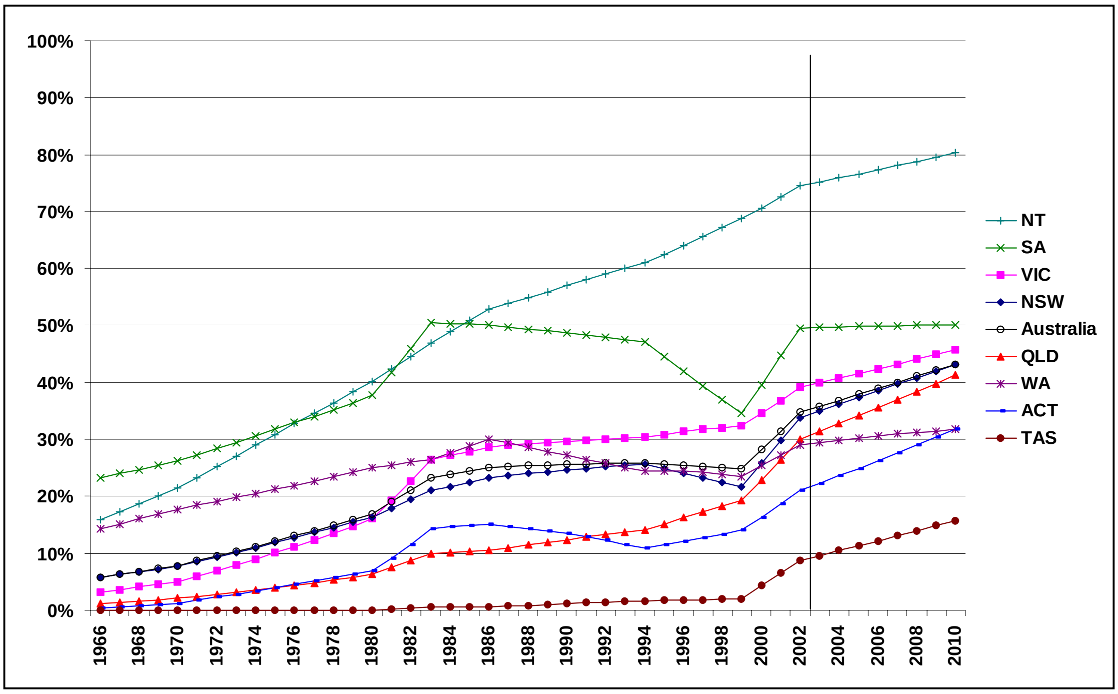
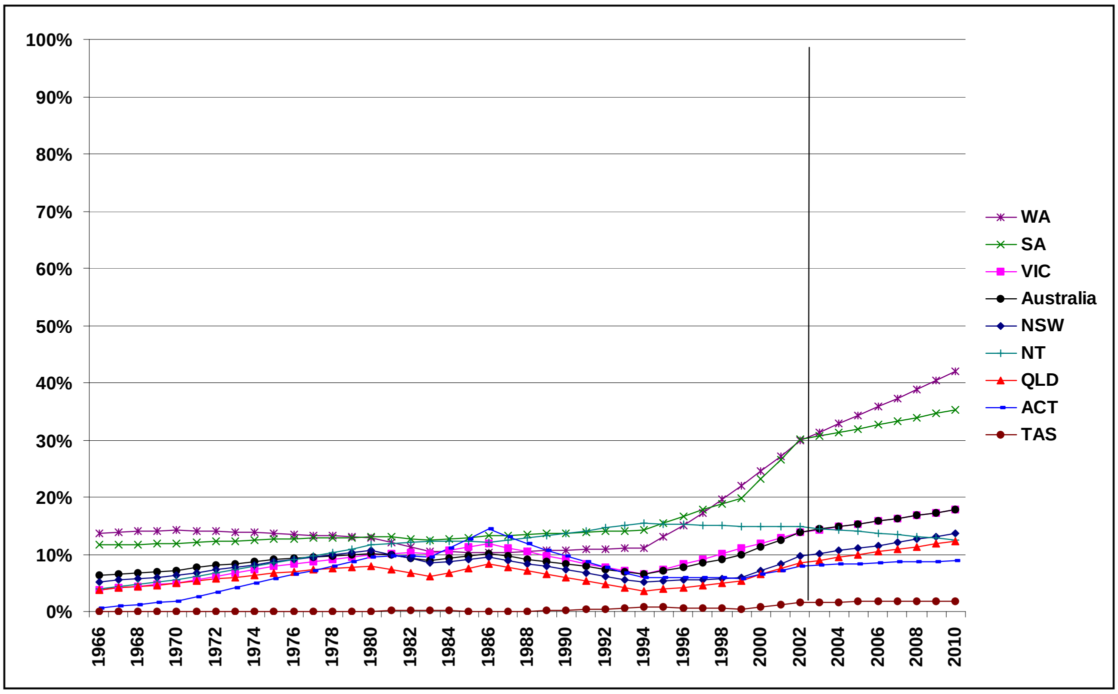


Figure 3 Share of State and Territory households with evaporative cooling – historical and projected



Sales

Australia-wide air conditioners were about 898,000 units in 2001 before dropping back to 762,000 units in 2002. Sales in 2004 are projected to be 933,000 (BIS 2002). Large variations in annual sales are not uncommon. Air conditioners have been to some extent seasonal and impulse purchases, and if the early part of the summer is cool then sales for that year tend to be lower.

However, there are signs that the dynamics of the market are changing permanently, for the following reasons:

- Rising household incomes and expectations of thermal comfort.
- Falling real air conditioner prices.
- Decades of promotion of air conditioners by some electricity utilities as a counter to gas heating
- Increasing noise, air pollution and crime problems in inner city areas, making it less attractive to open windows and rely on natural ventilation.
- The increasing tendency for project home builders to install air conditioning (or to provide a 3-phase power outlet to facilitate later installation) as a marketing edge.
- The combination of declining block sizes and increasing floor areas is reducing the scope to optimise orientation and to retain mature tree cover in new subdivisions. This increases the proportion of new houses that rely on air conditioning for summer comfort because they are poorly orientated and shaded, even if they have reasonable levels of insulation.
- The increasing number of high rise apartments, many with poorly shaded and/or west-facing glazing, and less able to rely on natural ventilation and openable windows due to their layout, safety concerns or wind velocity and exposure problems.

Given these drivers it is little wonder that an increasing proportion of existing dwellings are acquiring air conditioning, and more new houses are being equipped with air conditioning at the time of construction – especially as the capital cost can be rolled into the mortgage, and the real costs of peak demand to the electricity system are hidden.

Potential for increasing household use of air conditioning

Increasing ownership is not the only driver for increasing use of air conditioning. All else being equal, AC use will also increase if dwellings are larger, if more rooms are air conditioned and if the frequency and duration of use increase.

Table 1 summarises recent survey data for South Australia, which has the second highest penetration rate of air conditioners in Australia (after the NT) and the equal highest penetration of evaporative coolers (with WA). Apart from ownership and penetration, the survey also asked about the number of rooms served, hours of operation and preferred temperature settings, which makes it a useful complement to ABS surveys, which generally concentrate on ownership only. About 89% of SA household possess an air conditioner or an evaporative cooler, and those households own an average of 1.06 units each. About 71% of the units are air conditioners and the rest evaporative coolers.

Table 1 Air conditioner and evaporative cooler ownership, SA 2004

Type		**% of HH with type**	**Average rooms served**
Window/wall	Reverse cycle	31%	2.8
	Cooling only	13%	2.2
Split	Reverse cycle	12%	3.2
	Cooling only	1%	3.5
Ducted	Reverse cycle	11%	5.7
	Cooling only	0%	0.0
All air conditioners	**Reverse cycle**	**53%**	**3.4**
	Cooling only	**14%**	**2.2**
Evaporative coolers	Ducted	22%	5.5
	Fixed	4%	3.4
	Portable	2%	1.8
All evaporative coolers	**All types**	**28%**	**4.9**
Total, air conditioners and evaporative coolers		**94%**	NA
Households with at least one air conditioners or evaporative cooler		**89%**	NA
Average number of units per owning HH		**1.06**	NA

Source: MTR (2004): Data for Adelaide, but assumed to be representative of state as a whole

A single window-wall air conditioner or single split systems can only fully serve one space, although it can partly cool other spaces via open doors or common walls. Full multi-room air conditioning requires outlets in each room, achievable with a ‘multi-split’ configuration (one central condenser unit serving several evaporator units) or with air-ducted systems. Between 1998 and 2003, the window-wall market share of air conditioners halved, from about 44% to 22%, and the share of split and ducted types, better suited for multi-room air conditioning, increased in proportion.

About 16% of air conditioners in SA are ducted and, suprisingly, so are nearly 80% of evaporative coolers. Users report that non-ducted units typically serve 2 to 3 rooms, whereas ducted systems serve 5 to 6 rooms (Table 1).[3] The average number of rooms served per SA household with air conditioning is 3.2, whereas the average per household with evaporative cooling is 4.9. This suggests that there is still considerable scope for growth in the use of air conditioning, even in one of the most saturated markets in Australia, through the increase in the number of rooms served. It is possible that the evaporative cooling average of 4.9 rooms represents the potential demand for space cooling.

As the purchase price and running cost premium of air conditioners over evaporative coolers declines, the takeup of air conditioning may well will increase further. It also illustrates the size of the evaporative cooler market that may be vulnerable to air

[3] It is not clear whether respondents interpreted ‘rooms’ to mean open living areas (eg a space combining living, dining and cooking functions could be counted by some as 3 rooms) or rooms joined by doorways.

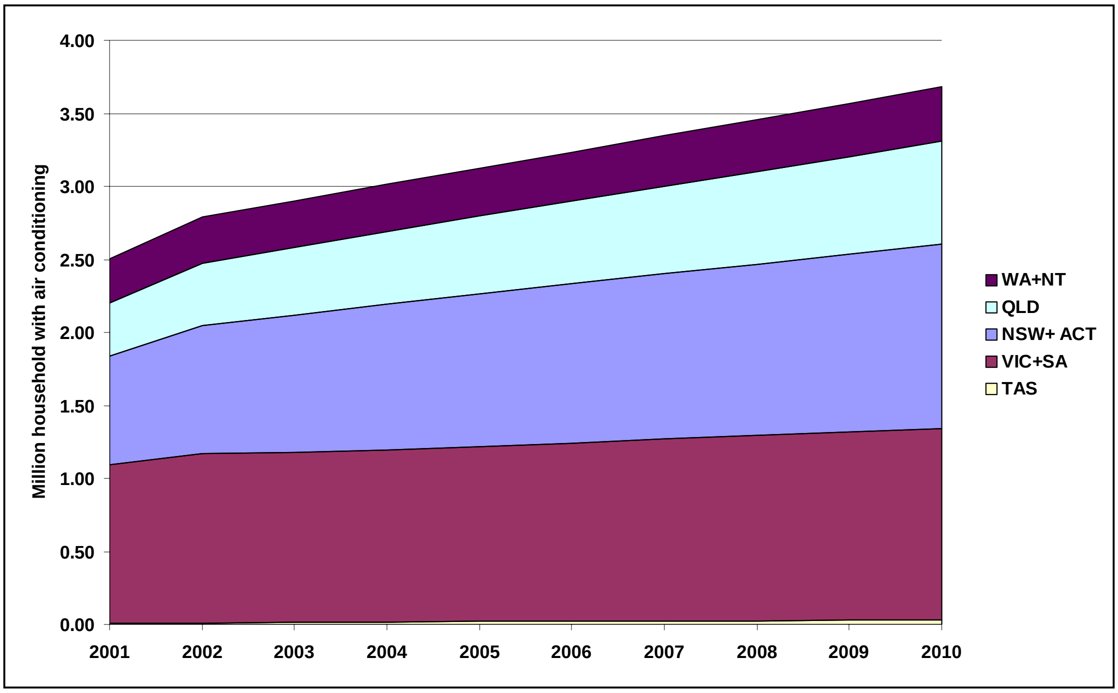
conditioning, especially if the electricity supply costs of air conditioning continue to be subsidised.

Other factors contributing to growing air conditioner use are increasing average dwelling sizes, and the probability that global warming will increase the frequency of very hot days in summer. SA respondents report using their air conditioners an average of 11.5 days month during summer at present, so there is significant scope for increasing frequency of use.

The projected increase in air conditioner penetration illustrated in Figure 2, combined with projected growth in the number of households, would lead to a 22% increase in the number of Australian households with air conditioning between 2004 and 2010, from about 3.01 million to about 3.68 million (Figure 4). However, with increased dwelling area served and increased frequency and duration of use, the total growth in AC demand could be much higher, and could conceivably double over the coming decade.

It is rare for changes in patterns of appliance use to occur so rapidly, but it is apparent that such a change is already under way in air conditioning, and that it could accelerate. Even if annual sales stabilise at around 625,000 (the average of the last 3 years), some 3.8 million units will be sold from 2005 to 2010 inclusive. In other words, the great majority of air conditioners that will be in use in 2010 are still to be purchased, and so could be affected by policies and programs targeting energy and peak load.

Figure 4 Projected number of air conditioners installed in dwellings, by National Electricity Market demand region, 2001 - 2010



1.2 Energy and Peak Load

Historically, air conditioning has accounted for a relatively small proportion of residential sector energy use (as distinct from peak demand), but a large proportion of commercial sector energy.

It is estimated that in 1999, the latest year for which a complete analysis has been carried out, ACs accounted for about 1.9% of household delivered energy, and 4.2% of household delivered electricity (Appendix 1). AC penetration has increased significantly since 1999 (Figure 1), so they could now account for 5% to 6% of household energy.

It is estimated that cooling and air handling accounted for about 32% of commercial sector energy use, and 45% of commercial sector electricity in 1999 (see Appendix 2 - packaged air conditioners accounted for about 10% of sector electricity and larger cooling tower units and air handling systems for about 35%).

Table 2 indicates the estimated contribution to NSW electricity system peak load from residential and commercial air conditioning in 2002/03. The winter peak day load on the system was 12,156 MW at 6 pm, with a secondary morning peak of 10,174 MW the same day. The summer peak load was 12,456 MW at 4 pm, and close to that level by 2 pm. The times indicate that the winter peak was driven by a combination of meal preparation and space heating, but the summer peak was dominated by cooling:

- Commercial sector cooling demand on the summer peak day was over 1,000 MW, accounting for about 32% of commercial sector demand, and over 8% of total system demand

- Residential sector cooling demand was almost as great (980 MW), accounting for about 39% of residential sector demand, and nearly 8% of total system demand.

- Cooling accounted for at least 16% of system peak demand and probably more, since there would also have been significant air conditioner use in the industrial sector, which is more difficult to identify.

Table 2 Estimated air conditioning contribution to NSW peak demand

Sector		**Winter peak day (18 June 2002)**				**Summer peak day (30 January 2003)**			
		08:30		18:00		14:00		16:00	
		MW	% system total	MW	% system total	MW	% system total	MW	% system total
Commercial	Cooling	114	1.1%	72	0.6%	1007	8.2%	1017	8.2%
	Other	2381	23.4%	1951	16.0%	2158	17.5%	2200	17.7%
Residential	Cooling	0	0.0%	0	0.0%	607	4.9%	980	7.9%
	RC heat	155	1.5%	264	2.2%	0	0.0%	0	0.0%
	Res heat	524	5.2%	495	4.1%	0	0.0%	0	0.0%
	Other	2310	22.7%	2930	24.1%	1650	13.4%	1522	12.2%
Other sectors		4690	46.1%	6444	53.0%	6894	56.0%	6737	54.1%
System total		**10174**	**100.0%**	**12156**	**100.0%**	**12316**	**100.0%**	**12456**	**100.0%**
Cooling/System total		114	1.1%	72	0.6%	1614	13.1%	1997	16.0%
Air Cond/System total		269	2.6%	336	2.8%	1614	13.1%	1997	16.0%
Cooling/Comm+Res			2.1%		1.3%		29.8%		34.9%

Source: derived by author from EMET (2004)

From the viewpoint of electricity supply, the air conditioner share of peak demand in the commercial sector is comparable to the energy share on an annual basis, so the 'load factor' of the air conditioning load is similar to that of other electric uses in the commercial sector (although the peak cooling segment of the air conditioner load has a lower load factor).

In the residential sector however, air conditioners contribute only 5 to 6% of energy but nearly 40% of peak day demand – in other words they have a very low load factor. This makes the residential air conditioning load very costly for the electricity supply system. Colebourne (2003) makes the following points with regard to the residential air conditioner load served by the EnergyAustralia (EA) network (covering most of Sydney, the NSW Central Coast, Newcastle and the Hunter Valley):

- The load factor of domestic air conditioners is only about 7%;
- On hot days the average demand of air conditioned dwellings more than doubles, at a time when network capacity is lower;
- Residential customers with air conditioners consume 40% more energy than average non-air conditioner customers, but contribute 200-250% more to the peak on summer days;
- It is estimated that every air-conditioned household received an annual cross-subsidy of $86 from non-air conditioner households (equivalent to $70 per non-air conditioner household, for a total annual cross-subsidy of over $50 M).

The peak load contribution of household AC is proportionally even higher in the Integral Energy (IE) network area, which serves western Sydney, the Blue Mountains and Wollongong, and the resulting cross-subsidy from non-AC users to AC users is estimated at $80-110 M per year (IE 2003).

The situation in other States is similar. An analysis of the relationship between system load curves and temperature in Victoria found that air conditioning is an even higher contributor to system peak demand, with state system peak loads on hot days up to 40% higher than on non-cooling days (Shevlin 2004). VENCorp projects a 2600 MW increase in temperature-sensitive summer load between 2001 and 2011 (Page 2004).

Taking the IE and EA figures as a guide, the total cross-subsidy from the 4.1 million non-AC households in the national electricity market (NEM) area to the 2.7 million AC-owning households could be in the range $300-500 M annually. Apart from the equity implications, this underpricing of the costs of supply to ACs is a serious distortion in the economics of the NEM, as is apparent from the National Electricity Market Management Company (NEMMCO) *Statement of Opportunities* (NEMMCO 2004).

Table 3 summaries the projected growth in energy and demand in the main NEM regions. Peak demand growth is projected to significantly exceed energy growth in the regions with the highest penetration of household air conditioning - NSW, Victoria and SA. Although the Statement of Opportunities does not analyse end uses, it is obvious from the deteriorating load factor and growing temperature-sensitivity of demand projected for the largest AC markets that air conditioning will account for a growing share of the summer peak day system peak, and so drive network capital expenditures.

In the larger commercial sector, air conditioning is widespread and the load factor is similar to other sector loads, so the costs of meeting the peak are spread reasonably widely in terms of time and customer base. The prevalence of time of use metering in the sector means that consumers with higher air conditioning demand make a greater contribution to the system cost. In the residential sector however the AC load factor is low and time of use metering is virtually absent, so the costs of meeting the peak represent a major cross-subsidy from non-AC users to users.[4]

Table 3 Projected energy and demand factors in National Energy Market regions

National Electricity Market region	Projected 10-yr annual growth rates		Projected summer max demand 2004/05 MW				Committed Demand Management	
	Energy	Demand	Average	Peak day	Diff	Diff/avg	MW	% of Diff
Queensland	3.1%	2.9%	8187	8503	316	3.9%	157	50%
NSW	2.2%	2.9%	12660	13430	770	6.1%	14	18%
Victoria (a)	1.9%	2.9%	12023	13081	1058	8.8%	163	15%
SA (a)	1.5%	2.9%						
Tasmania	1.6%	1.6%	1457	1476	19	1.3%	0	0%

Source: NEMMCO (2004) (a) These regions are combined for peak demand projection purposes

1.3 Recent developments

The increasing contribution of air conditioning to energy consumption, and especially to peak loads, has received considerable attention in Australia in the past few years, from governments, from the managers of energy efficiency programs, from electricity suppliers and from electricity market regulators.

There are moves to improve the thermal performance of buildings and the energy efficiency of air conditioners themselves. From the viewpoint of peak demand these are indirect measures, since they address energy consumption rather than peak load directly. However there is an expectation they would have some impact on the general need for cooling to maintain thermal comfort, on the tendency to install air conditioning and on the peak day demand for cooling where air conditioning is installed.

The issues have also received increasing attention from electricity suppliers and electricity distribution regulators, who have grappled with the impact of air conditioning on capital investment, on how to limit that impact by demand management (DM) measures and on ways to fund DM programs and capital investment. There have been a number of investigations of the most direct approach of all – direct load control by the utility to cycle air conditioners or switch them off entirely during peak periods.

Building thermal performance

[4] The situation would be less inequitable if all household consumers had AC. Even if other household uses of electricity continued to cross-subsidise ACs, all households would be recipients as well as donors of the cross-subsidy so the net effect would be neutral. However the use of AC is still confined to a minority of households (in most States) so there is a transfer from one group of households to another..

There are three typical modes of air conditioning:

(a) Continuous whole-building air conditioning during business hours. This is the typical mode in the commercial sector. Operation tends to commence early on work days (often after night-time pre-cooling with outside air) and is continuous throughout the day, so that when the peak heat load comes in the early afternoon the building fabric is already at temperature;

(b) Intermittent peak day air conditioning. This is typical of residential sector. The air conditioner only cools one or two rooms and is activated on hot afternoons when the occupants return home, and so must operates at maximum capacity for several hours to deal with the heat load of the building fabric as well as cool the air;

(c) An intermediate mode of whole house and/or extended period air conditioning, where air conditioner use is more regular and becomes continuous during heat wave conditions (ie runs of hot days).

In mode (a) there is a strong link between building thermal performance and air conditioning demand. If the rates of heat gain through the building envelope and from occupants and internal equipment are reduced (eg by better glazing and insulation and more energy efficient lighting), the demand for cooling will fall more or less in proportion. Provided the air conditioning plant is correctly sized and the controls are responsive, the cooling energy and the peak demand should fall as the building thermal performance improves.

In mode (b) however the link between thermal performance and air conditioning demand is relatively weak, so improvements in shading, orientation and insulation will have only limited impact in air conditioner energy consumption and even less impact on peak load. Most air conditioners will be probably be operating at full capacity during peak periods anyway, although they may be able to achieve more comfortable internal conditions and reduce output more rapidly after the peak period in buildings with better shading and orientation.

The most effective contribution of higher building thermal performance standards to reducing the cost of domestic air conditioning would be through reducing the takeup of air conditioners, by increasing summer thermal comfort in dwellings to the point where air conditioning is not required. However, there is no evidence that previous initiatives to improve thermal performance have had this effect. The rate of increase in domestic air conditioner ownership since 1990 has been no lower in those States and Territories which adopted mandatory insulation or building performance standards than in those which did not.

Victoria adopted mandatory ceiling and wall insulation standards for new dwellings in 1992, with the result that the average energy efficiency of new housing was equivalent to about 2.2 stars on the Victorian Home Energy Rating System (VicHERS) scale (EES 2000). There was no noticeable impact on the rate of increase in air conditioner ownership (Figure 2).

These requirements were recently strengthened. Since July 2004, new dwellings in Victoria must achieve a rating of at least 4 stars on SEAV's *FirstRate* rating program, and from July 2005 a rating of at least 5 stars. The introduction of a 5 star minimum requirement is expected to reduce the demand for space heating in new dwellings by around 40% compared with the BAU case (EES 2000). The reduction in the theoretical demand for cooling may be comparable, but much of this demand is unmet because householders do not have air conditioners or, if they do, operate them less than assumed in the *FirstRate* model.

It is projected that the internal temperature of a 5-star house will stabilise at about 23ºC at an external temperature of 35ºC, whereas a 2 star home would reach 37ºC (APEC 2004). If so, air conditioning would be unnecessary. However, if an air conditioner is installed, as a selling point by the developer or as the main means of space heating (as is increasingly common where natural gas is unavailable) then it is near certain that it will be used for cooling at least on the hottest days, whether or not internal temperature stabilises as modelled. The key to realising the potential cooling energy and peak load savings from 5-star houses therefore lies in discouraging the installation of air conditioners.

The ACT has had thermal performance requirements for as long as Victoria. Mandatory insulation of walls and other inaccessible voids in new dwellings was initiated in 1992 and a mandatory ACTHERS rating of 4 stars for new dwellings in 1996, all without appreciable impact on the rate of increase in air conditioner penetration.

More recently, South Australia adopted a mandatory 4 star minimum rating for new dwellings constructed from 1 January 2003, and is considering increasing this to 5 stars from January 2005. In mid 2004 NSW introduced the BASIX scoring system for new dwellings. Applicants for building approval must meet a minimum points score for energy, water efficiency and overall. Building designs can obtain points towards their minimum energy-efficiency score through a range of measures, including glazing, orientation and shading to reduce cooling demand.

Where an air conditioner is installed and intermittent operation remains the typical mode of use, increasing thermal performance standards are likely to reduce cooling energy consumption more than cooling peak demand. Ironically, this would *reduce* the load factor of domestic air conditioning and exacerbate cross-subsidy and equity issues. However, while the encouragement of whole-house or longer-period air conditioning would improve load factor, it would also increase total electricity energy consumption and greenhouse gas emissions.

One final constraint on the ability of domestic building codes to affect the demand for air conditioning is the slow rate of change in the building stock. Well over 90% of the housing that will be in use in 2010 has already been built. By contrast, over 90% of the air conditioners that will be in use in 2010 are still to be made.

Energy labelling and MEPS

Another approach to reducing energy consumption for air conditioning, with some benefits for peak demand, is to increase the average energy-efficiency of the air conditioner stock compared with Business as Usual (BAU). This has been the focus of the mandatory energy labelling and Minimum Energy Performance Standards (MEPS) programs for air conditioner, which are now part of the NAEEEP.

Mandatory energy labelling of window-wall and split air conditioners with cooling capacities up to 7.5 kW was introduced in 1987. The star ratings on the label are based on the cooling EER and, for reverse cycle units, there is a separate star rating scale for the heating COP.[5] The label originally indicated the energy consumed for 500 hours operation at full load: eg a unit with a cooling output of 4.5 kW and an EER of 2.1 would consume 4.5/2.1 = 2.14 kW when operating at full load, or 1071 kWh over 500 hours.

The following changes have been made to the energy label in recent years:

- The criterion for mandatory labelling was changed to all units taking single-phase electricity supply: this change clarified the scope of units to which MEPS would apply (see below);

- The star rating scale was revised to show fewer stars for the same COP; and

- Because of the great variation in patterns of use, the 500 hr energy value was replaced with a 'kWh per hour at full load' value: eg the label for the example model used above would now indicate '2.14 kWh per hour' rather than '1071 kWh for 500 hrs'.

In October 2001, MEPS came into effect for most configurations of air conditioners taking three-phase electricity supply and with up to 65 kW cooling capacity.[6] Suppliers also have the option of labelling three phase air conditioners, in which case the same labelling requirements apply as for single-phase units.

In 2002 NAEEEC announced proposals to:

- make the MEPS levels for 3-phase air conditioners more stringent, with the new levels, based on those which took effect in the USA in 2003, to take effect from 2007; and

- implement MEPS for single-phase air conditioners in two stages, to take effect in 2004 and 2007 respectively (NAEEEC 2002). The second stage MEPS are based on those which took effect in Taiwan in 2001. In June 2004 the Air Conditioning and Refrigeration Equipment Manufacturers Association of Australia (AREMA) agreed to bring forward the implementation of the second stage form October 2007 to April 2006 (APEC 2004). A further proposal for a third stage increment in 2007 is currently being discussed. This would bring local MEPS levels up to the Korean level, which is world's best regulatory practice for single phase ACS.

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[5] The energy efficiency of an airconditioner is indicated by its Energy Efficiency Ratio (EER) in cooling mode and Coefficient of Performance (COP) in heating mode under standard heating conditions. The higher the COP or EER value, the more energy-efficient the unit. (In Australia, both COP and EER are expressed in Watts per Watt, but the USA and parts of Asia use different units like BTUs per Watt or KJ per Watt so great care is required when making international comparisons).

[6] MEPS covers those units with a single outdoor unit (one or more compressors) and one or more indoor units, and with a single indoor control. This includes packaged units, packaged ducted units, and single, double and triple split systems. It does not cover multi-split systems or portable systems without an exhaust duct.

As at mid 2004, only about 14% of the single-phase AC models on the Australian market would meet the 2007 MEPS levels (Table 4). The average EER of window/wall models was 2.44. From April 2006 no model will be able to be sold unless its EER is at least 2.75. The efficiency increment required for split units will be less, but still appreciable.

Table 4 Proposed cooling MEPS levels, single-phase air conditioners

Configuration	Average EER, mid 2004 (a)	Proposed MEPS from April 2006	Number of models, mid 2004	Number meeting 2006 MEPS	% models meeting 2006 MEPS
Window/wall	2.44	2.75	219	13	6%
Split type – cooling capacity <= 4 kW	3.00	3.05	557	54	10%
Split type – cooling capacity > 4 kW	2.61	2.75	1332	227	17%
All of above			2108	294	14%

(a) EER on cooling for reverse cycle units

It requires detailed information on model sales and an assumption about the BAU trend in energy efficiency to estimate the increase in sales-weighted EER which MEPS will bring about. The draft RIS (Syneca 2003) estimates that the sales-weighted EER for single phase units will be about 13 to 14% higher with MEPS than it would have been without.

However, the reduction in actual energy use compared with BAU may well be lower than 13 to 14%. If a given model falls short of the required EER, the supplier can redesign it to increase the cooling output for the same energy input, reduce the energy input for the same output, or somewhere in between. Given that the redesign effort and material costs are likely to be about the same, the rational commercial response is to increase cooling output for the same input, since AC marketing always emphasises (and often exaggerates) output. The higher the cooling capacity for a given model, the greater its value in the market, and particularly so for units whose electricity demand is at the limits of single phase supply. It is highly likely that suppliers will maximise cooling output without reducing electricity consumption, so the average cooling output of model sold will rise.

A MEPS-induced increase in efficiency, whether achieved as higher cooling capacity or lower motor power, should translate into a reduction in energy consumption where cooling is more or less continuous (ie mode (a) in the preceding section). This should also have benefits for peak demand, since even if the motor power is the same, the more efficient air conditioner will cycle more often during the peak period.[7]

However, where cooling is intermittent (mode (b), typical of the residential sector), it is more likely that a MEPS-induced increase in efficiency will lead to somewhat cooler internal conditions at the peak, since the cooling output will be higher, but have little effect on the peak, since the motor power would be the same as without MEPS.

[7] Inverter units, which are becoming more popular, are well suited to such part load operation. Single-speed compressors can only cycle on or off, and operating efficiency may be lower at part cooling load than at full load. At present energy label ratings and MEPS compliance are determined on the basis of a full load test only.

Given the high incidence of intermittent cooling in the residential sector, it is therefore likely that the reduction in peak demand associated with MEPS-induced increases in the average efficiency of single-phase air conditioners will be significantly less than the reduction in energy consumption. This would lead to a further reduction in the load factor of the domestic air conditioning load.

2. Demand Management

2.1 The principles

Managing the demand on the electricity system at times of heavy or peak load is the most direct way to address the air conditioner peak load issue. While improving thermal performance in buildings and increasing the energy-efficiency of air conditioners will have some impact on AC conditioner peak demand, the magnitude is difficult to predict, and will fall away sharply at the times of critical peak demand, when it is needed the most.

The demand management (DM) of domestic air conditioners is not a straightforward matter, since it potentially involves millions of dispersed decision-makers and AC units. For this reason electricity utilities have concentrated their DM efforts on larger industrial and commercial users, who can take large blocks of load off line or switch to back-up generation on request or in response to electricity price signals.

Many electricity suppliers in the USA have implemented successful DM programs for large users, often at the direction of their State public utilities commissions (eg Smith et al 2004). To recruit large users to participate in such programs it is necessary to offer a financial benefit that exceeds the cost in lost production, reduced amenity (eg through temporary shut-down of large central air conditioners), the costs of operating standby plant and the additional wear and tear of plant restarts after interruptions.

Almost all large electricity users purchase under contracts with time of use and/or peak demand pricing features, so it is relatively straightforward to determine their load profile and the value of load withdrawals. Also, there is usually a range of communications channels available – from telephone to wireless to internet-based systems – by which the utilities can signal impending peak load events and interruptions, customers can signal their intention to participate or not (if the agreement allows them a choice) and utilities can monitor customer behaviour.

Depending on the structure of the wholesale market, it is possible for very large electricity users to bid demand reductions directly into the pool, in the same way as generators bid increments of energy. However, in Australia the magnitude of committed demand management in the largest AC markets (NSW, Victoria and SA) only covers 15 to 18% of the air-conditioner-induced load increment on peak summer days (Table 3).

Even though there is probably scope to increase large DM resources in Australia, it is likely that the peak demand from smaller ACs will grow more rapidly than those DM resources can be developed. Therefore there appears to be no alternative but to address the peak load of domestic and small business air conditioners directly.

In the USA, several DM programs have been developed and trialed for smaller customers, with mixed success. The essential building blocks of such programs are:

- A financial incentive to users to participate: this may be in the form of annual payments, payments per interruption episode, the prospect of lower electricity bills or the threat of higher ones for non-participants. The incentive must obviously be high enough to ensure a useful level of participation, but not so high that the cost to the program sponsor outweigh the benefits. It is also common for utilities to reduce the risk to participants by offering over-ride or opt-out provisions - eg users can manually restart their air conditioner in the event that it is cycled off, but lose some financial benefit - but these can greatly reduce the program's effectiveness.

- Means for the energy supplier to communicate with the user when a peak load event is impending, and to communicate which of the previously agreed responses will be or should be invoked.

- A range of pre-agreed decision points and response options: for air conditioning these include complete interruption, cycling (eg limiting operation to 10 minutes out of every 30 during the peak event) or an increase in internal temperature settings. The choice of action could be left to the customer, signalled directly to the electrical circuits supplying the AC equipment (and perhaps other interruptible loads such as pool pumps and water heaters) or communicated directly to the AC equipment itself. The benefit of signalling directly with AC equipment is that fan operation (typically powered by a 0.1 – 0.3 kW motors) can continue even while the compressor motor (typically 1.5 – 3.0 kW) is off. For more advanced air conditioners, especially those with DC motors ('inverter' models) the optimum response could be left to the machine itself. For example, it could be programmed to optimise cooling while limiting total power to 0.5 kW during periods when it detects a 'critical price' signal from the supplier.

- The participation of the regulator. Given that electricity prices, metering and continuity of supply to residential and smaller business consumers is subject to regulatory control in every jurisdiction (in Australia as in the USA), as is the mode of recovery of network costs and DM program costs, the approval of the regulator is essential.

There is no lack of alternative models for the design of DM programs targeting domestic AC use, and many have been trialed, with mixed success (eg Agnew et al (2004) Masiello et al (2004)). While it is useful to test different approaches during program development, it is arguable that too much diversity at the implementation stage is less helpful, especially in relatively small electricity markets such as Australia.

2.2 The situation in Australia

Utility trials

Some Australian utilities have carried out trials of direct load control for ACs. In 2001/02 Integral Energy, the distributor serving western Sydney, conducted a trial of interruptible tariffs jointly with the NSW Sustainable Energy Development Authority (SEDA).

Customers in the target area were offered a financial incentive to participate, subject to their air conditioners having an auto restart capability. Two communication systems were trialed: a pager system, and frequency injection. A controller and 'smart' meter was installed at the customer's switchboard. The duration of interruption was limited to 30 minutes, but the interrupt also affected the fan.

The trial was successful at the technical level, for both methods of communication, but the economic benefit to the utility was not clearly demonstrated. In particular, the administrative costs were high. These could be reduced if there were direct linkage to the metering and billing system (BES 2003).

Regulator Actions

The state electricity regulators have recognised, with increasing urgency, the need to address peak load investment in general and the role of air conditioning in particular. They have focussed on:

- Encouraging and sometimes requiring distributors to investigate DM opportunities before receiving regulatory approval for network extension or enhancement.

- Ensuring that distributors and retailers have an incentive to implement DM programs, or at least no disincentive, and ensuring that each party can capture sufficient share of the value of any benefit to make its participation cost-effective.

- In the case of Victoria, mandating the roll-out of interval metering for smaller users in order to, among other things, provide a platform and a framework for DM programs targeted to small users.

However, there is no uniformity of approach to this issue among the different state regulators in the NEM. One major point of difference is whether clearer electricity price signals alone would motivate suppliers to offer, and customers to take up, DM opportunities, or whether the emphasis should be on direct load control. A recent report by the Essential Services Commission of SA states:

> 'From a distribution perspective, specific difficulties posed by demand management options include the following:
>
> - In order to defer augmentation costs, the demand management initiatives under consideration must be able to guarantee the load reduction at peak times. This requirement can particularly act against pricing based strategies where consumer behaviour is unpredictable (especially over long hot spells). Thus direct control of loads by a distributor appears to be one of the essential features of any demand management scheme that is designed to defer network augmentation costs. The rollout of interval meters (by themselves) does not guarantee any load reduction during peak load periods.
>
> - Network operators in general lack the skills to accurately identify and quantify the amount of customer load available for demand management purposes. This task is made more difficult by the fact that demand management initiatives are usually a combination of many small load reductions, of possibly uncertain magnitude, whereas network augmentation generally requires new substation equipment or sub-transmission lines with large design capacity.

- Demand management initiatives may be viewed as compromising network reliability and security in comparison with supply-side initiatives.

In general, therefore, electricity demand management potential, both at the distribution network level and more generally, are underexploited' (ESCOSA 2004).

ESCOSA advocates DM approaches that do not rely on price response alone, even among customer classes that already have interval meters. While it considers non-residential loads as higher priority for DM programs it recognises direct load control of air conditioning as the most promising of the next group (Table 5). Given the high projected growth rate in the peak demand contribution of residential air conditioning previously discussed however, it is likely that AC DM will have to be addressed sooner rather than later, especially if technical developments in the air conditioners themselves can lower the cost and increase the reliability of AC DM.

Table 5 ESCOSA summary of Demand Management potential by customer class and end-use

Customer Category	DM Potential	Applicable DM strategies
Large Business	High	• Curtailable loads • Power factor correction • Thermal energy storage for commercial space cooling or industrial process cooling • Remote load management of air conditioning chillers • Embedded generation
Residential	Medium	• Direct load control of air conditioning • Direct load control of pool pumps • Voluntary load reduction via customer education
Medium Business	Low	• Direct load control of air conditioning • Voluntary load control of air conditioning and other appliances
Small Business	Low	• Direct load control of air conditioning • Voluntary load control of air conditioning and other appliances

Source: ESCOSA (2004)

The Essential Services Commission of Victoria (ESC) is the first State regulator to mandate a rollout of interval meters to all electricity customers, including residential users (ESC 2004). The target is to complete the rollout by 2011 for all users above 20 MWh per annum, which would cover most small businesses but only the largest of households.[8] For all existing consumers of less than 20 MWh per year, those with offpeak or three-phase metering are to be equipped with interval meters between 2006 and 2013. From 2008, all new and replacement services will be equipped with interval meters.

The ESC estimates that in the seven years from 2006, up to one million large customers and customers with electric water heating will have their accumulation meters upgraded

[8] In 2001/02 the average Victorian household used 5.3 MWh (*Electricity Australia* 2003).

to interval meters. In time, all remaining meters (around 1.3 million) would be upgraded, but only at the rate that new or replacement meters are required (ESC 2004).

At present that are about 2 million household electricity users in Victoria. This means that there will be about 0.7 million in the group that will get interval meters by 2013. It is likely that this group will have a high penetration of air conditioning, since it will include:

- New dwellings, where AC penetration is high;

- Off-peak water heater users, who are disproportionately in the non-gas supply area, where AC penetration is high; and

- Very large household electricity users, where AC penetration is high.

Thus by 2013 there could be around a half million households in Victoria alone with both an interval meter and an air conditioner. This would provide a unique set of DM program possibilities, in addition to those available in markets without widespread residential interval metering.

2.2 Pricing, metering and air conditioner demand response

Pricing and metering options

In the National Electricity Market area, electricity retailers purchases energy on the wholesale market. The yearly average wholesale price (covering generation and transmission) is about $35-40/MWh, but the price varies on a half-hourly basis depending on generator price bids to the pool. On peak load days in summer the wholesale price can reach the regulated cap of $ 10,000/MWh for brief periods.

The largest electricity users are supplied via interval meters, which record consumption in the time blocks corresponding to wholesale market time periods. This enables the retailer to pass on varying prices to the customer, although wholesale price volatility is usually moderated to some extent, with risks of price spikes shared between the retailer, the customer and perhaps other parties as well. Part of the risk-sharing arrangements may be an agreement that the customer will reduce its load under certain circumstances if requested.

The interval meter may be a simple recorder to allow for billing after the fact, or it may have other capabilities that make it ‘smart’. These could include:

- Real time price display, so that the retailer can keep the customer up to date with varying prices and the customer can decide (usually with the aid of pre-programmed decision algorithms) when it may be worth modifying or curtailing its energy use;

- Measurement of power factor, so that pricing features based on real and reactive power can be offered;

- Remote meter reading capability.

The great majority of residential and small business customers are billed for electricity using the traditional energy or accumulation meter. This only registers the kWh supplied since the meter was first installed, and customers are billed according to the difference in registered kWh between the latest reading and the one previous. The readings are generally taken by personnel who visit the customer's site and key the meter data directly into a portable data logger. Most accumulation meters are read only four times per year (six times for utilities which bill two-monthly) compared with a possible 17,520 readings per year for a half-hour interval meter.[9]

The retail tariff for day-rate electricity is about 12-14c/kWh ($ 120-140/MWh) irrespective of when it is used, so there is on average a margin of about $80-100/MWh between the wholesale and retail price, most of which covers regulated distribution charges and the balance retailer costs and profit.[10] However, when the wholesale price is much higher than the average price the retailer can lose money - at the price cap of $10,000/MWh the loss can approach 90c per kWh sold, although in practice retailers have complex hedging arrangements to offset this risk. In SA the price risk has been passed on to customers to some extent by charging them a higher seasonal electricity tariff during the summer months.

Even with seasonal pricing, individual air conditioner users with accumulation meters do not face the real costs they impose on the system. One way to do this would be to install interval meters and charge time-variable prices reflecting smaller customer's actual pattern of use, as is the case for larger users. Another, simpler way would be for users with air conditioners to be charged according to a different deemed load profile, which would embody an assumption of the probability that the air conditioner would be in use during peak price periods.

While this would penalise households which had air conditioner but did not actually use them, it is arguable that the inequity would be much less than the present arrangement, which penalises households with no air conditioners at all. The approach would require administrative arrangements such as mandatory notification of air condition installations (perhaps by installers or electricians) and a need for mechanisms to 'de-notify' removed air conditioners, but it is feasible.

The most direct and equitable way to assign the costs of air conditioner use - as well as all other electricity use - is by interval metering of the premises.

The COAG Energy Markets Review (COAG 2002) found that:

> The extent and effectiveness of demand side involvement in the electricity market will likely be affected by the availability to consumers of information regarding the costs of consumption at various times of the day and their ability

[9] The ESC's rollout schedule for interval meters in Victoria also specifies when the retailers must utilise the full data capabilities, which will require them to incur significant additional data handling costs. Otherwise retailers may choose to treat interval meters simply as expensive accumulation meters.

[10] Some households have a separate controlled load circuit which is most commonly used for 'off-peak' water heating, although other interruptible loads such as swimming pool pumps may also be connected. The controlled load energy tariff is typically about 6-8c/kWh, which is well below the day rate.

> to then respond. Consumers' ability to select from differing products and services, resulting in a reduction or shift in consumption, will assist competing electricity retailers to manage wholesale market price risks…
>
> It is essential that consumers in demand reduction bidding have accurate metering infrastructure installed, so that their usage can be accurately monitored…. The Panel believes that a mandatory roll-out of interval meters to all consumers is necessary to achieve the full benefits of electricity market reform (COAG 2002).

The Essential Services Commission of Victoria has recently mandated a rollout of interval meters for small users (ESC 2004). However, while interval metering enables the equitable *recovery* of the costs imposed by air conditioners after the fact, it does not by itself ensure the *control* or minimisation of those costs. Over time, air conditioner households would be alerted to the true cost of their air conditioner use from their electricity bills, and the retailer could assist this process with diagrams based on bill analysis algorithms. Changing behaviour would probably lead to a moderate reduction in overall air conditioner energy use, but less reduction in peak load, since customers would only know after the fact when the peak occurs, and the summer peak is precisely the time when the motivation to keep the air conditioner operating, whatever the cost, is highest.

Load Control and the role of the air conditioner

'Load control' (LC) transfers the initial decision to cycle the AC or adjust its settings from the user to some other agent, although the user is almost always able to over-ride the decision if desired. The agent may be the retailer, the distributor, or some other load aggregator (ie a party that has contracts with a large number of AC users, and is able to deliver their load reduction as a block). Alternatively, the decision can be made by the microprocessor controls in the AC itself in response to price signals.

There are many possible ways to structure, recruit participants for and operate load control programs, involving a range of financial incentives and communications channels. A given air conditioning unit not be immediately compatible with a given LC approach, for range of technical reasons. If so, the LC operator can either compensate with its own equipment and systems – thereby raising the cost – or exclude the unit from the LC program , so reducing the potential benefit.

The more standardised the elements of load control systems, the more likely that AC suppliers will ensure that their products are compatible, and hence the lower the overall costs of implementing load control system.

It is neither necessary nor practical to make every AC compatible with every possible approach, but there would be considerable benefit in standardising at, say, discrete levels of compatibility, for example:

- Basic load control compatibility: the AC is able to cycle the compressor off without affecting fan operation, can restart automatically, has user over-ride, is equipped for at least one mode of communications (eg power-line carried signals, internet).

- Advanced load control compatibility: the AC is equipped for at least one mode of communications (eg power-line signals, internet), and is able to optimise operation within a preset kVA limit (say 0.5 kVA for a period of 1 hour), balancing compressor run time and fan operation. Inverter units would be well suited for this.

- Smart meter load control compatibility: as for advanced, plus ability to program responses to real-time price signals received via a smart meter interface.

3. The way forward

3.1 Summary of measures

Impacts

Air conditioner peak demand is one of the major factors driving capital investment in the National Electricity Market, as well as a mechanism for cross-subsidy between AC users and non-users. If no action is taken, both energy and peak demand are projected to increase rapidly in the coming years. This paper has reviewed a range of measures potentially impacting on the energy use and contribution to summer day peak demand of domestic and small business air conditioning in Australia.

The potential 'medium term' (say 10 year) impact of different measures is indicated qualitatively in Table 6. It would be possible to model impacts quantitatively, as has been done for measures that aim to increase average AC efficiency. Modelling the peak load impacts of a program or the combined effects of several programs is a more complex matter, although given the magnitude of the likely benefits, is certainly a worthwhile next step in developing a co-ordinated national response.

The table distinguishes between the impact of measures on participating individual households or buildings and the impacts on the air conditioning load as a whole. Measures targeting building thermal performance alone have relatively limited impact on the whole load in the medium term because of the slow rate of building turnover. The greatest impact of such programs on individual households would occur if the takeup of air conditioning is avoided altogether – once ACs are installed, the impacts in the growth in peak demand are limited.

The programs with the greatest impact on peak load are those where there is a load curtailment signal and the AC's response to that signal does not require an active decision by the occupant – in other words, direct load control by the utility or predetermined automated responses by the AC itself. Furthermore, these are the only programs which will improve the load factor of air conditioning and so redress the class cross-subsidy issue.

Table 6 Medium term impacts of measures targeting household and small business air conditioning

Measure		**Impact on buildings targeted**		**Impact on entire air conditioner load**		
		Energy reduction	**Peak load reduction**	**Energy reduction**	**Peak load reduction**	**Load factor**
Improve new building thermal performance only	Avoid AC	V.High	V.High	Medium	Medium	No change
	With AC	Medium	Low	Low	V. Low	Reduce
Improve new AC efficiency only		Medium	Low	Medium	Low	Reduce
Improve building thermal performance and improve AC efficiency		High	Medium	Medium	Medium	Reduce
Time of use pricing only	Customer response	Medium	Low	Medium	Low	Reduce
	Auto AC response	Medium	High	Medium	High	Increase
Direct load control only		Low	High	Low	High	Increase
All measures together		V.High	V.High	V.High	V.High	Increase

Cost-effectiveness

The costs and benefits of programs to increase the thermal performance standards of new dwellings have been analysed in a number of studies, both at the national scale (EES et al 1999) and in particular, for the recent tightening of thermal performance requirements in Victoria (EES 2000).

The cost and benefits of mandatory energy labelling and minimum energy performance standards for single phase and three-phase packaged air conditioners have also been studied, in a series of Regulation Impact Statements for the NAEEEP (GWA 1999, GWA 2000, Syneca 2003). These RISs concluded that labelling and MEPS for ACs was cost-effective based on projected energy savings alone, irrespective of peak load reductions, which were not quantified.

There has been less investigation of the costs and benefits of load control and demand management programs. A study by Charles River Associates (CRA) for the Essential Services Commission of SA (ESCOSA) concluded:

> 'There is very little experience in Australia in implementing either network DSM programs or mass-market DSM programs targeted at peak load management. On some levels, until such experience is developed the lack of experience itself will serve as a barrier to involvement in the activity. There is also very little experience in several pricing approaches that could assist management of network peak demand growth.' (CRA 2004).

CRA suggested that the key attributes affecting the relative cost-effectiveness of alternative demand management options are:

- reliability of availability;
- cost per kVA reduced;
- gross amount of kVA reduction available; and
- timeliness with which the option can be made ready to be available for use (ESCOSA 2004).

All of these factors can be positively influenced by the design of the air conditioner itself.

3.2 Facilitating AC Demand Management

Air conditioner technology

It would be feasible to incorporate elements and features into the design of air conditioners specifically to facilitate participation in DM programs. The aim would be to reduce the costs and risks to both DM sponsors and to AC users, so increasing the likelihood that the former will develop and offer AC DM programs, and that the latter will participate.

Customers will be willing to participate in AC DM programs if:

- the AC supplier can assure that interrupted operation will not harm the system
- the AC fans continue to operate during interruptions
- the customer can over-ride a load control signal if necessary
- the AC unit responds automatically to price signals or interrupts, without requiring decision-making by the user
- the AC unit can anticipate periods of interruption and perhaps over-cool ahead of time (ie limited time-shifting).

Electricity suppliers (distributors and retailers) will be more willing to implement AC DM programs if:

- they can easily identify AC-owning households and businesses
- they know that the AC units already incorporate the features necessary to facilitate user participation
- the costs of establishing communications and signalling with ACs are low, because standard features built into new ACs contain many of the system elements which suppliers would otherwise have to provide themselves. (This is particularly important for retailer commitment to DM, because retailers are less assured of long-term retention of customers than are distributors).

Clearly, these conditions will not be met without a significant degree of co-ordination and standardisation with regard to:

- The technical specifications for DM communications and signalling;

- The interface between ACs and interval meters (if installed – although the general standards should not presuppose the present of interval metering); and

- The specifications for air conditioner DM response features.

Present circumstances are uniquely conducive to the development of standardisation in these areas. One of the contributing factors is the common realisation by all State government energy agencies of the difficulties caused by summer peak demand, and air conditioning in particular. Another is the convergence of State-based electricity regulation, which raises the possibility of the development of a common regulatory approach to DM and LC programs, which would in turn allow a common technical approach.

Convergent Regulation

In December 2003 the Ministerial Council on Energy (MCE) announced a program for major reforms to the Australian energy market to be implemented in the period 2004 to 2006, with the intention of strengthening competition and encouraging investment in the Australian energy market. One of the critical elements of the package, which was subsequently endorsed by the Council of Australian Governments (COAG), is the reform of electricity (and gas) market regulatory structures and institutional mechanisms. The proposed new governance arrangements entail the separation of:

- policy making – which is the responsibility of the MCE;
- rule-making and energy market development - which is to be the responsibility of the new Australian Energy Market Commission (AEMC); and
- economic regulation and market rule enforcement – which is to be the responsibility of the new Australian Energy Regulator (AER).

It is intended that by the end of 2006 the AEMC should assume responsibility for rule-making and market development in respect of electricity and gas distribution networks and retail markets (other than retail pricing) following the development of an agreed national framework. The primary objective of the AER, like the AEMC, will be to

> 'promote the long term interests of consumers of electricity with respect to price, quality and reliability of electricity services and economically efficient investment and innovation. In seeking to achieve this primary objective, the AER will be required to have regard to the following objectives:
>
> - the market should be competitive;
> - **the operation and use of, and investment in, infrastructure in the electricity industry (including transmission and distribution services) should be economically efficient;** [emphasis added]
> - customers should be able to choose which supplier (including generators and retailers) they will trade with;
> - any person wishing to do so should be able to gain access to the interconnected transmission and distribution network;
> - a person wishing to enter the market should not be treated more favourably or less favourably than if that person were already participating in the market;
> - a particular energy source or technology should not be treated more favourably or less favourably than another energy source or technology; and
> - the provisions regulating trading of electricity in the market should not treat intrastate trading more favourably or less favourably than interstate trading of electricity.' (MCE 2004).

As the lack of price signals for air conditioner use is one of the main factors driving investment in transmission and distribution services, and is patently economically inefficient, it would appear that early attention to the matter fits squarely with the AER's objectives. If consistency of approach can be achieved through the NEM as a whole, the scope for cost-effective DM initiatives should greatly increase.

Complementary Market Mechanisms

Increasing the availability or sales of LC-compatible air conditioners would lower the costs of implementing load control programs, but would not of itself compel utilities to offer such programs or motivate consumers to participate. However, introducing LC factors into the AC purchase process would facilitate other potential measures, eg:

- Requiring AC buyers to install smart metering and to go on time of use tariffs;

- Alternatively, including a 'demand management bond' in the purchase price (say $500-$1,000, depending on maximum motor power) to be forwarded to a publicly-administered fund and to be redeemable after a specified period of participation in a utility LC program.

Measures such as these are justified on equity grounds, to ensure that new AC users do not add to the cross-subsidy burden on non-AC users, and on the grounds of increasing the security of electricity supply in a period where one of the highest risks of supply disruption is from air conditioner load. They should also have the benefit of increasing the competitiveness of demand-side responses in the national electricity market, by enabling the cost-effective aggregation and block demand bidding of AC loads.

Measures of this type would increase the efficiency of the market for air conditioning services by signalling some of the AC operating costs which are hidden at present. A large enough 'demand management bond' could also encourage buyers to:

- Delay consideration of installing an air conditioner in a new home for a season or two, which could be long enough to determine that it is not necessary;

- Consider evaporative cooling as an alternative to refrigerative air conditioning (provided the local climate is suitable).

State government agencies and local government would be well placed to develop and administer programs such as these.

3.3 The role of the NAEEEP and APEC

The NAEEEP offers a ready made framework for developing standards for air conditioner demand management technologies. The NAEEEP already invokes (via State and Territory legislation) a number of Australian and New Zealand standards for the testing, performance, energy efficiency and labelling of air conditioners, largely based on international ISO standards.

If criteria for DM capability were developed, it would be relatively straightforward to incorporate them into the existing standards. At the very least, AC suppliers could choose to state whether their products were DM-compatible, and buyers who wished to participate in their utility's local DM program could identify those products.

The next level of response may be to require disclosure of DM-capability (or possibly the level of capability) on the energy label. Ultimately, meeting a certain minimum level of DM-capability may become a mandatory requirement, like meeting a minimum level of energy-efficiency. Any mandatory requirements would of course be subject to formal benefit-cost analysis and regulation impact assessment.

The NAEEEP has shown itself capable of successfully taking up new challenges in the past. Some years ago it moved into the area of standby energy rather than just operating energy. It is a natural progression for it to investigate the peak demand implications of air conditioners and whether these can be addressed through product design.

Obviously, DM standards for air conditioner cannot be developed in isolation. It will be necessary to engage many interest groups, not just in Australia but beyond, since all single phase airconditioners sold in Australia are now imported. Air conditioner demand management is a world-wide problem, and manufacturers in other APEC countries (eg Korea) are already experimenting with DM-capable features, so it should not be difficult for the NAEEEP to engage product manufacturers.

Indeed, the major stakeholders have already agreed jointly investigate these issues. A workshop entitled *Air conditioning and Peak Load Issues*, held in Sydney in June 2004, involved 40 delegates from 9 APEC economies, representing major air conditioning equipment importers and manufactures, power supply companies, government energy regulators and industry experts (APEC 2004) The program dealt with:

- International Energy Agency DSM Task XIII: Demand Response in a Competitive Electricity Market, a look at new work on demand supply management & solutions - hedging tools for peak load
- Air conditioning trends, use and technology and demand side response
- Refrigeration technologies, energy use and Kyoto
- Summary of Australian and international actions to address peak load issues

The conference identified actions that will improve the efficiency of air conditioning, especially over the next 5 years. In the specific context of peak load impacts and issues, as distinct from building codes and product energy efficiency, the delegates agreed to the following:

1. Maintain and enhance the dialogue within the electricity industry, equipment suppliers, government and other stakeholder on a regular basis to create plans for managing the impact of air conditioning on electricity peak load over the next 5 years.
2. Support efforts to encourage correct sizing, maintenance and installation of air conditioners to minimise excessive demand.
3. Support IEA Task XIII, which aims to provide tools for countries to implement demand side response in electricity markets, by involving air conditioning industry stakeholders in the task.
4. Encourage the use of demand side response, where technically and financially appropriate to ensure system wide benefits.
    - Consideration needs to be given to the various technical issues surrounding the load control of air conditioners, particularly inverter technology.
    - Air conditioning suppliers offered to work with utilities and stakeholders to assist with the enabling of DSR technology
    - Introduce more cost reflective pricing to enable market signals for commercial and residential customers to mange peak load created by air conditioning.
    - Promote efforts that provide the metering and signalling systems to enable DSR.

The present paper is intended to further the deliberations begun at that workshop.

3.4 Conclusions and Recommendations

The development of a national strategy to directly address the peak load effects of air conditioners is becoming increasingly urgent. Air conditioning use is growing rapidly in homes and small businesses, and could conceivably double within 10 years.

This rate of growth in peak demand from air conditioners is likely to outstrip the countervailing effects of energy efficiency programs, which have a limited, indirect and uncertain effect on peak load, and even of programs which seek to reduce the demand of larger users at times of summer peak demand.

The development of direct load control, more efficient means of signalling prices and other demand management measures targeting air conditioners has been relatively slow because of high supplier costs, differences of approach by State regulators and a lack of technical standardisation.

These barriers can and should be addressed, and a wide range of stakeholders has already indicated their willingness to do so. The Australian Greenhouse Office and the National Appliance and Equipment Energy Efficiency Program can play an important role in the process.

It is recommended that:

1. The Ministerial Council on Energy ensure that the development of uniform Demand Management rules, particularly those concerning load control programs for air conditioners, is placed on the agenda of the new Australian Energy Market Commission (AEMC) and the Australian Energy Regulator (AER).

2. The Ministerial Council on Energy should direct the Energy Efficiency Working Group to convene an Air Conditioner Load Management Task Force to address regulatory, pricing and technological barriers to the development of air conditioner load control.

3. The Task Force should develop a National Demand Management Strategy for Small Airconditioners covering the next 10 years, with the early phase of the plan recognising and working with the existing framework of State-based electricity legislation and regulation, and the latter phase recognising the transition to a national framework.

4. As part of developing the 10-year plan the Task Force should consult with:

    - air conditioner importers, manufacturers and standards bodies
    - electricity distributors and retailers
    - State, Territory and Commonwealth electricity regulators (economic and technical)
    - State and Territory energy agencies
    - State and local government agencies responsible for planning and building.

5. The MCE commission modelling of the costs and benefits of a range of approaches to demand management for small airconditioners (including avoidance of air conditioner installation in new dwellings and promotion of evaporative cooling) using local case studies; and

6. MCE explore ways of funding trails and programs, including use of public sector funds as well as market or consumer levies.

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Appendix 1 Residential sector energy use, 1999

Appliance/End Use		Energy form	Delivered PJ	FFPE PJ	% of Delivered	% of Electricity
Airconditioners	Cooling	Elec	5.8	18.1	1.5%	3.4%
	Heating	Elec	1.1	3.4	0.3%	0.6%
	Standby	Elec	0.3	1.1	0.1%	0.2%
Electric resistance	Heating	Elec	5.5	17.1	1.4%	3.2%
	Standby/fan	Elec	0.1	0.4	0.0%	0.1%
Gas heater	Heating	Gas	68.3	77.1	17.9%	
	Standby/fan	Elec	0.7	2.3	0.2%	0.4%
LPG heater	Heating	LPG	4.2	4.4	1.1%	
	Standby/fan	Elec	0.0	0.1	0.0%	0.0%
Other petroleum fuel	Heating	Oil	2.7	2.9	0.7%	
Coal	Heating	Coal	0.1	0.1	0.0%	
Wood	Heating	Biomass	81.4	NA	21.4%	
Electric water heater	Losses	Elec	14.4	45.0	3.8%	8.5%
	UE	Elec	30.8	95.9	8.1%	18.0%
Solar-electric	Boosting	Elec	1.5	4.7	0.4%	0.9%
	Solar gain	Solar	2.4	NA		
	Losses	Solar	1.3	NA		
	UE	Solar	2.6	NA		
Gas-storage	Losses	Gas	12.6	14.2	3.3%	
	UE	Gas	20.1	22.7	5.3%	
Gas-instantaneous	Losses	Gas	3.2	3.7	0.8%	
	UE	Gas	6.0	6.8	1.6%	
	Standby	Elec	0.2	0.5	0.0%	0.1%
LPG water heater	Losses	LPG	2.0	2.1	0.5%	
	UE	LPG	2.9	3.1	0.8%	
	Standby	Elec	0.0	0.1	0.0%	0.0%
Cookers		Elec	8.4	26.2	2.2%	4.9%
		Gas	5.7	6.4	1.5%	
		LPG	1.2	1.2	0.3%	
Refrigerator	Operating	Elec	22.3	69.5	5.9%	13.1%
Freezer	Operating	Elec	6.4	20.1	1.7%	3.8%
Clothes washer	Operating	Elec	1.2	3.9	0.3%	0.7%
	Standby	Elec	0.7	2.1	0.2%	0.4%
Clothes dryer	Operating	Elec	1.5	4.6	0.4%	0.9%
	Standby	Elec	0.3	1.0	0.1%	0.2%
Dishwasher	Operating	Elec	1.5	4.8	0.4%	0.9%
	Standby	Elec	0.2	0.8	0.1%	0.1%
TV	Operating	Elec	3.4	10.6	0.9%	2.0%
	Standby	Elec	1.0	3.0	0.3%	0.6%
VCR	Operating	Elec	0.1	0.2	0.0%	0.0%
	Standby	Elec	1.5	4.7	0.4%	0.9%
Computers	Operating	Elec	1.6	5.1	0.4%	1.0%
	Standby	Elec	0.5	1.6	0.1%	0.3%
Other uses - covered	Operating	Elec	5.0	15.6	2.1%	4.7%
	Standby	Elec	1.0	3.1	0.5%	1.2%
Other uses - balance	Operating	Elec	28.3	88.2	6.6%	14.8%
	Standby	Elec	8.3	25.9	1.9%	4.3%
Lighting	Fluoro	Elec	0.8	2.4	0.2%	0.5%
	Ballast	Elec	0.2	0.7	0.1%	0.1%
	Non-fluoro	Elec	15.7	49.0	4.1%	9.2%
Garden & lawn equpt	Motors	Oil	5.1	5.4		
			386.1	681.9		

Source: GWA (2004)

Appendix 2 Commercial sector end use, 1999

Appliance/End Use		Energy form	Delivered PJ	FFPE PJ	% of Delivered	% of Electricity
Air Handling	Fans	Elec	29.0	90.4	14.5%	20.7%
Cooling	Towers	Elec	24.3	75.6	12.2%	17.3%
	Packaged	Elec	10.0	31.2	5.0%	7.1%
Fluid pumping	Pumps	Elec	5.2	16.2	2.6%	3.7%
Heating (heat pump)	Packaged	Elec	3.8	11.8	1.9%	2.7%
Heating (thermal)	Resistance	Elec	1.6	5.1	0.8%	1.2%
	Boiler	Gas	40.7	45.2	20.4%	
	Boiler	LPG/Oil	9.7	10.4	4.9%	
	Boiler	Coal	1.4	1.4	0.7%	
	Boiler	Biomass	0.8	NA	0.4%	
Lighting	Fluoro	Elec	25.3	78.9	12.7%	18.1%
	Ballast	Elec	6.6	20.6	3.3%	4.7%
	Non-fluoro	Elec	3.4	10.7	1.7%	2.5%
Cooking		Elec	0.6	1.9	0.3%	0.4%
		Gas	1.9	2.1	1.0%	
Water heating	Storage	Elec	1.2	3.9	0.6%	0.9%
	Storage/Inst	Gas	2.9	3.2	1.4%	
	Storage/Inst	LPG/Oil	1.4	1.5	0.7%	
	Boiler	Coal	0.5	0.5	0.3%	
Water boiling		Elec	3.1	9.6	1.5%	2.2%
Office equipment		Elec	7.1	22.1	3.6%	5.1%
Lifts, etc		Elec	1.5	4.8	0.8%	1.1%
Refrigeration - unitary		Elec	5.6	17.3	2.8%	4.0%
Refrigeration - split		Elec	11.1	34.7	5.6%	7.9%
Other		Elec	0.6	1.9	0.3%	0.4%
			199.5	501.2	100.0%	100.0%

Source: GWA (2004)