STRATEGIC STUDY OF HOUSEHOLD ENERGY AND GREENHOUSE ISSUES

A REPORT FOR ENVIRONMENT AUSTRALIA

JUNE 1998

Alan Pears
Sustainable Solutions Pty Ltd
2/78 William Street
Brighton 3186

SUMMARY - STRATEGIC STUDY OF HOUSEHOLD ENERGY AND GREENHOUSE ISSUES

A REPORT FOR ENVIRONMENT AUSTRALIA

Alan Pears, Sustainable Solutions Pty Ltd, 2/78 William Street Brighton Vic 3186 June 1998

Overview (Chapter 1)

Australians spend $3 billion on new appliances, and $15.6b on construction and renovation of houses each year. They spend almost $5.8 billion on non-transport energy, but this is only 2.8% of expenditure on goods and services, so energy is seen as a minor consideration in most decisions.

If all major contributions of households to greenhouse gas emissions are included (transport, embodied energy, landclearing, emissions from wastes and CFCs, as well as non-transport energy), household activities generate between 130 and 160 Mt of CO_2 equivalent each year, of which non-transport energy comprises around 50 Mt (excluding emissions from woodburning).

Trends (Chapter 2)

ABARE expect household energy-related emissions to increase by more than a quarter, from a 1990 value of 44 Mt pa to peak at 56 Mt pa early next century, then decline slowly, despite population growth. This projection actually implies an increase in emissions per capita from household energy use from a 1990 value of 2.58 tCO_2/capita to 2.84 in 2001, declining again to 2.66 by 2010.

At a state level, greatest growth in emissions, in both total and per capita terms, over the past decade has occurred in Queensland and Western Australia, followed by Northern Territory. This seems to reflect strong growth in cooling energy consumption, and possibly increased appliance ownership, as well as population trends.

The Household Context (Chapter 3)

If greenhouse strategies are to be optimised, it is necessary to identify target groups with greatest potential for emission reductions, and factors contributing to emission reduction or growth that can be influenced.

Households in extreme climates use much more energy than those in moderate climates, and have greater scope for large cost-effective savings. In temperate climates, variations in emissions are sensitive to the availability of different energy sources and building thermal performance characteristics.

Within each geographical area, there is wide variability in emissions from household to household. Electricity consumption varies widely, with some households using three times the Australian average amount of electricity. Around 20% of household electricity is used by 7.5% of households. Variability in emissions is amplified by fuel choice. There is scope to identify and target programs towards households with high levels of emissions.

Some types of households, such as rural homesteads and caravan-dwellers, experience high energy costs relative to the level of energy services delivered.

Household expenditure on energy has varied little in real terms over the past decade, and may decline under market forces. The possibility of changes in tariff structures after de-regulation could create serious financial barriers to fuel-switching and energy-efficiency. This issue requires careful management and appropriate regulatory direction to ensure that fixed supply charges are minimised and marginal unit prices are not reduced.

The cost of supplying energy to households varies markedly, with large cross-subsidies to rural households, and some cross-subsidies to some appliance loads (eg airconditioning and cooking). While, in theory, the competitive market is intended to remove these cross-subsidies, it is clear that there will be strong political pressure to maintain some of them, and energy suppliers will maintain others for strategic reasons or because of limitations on metering in homes. Practical mechanisms are needed to address these energy loads, as reducing the level of cross subsidy (by changing pricing, or by reducing the amount of energy subsidised by improving energy efficiency or fuel switching) saves Australia money by reducing the scale of subsidies: while this may not be as elegant in policy terms as removing subsidies, it may be more easily implemented.

Australian households are becoming smaller, and some groups (such as retirees and home-based workers) are spending more time at home. The decline in household size is a factor in the increase in household sector energy consumption, as the reduction in energy consumption due to a decline in household size is smaller than the resulting increase in the number of households using energy. The potential for people to spend more time at home leads to an increase in energy use, and requirements for larger homes. These trends increase the importance of minimising standby energy consumption of water heaters and electrical appliances, as there will be more equipment doing, on average, less activity.

Greenhouse intensity of energy (Chapter 4)

The greenhouse intensity of each unit of energy consumed by a household influences the quantity of emissions for a given level of energy consumption. ABARE estimates that the average greenhouse intensity of energy used by households will decline by about 5% between 1990 and 2010, although this is only equivalent to the same intensity as that achieved in 1994. Changes in greenhouse intensity can be achieved by changing the fuel mix (either at the power station or at the house), or by cutting conversion and delivery losses.

Householders can contribute to reduction in the greenhouse intensity of energy by supporting schemes such as *Greenpower* and by switching to lower greenhouse intensity fuels. Government can influence this factor by policies such as the 2% renewables target, conversion efficiency requirements, ensuring provision of both gas and electricity infrastructure to homes, and promotion of low greenhouse impact energy options.

If the greenhouse intensity of household electricity declined by 20% between 1990 and 2010, instead of the projected 5%, household emissions would decline by almost 13% from the BAU estimate, to 48.4 Mt per year. This reflects the critical contribution of electricity to household greenhouse emissions.

Indirect emissions associated with the impact of fuelwood on landclearing may be significant, and highlight the importance of ensuring that fuelwood production and use is sustainable.

Fuel switching from electricity to gas and renewables is potentially a very significant contributor to emission reduction. Shifting 10% of household electricity consumption to gas (which would involve the equivalent of a third of households with electric hot water switching to gas) would reduce 2010 household emissions by around 3 Mt. However, similar emission reductions could be achieved if high efficiency electric technologies were adopted. This highlights the importance of using a balanced approach which links incentives or regulations to actual greenhouse outcomes, rather than to the specific means of achieving those outcomes.

Overview of Buildings, Appliances, Energy and Greenhouse Gas Emissions (Chapter 5)

Almost 30% of Australian household greenhouse gas emissions are generated by hot water services, most of this from electric units. And around a third of these emissions result from heat losses from storage tanks. Refrigeration accounts for almost a fifth of total household emissions: many households have more than one refrigerator or a separate freezer. Space heating and cooling generates just over an eighth of household emissions - much less than most people expect. Lighting and appliances are responsible for around 40% of household greenhouse gas emissions.

Appliance and energy source selection are responsible for substantial variation in household emissions. For example, a typical 'all electric' household could generate 10 tonnes of CO_2 per year while a comparable household with gas appliances generates just over 6 tonnes. If these houses used the most efficient appliances now available, emissions would be reduce to 4.4 and 3.6 tonnes respectively. Even larger reductions are feasible if projected appliance efficiency improvements are achieved. Emissions per household of 2 to 3 tonnes per year are feasible as technologies improve over the next few years.

Appliances
ABS survey data showing ownership trends for major appliances are shown in the main report:

- almost all households own a refrigerator and washing machine
- over 80% of households own microwave ovens
- 30% of households own at least two refrigerators, and 43% own a separate freezer
- over 55% of households own clothes dryers
- 41% own airconditioners
- 30% own dishwashers
- 12% own swimming pools
- 8% own waterbeds
- 8% own bore pumps

Just under 60% of households own electric hot water services, while just over a third own gas HWS units and 5% own solar units. The share of electric units is declining slowly, but the proportion of electric units that are large capacity models has increased to three-quarters, from less than 60% in the late 1980s.

Just over a third of Australian households use electricity for their main heating, while a similar proportion use gas and almost 20% use wood or solid fuel. Just over 10% of households have no heating. There is strong growth in gas central heating (to a quarter of gas heated homes) and electric reverse cycle heating (to a quarter of electrically-heated homes).

With existing gas networks, there is scope for up to 30% more Australian households to use gas for heating and/or hot water. Gas pipelines are being extended, so this number should increase.

Buildings
On average, around 125,000 new homes are built each year. The share of apartments and townhouses has increased from 21% in 1983 to 32% in 1997. The highest rates of activity have been in Queensland, Western Australia and Northern Territory.

Trends in household size play an important role in determining building activity: if household size in 2010 falls to 2.3 people, from today's 2.6 people, around a million extra homes will be required. Changes in size of dwellings are probably less significant in terms of energy than trends towards central heating and increased cooling.

Data on home renovation are not well-defined. $2.5 billion is spent on major renovations, but up to $6.5 billion in total is spent on renovation, half that spent on new homes. So large numbers of homes experience some renovation work each year. The renovation market is an important one for greenhouse strategies, as the householders themselves are often much more closely involved in decisionmaking than for new houses.

Home construction and renovation activities are important targets for greenhouse strategies, because many long-lasting decisions with large lifecycle greenhouse impacts are made during this process. In 2010, less than a fifth of all homes will have been built post-1998, so renovation and retrofit activities are important if total building-related emissions are to be reduced by 2010.

Appliance and Building Markets (Chapter 6)

These markets are very complex, with many participants, all with their own agendas. The clear conclusion that can be drawn from review of these markets is that no participants except the householder and a few manufacturers of low greenhouse impact products have any significant vested interest in reducing greenhouse gas emissions. Indeed, many market participants have interests in promoting product and building attributes that contribute to increased greenhouse gas emissions. Further, the householder has very little influence over many critical decisions that influence both long-term energy costs and greenhouse gas emissions. The householder is also poorly informed and faces a difficult task in balancing a large number of complex factors when making decisions. Mechanisms to encourage resale or disposal of appliances and equipment that are no longer required are limited, so many appliances remain in use when they are not really required.

In limited areas, mainly appliances carrying energy labels and building insulation, energy-efficiency has become a factor in decisions. But, in most cases, there is not even sufficient easily-accessible information for an interested consumer to use as a basis for informed decision-making.

To influence the structures of markets so that reasonable consideration is given to greenhouse factors will be a substantial task that will require serious effort over an extended period. Key elements of action must include:

- provision of credible information in appropriate forms suited to decisionmakers
- creation of consistent and ongoing incentives or pressures for market intermediaries to promote low greenhouse impact options over high greenhouse impact solutions
- supply of suitable products, and service infrastructure to support low greenhouse impact options

Appliance Technologies and Scope for Emission Reduction (Chapter 7)

A systems approach to analysis of energy service delivery is required if the full potential to improve energy efficiency is to be recognised. When this approach is taken, it is clear that there is very large potential for appliance energy efficiency improvement, and for the delivery of energy services at much lower energy cost. For example, many central heating systems operate at around 35% efficiency, while efficiency of hot water systems in small households can be as low as 30%.

Energy efficiency of most major appliances has improved over the past decade, largely due to increased awareness resulting from appliance energy labelling. However, rapid growth in other appliances has occurred and, in many cases, their energy efficiency has declined as their complexity has increased.

Existing appliance energy efficiency programs have addressed only a proportion of the products that need to be improved if overall greenhouse gas emissions are to be reduced. Programs must be extended to include these products, which range from televisions and electronic products to swimming pool pumps.

Energy efficiency programs need to target the design stage, where a single decision is replicated hundreds of thousands of times, and influences energy consumption for the lives of the products produced to that design. The purchase decision, installation, and user behaviour are also critical points for intervention.

Hot water is responsible for 30% of household greenhouse gas emissions, and most of these result from use of resistive electric HWS units. Replacement of resistive electric units by heat pump, solar or gas units must be a high priority: just applying MEPS to reduce tank heat loss falls far short of the scale of reduction needed. Retrofit systems which reduce heat loss from tanks, use solar pre-heating, or replace the resistive elements with heat pump or gas burner modules could also play a useful role. Gas storage units must also be improved: pilot lights should be banned and heat losses minimised. A combination of improvement in efficiency of hot water usage and HWS improvement could reduce emissions per household from today's average of almost 2.2 tonnes of CO_2 per year to around 0.5 tonnes.

Refrigeration is the second largest contributor to household greenhouse gas emissions. Appropriate policies should aim to reduce average appliance consumption to less than 400 kWh per year, from today's average for installed stock of over 900 kWh. Best technology can already deliver less than 200 kWh per year for a 450 litre refrigerator, and this should drop below 150 kWh over the next few years. It will also be important to remove some of the large number of second (and third) refrigerators and separate freezers from homes, by offering incentives for their collection.

Cooking is responsible for up to a tenth of household greenhouse gas emissions. Cooking energy use is declining as people eat more meals away from home, or simply heat pre-prepared meals. Cooking technology is also improving. However, user behaviour is a very significant factor in this activity.

Lighting energy consumption is probably increasing, although we do not have data to confirm this. Lighting levels are increasing, and extremely inefficient low voltage halogen lamps (with extremely inefficient transformers) are capturing the market, because they are very cheap to buy and they look 'modern'. In principle, lighting energy consumption should decline, as more efficient technologies are emerging, but in practice consumption may increase unless there is market intervention. Further substantial improvements in technological efficiency can be expected over the next decade.

Energy consumption for clothes washing has been declining as washing temperatures have declined and the market share of front loading washing machines has increased. Top loading machines are also becoming more efficient. However, the introduction of electronic controls has meant that standby power consumption may now exceed the energy used for washing when cold water is used in small households.

Clothes drying is not generally seen as a major energy issue, although over half of Australian households own a clothes dryer. However, if more households switch to electric clothes drying as we shift to medium density housing, it could become a major issue, as a household could use up to 1500 kWh per year if all clothes were dried electrically. If electricity is used for drying, the only technology improvements that could deliver large savings (that is, beyond 30%) are the heat pump clothes dryer and gas dryers, which can deliver savings of 50% or more. Heat pump dryers will cost more, but they do not cause condensation problems, nor do they require venting to outdoors. Gas dryers are also more expensive, and require a gas connection in the laundry. A combination of high spin speed and a heat pump clothes dryer could limit drying energy to around 300 kWh per year for a household that dries all its clothes electrically. It will be important to encourage households to minimise their use of electric clothes dryers by ensuring practical alternatives are available.

Dishwashers are now owned by more than 30% of households, and now use similar amounts of energy to washing in the sink. New models have much improved efficiencies, and further gains are occurring, with a likely limit of around 0.5 kWh/wash, compared with around 1.3 kWh/wash now. Rinsing of dishes under running hot water may be comparable in its contribution to greenhouse emissions with operation of dishwashers.

Electronic appliances have proliferated in Australian homes. Many of these appliances use power when switched 'off' at the appliance, as well as when in use. This standby power consumption may now comprise 5 to 20% of household electricity consumption, and is rising. Also, some equipment that is used for long periods can consume large amounts of power: for example, a TV watched for long periods can use 300 kWh per year - more than a dishwasher or clothes washer. Standby power can easily be slashed to less than 1 watt per appliance, although this will probably require regulation. Information on operational efficiencies of appliances is needed before consumers can respond.

Households own a variety of energy-consuming equipment, including pool and bore pumps, heated waterbeds, aquaria, fans, etc. Many of these items use significant amounts of energy, and there is scope for substantial efficiency improvement in all cases. However, very little attention has been paid to them to date. Many of these products are distributed through specialist networks, so there is scope to work closely with suppliers to achieve improvements.

Buildings and heating and cooling equipment (Chapter 8)

The obvious justification for programs focusing on building heating and cooling is that these are major contributors to greenhouse gas emissions. However, these activities comprise less than 15% of household greenhouse gas emissions. Nevertheless, the implications of decisions made during home purchase or construction have much broader implications for emissions. Fuel selection, hot water systems, cookers and lighting are installed during construction, and many major appliances are purchased at this time, too. Comfort is also an important quality of life issue.

Australian dwellings are, on average, extremely inefficient in their construction and design, with only 56% even having ceiling insulation. This thermal inefficiency is compounded by the rapid growth in use of central heating and airconditioning to provide comfort. Not only should the thermal performance of new dwellings and major renovations be improved, but there is also a need for retrofitting of energy efficiency improvements, especially ceiling and wall insulation, shading and draughtproofing. Cultural barriers to adoption of these strategies, especially in hot and mild climates, will have to be addressed.

There is enormous variation in the capital and operating costs of home heating and cooling equipment. However, decisionmaking rarely considers lifecycle costs and the full range of costs and impacts, which are distributed over a number of market intermediaries, several occupants, energy utilities and society.

Electric off-peak heating systems generate very high greenhouse gas emissions of up to 15 tonnes per year (except in Tasmania). Other options typically generate between 1 and 6 tonnes per year. Although day-rate electric heating is greenhouse intensive, its high running cost means that it is usually used in mild climates or, where it is colder, very sparingly. However, annual emissions from households using day-rate electric heating still often exceed 1 tonne of CO_2. Central heating systems are particularly inefficient, due to large losses from ducts or pipes, localised losses around heating outlets, and the tendency to heat larger areas.

In dry climates, evaporative cooling is a practical alternative to refrigerative cooling, and uses less than half as much electricity. Airconditioning is a very expensive load for electricity suppliers to satisfy, as it is a large load for relatively short periods.

There is substantial scope for reduction of greenhouse gas emissions through improvements in heating and cooling technologies combined with improved building thermal efficiency. Heating and cooling technologies have potential for 20 to 50% efficiency improvements. When combined with building thermal performance improvements capable of at least halving heating and cooling requirements, an overall reduction in heating and cooling energy emissions of around 70% is feasible if existing levels of comfort are maintained. Given the trends towards greater comfort, it would be safer to predict much smaller savings, though. However, if more efficient solutions are not pursued, it is likely that heating and cooling greenhouse gas emissions would continue to increase, as people seek greater comfort. Adoption of best technology building and heating/cooling technologies could achieve both a high standard of comfort and very low heating and cooling energy use.

While there has been much useful innovation in building thermal performance and heating/cooling systems over the past decade, there is a need to continue development. We are only in the early days of developing user-friendly tools (such as HERS software) to assist designers and homebuyers to make optimal choices: these methods could be applied to protection of solar access and selection, installation and operation of heating and cooling equipment. Effective market transformation programs will be required to achieve significant change.

Priorities and Principles for a Household Greenhouse Emission Reduction Strategy (Chapter 9)

To date, household energy strategies have focused on building thermal performance and energy use by major appliances. There is scope to redirect the $25 billion spent each year by households on home and appliance purchase and operation towards cost-effective low greenhouse impact options. This will require implementation of a wider range of targeted programs, including provision of incentives or pressures for market intermediaries to place greater weight on energy-related factors.

To create a context that facilitates greenhouse emission reduction, key actions include:

- continue to develop a comprehensive knowledge base to support program development, using surveys, monitoring, RD&D and pilot programs
- support development of infrastructure to implement emission reduction actions, including improved products and materials, decision-making and design tools, and training of tradespeople and salespeople
- provide effective ongoing information and advisory services and materials to support decision-making and behaviour change. This includes provision of model-specific information on operating energy use of a much wider range of appliances and equipment
- establish state-level (and possibly regional) emission indicators for the household sector and use them to monitor performance and guide allocation of funding. Provision of feedback to individual households on their performance is also desirable

Policy frameworks that support emission reduction must also be introduced, with key aspects including:

- energy supply industry policy must be reviewed to ensure that market signals encourage both the energy supply industry and household consumers to choose low greenhouse emission solutions. This will involve careful control of tariff structures and billing procedures. Where subsidies exist but cannot be immediately removed, compensating programs to promote energy efficiency, fuel switching and renewables should be put in place and phased out in parallel with the reduction of the subsidies
- a policy approach to the appliance and equipment industries which incorporates a long-term perspective and considers costs and benefits to all market participants. It is important that industry sees positive incentives to make progress
- urban planning policy must protect solar access, provide access to open space for occupants of medium-density housing, make appropriate provision for clothes drying, and minimise the cost of installation of gas supply infrastructure

Specific program opportunities and issues include:

- implement programs to minimise 'energy leaks' (ie standby energy waste) from gas pilot lights, hot water storage tanks and electrical appliances, which serve no useful purpose. As household size declines and the amount of low-usage equipment increases, this will be an increasingly large component of total household energy use
- target decisions with significant lifecycle implications, such as design of appliances and houses, purchase decisions, installation methods and recovery of equipment that is no longer needed
- target greenhouse-intensive equipment, that is equipment capable of generating large amounts of emissions through either long hours of usage or high emissions-intensity during each cycle of operation
- work with market intermediaries to target key types of emissions and households such as households with high energy bills, owners of swimming pools, people planning for retirement, etc. This may involve creating incentives or pressure for market intermediaries to change their priorities. Community networks are potentially powerful and cost-effective allies
- implement a fuelwood strategy. An integrated approach that involves sustainable fuel sources, and new sizes and designs for heaters is needed if the trend away from use of wood is to be arrested
- develop and implement strategies addressing other major household-related greenhouse gas emissions, such as CFCs, personal transport, etc

Using piecemeal programs with commitment that varies over time and aims only for gradual improvement will not deliver the scale of emission reductions necessary, nor will it deliver the cost-effective optimum outcome.

TABLE OF CONTENTS

Chapter 1: Overview of Household Greenhouse Gas Emissions

Australian households spend 2.8% of expenditure on goods and services - almost $5,800 million, on non-transport energy (ABS 6530.0, 1994) and $3,000 million on energy-using appliances (ABS 6535.0, 1995) each year. 120,000 to 170,000 new dwellings are built each year (ABS 4102.0, 1996), and many existing homes are renovated, with expenditure on housing construction and renovation costing $15,600 million in 1996-97 (ABS 1998). Households spend $31 billion each year - 15% of household expenditure on goods and services, on transport (ABS 6530.0, 1994), most of which is spent purchasing ($9.3b) and operating ($8.8b on fuel) around 8 million privately-owned cars. All of these investment expenditures have long-term impacts on greenhouse gas emissions, as each appliance, car or house generates more or fewer greenhouse gas emissions throughout its useful life. The expenditures on energy reflect the annual rates of greenhouse gas emissions, which are the outcome of both ongoing behaviour and the influence of investment decisions.

Major sources of greenhouse gas emissions from household activities include:

- energy use in homes
- personal transport (including commuting, access to facilities and services, and recreation)
- energy and resource use in manufacture of goods and materials used in homes and services utilised by households (embodied energy)
- landclearing associated with fuelwood use and urban expansion
- emissions from wastes and sewage
- emissions associated with use of CFCs and HCFCs (which are addressed under the Montreal Protocol) and HFCs in household and private car airconditioning and refrigeration

Estimates of the scale of these emissions are given in Table 1. Note that some of these estimates are very approximate. As can be seen from the Table, private transport activity is comparable in emissions to household energy use, while emissions associated with municipal waste and embodied energy are substantial. Release of CFCs from existing equipment would exceed one year's greenhouse gas emissions from household energy use, although CFCs are not included in the NGGI inventory, on the grounds that they are being managed under the Montreal Protocol. The management and use of fuelwood resources raise significant greenhouse policy issues.

Transport emissions are being managed under separate programs, but they will be influenced by urban planning strategies which also affect home energy use. For example, where higher density housing involves more sharing of walls and multi-storey housing at the expense of detached housing, building energy efficiency is likely to improve and greenhouse gas emissions associated with building heating and cooling are likely to decline in tandem with transport emissions (Loder & Bayly et al, 1993, Energy Victoria et al, 1996).

There is scope for reduction of methane emissions from municipal wastes to be dealt with under waste reduction strategies and, if landfill and biogas are defined as renewables, within the 2% mandatory renewable energy contribution to electricity generation. It is important to ensure that methane from wastes is captured, and that this energy resource is effectively utilised, instead of just being seen as a waste management problem, as it is a substantial energy resource.

The preferred methods of energy recovery from wastes do not include incineration systems, due to public concerns regarding air pollution. Biogas generation may be a preferred solution, as it operates at relatively low temperatures in a reducing environment, and is much more effective at avoiding fugitive methane emissions and at extracting useful energy than extracting gas from landfills. Conversion of wastes to ethanol is also under development.

Table 1. Estimates of annual greenhouse gas emissions from activities associated with households (various sources)

ACTIVITY	EMISSIONS (Mt CO_2e pa)	COMMENTS
Home energy use (inc natural gas leakage)	51.4	From Wilkenfeld (1996) for 1990. Includes emissions from electricity generated for use by households
Embodied energy	15	very uncertain, based on 100t CO_2/new house (Lumb et al 1996)
Road travel to/from work	11.9	From Wilkenfeld (1996) for 1990
Private car use	22.3	From Wilkenfeld (1996) for 1990
Unladen business vehicle use	11.3	From Wilkenfeld (1996) for 1990. This seems to be a surrogate for private use of business vehicles, and may include business travel where unladen vehicles are returning to base
Rail, air, marine passenger travel	3.6	From Wilkenfeld (1996) for 1990. This includes business air travel
Landclearing for urban expansion	10	Maximum likely. Based on ABARE popn growth (Bush et al 1997) and assuming approx 15 people/ha, and 200tC/ha (ie 730t CO2/ha) released by clearing - often indirect, as urban development encroaches on farmland, and more land is then cleared for agriculture
CO_2 content of fuelwood harvested (possibly includes impact on soil carbon - see comment)	12.5	From p.40, NGGI Workbook 4.1, 1996 - 24% of biomass harvested from forests and woody biomass. ABARE estimates 7Mt CO_2 pa from residential fuelwood combustion - difference from NGGI may reflect soil carbon loss and oxidation of waste wood
Emissions from municipal wastes	18.7	From Wilkenfeld (1996). Benefit of converting CH_4 to CO_2. Use to replace natural gas could further cut ghgs by up to 5 Mt CO_2 pa. Larger savings if used for cogeneration.
CFCs, HCFCs and HFCs	1 to 7	Upper value is 1988 usage of CFCs from Greene et al (1990). Total CFCs in stock estimated at around 60Mt CO2 equiv (see appliance technology section) Lower value is if HFCs replace CFCs in refrigerators and airconditioners, see text
TOTAL	130 to 160	

These emissions comprise at least a quarter of Australia's total annual greenhouse gas emissions (if land-use changes is included) and, if the upper value in Table 1 is compared with the net emissions (excluding land-use change) for 1990 of 379.6 Mt (Commonwealth of Australia, 1997), they comprise around 40% of Australian emissions.

Chapter 2. Past and Projected BAU Trends in Greenhouse Gas Emissions from Household Energy Use

National Trends

The past trend and 'Business As Usual' projection by ABARE of residential sector greenhouse gas emissions on a fuel-by-fuel basis are shown in Figure 1. Electricity is the dominant contributor, generating 84% of total emissions in 1995. The share of emissions from electricity is expected by ABARE to decline slightly to 82% by 2010, due to a slight decline in greenhouse intensity of electricity over the period and an increase in market share of gas (although around half of the growth in gas seems to be expected to replace wood use).

Emissions from wood combustion are reported, but CO2 emissions from wood are not included in greenhouse inventories (NGGI 1996) because this is considered to be 'recycling' of recently absorbed CO_2. So emissions from wood burning are indicated in Figure 1 but, throughout this paper, they are excluded from analyses of overall household greenhouse gas emissions from energy use. If non-CO2 emissions (especially methane) are included, emissions from burning wood in open fires, which are poorly controlled, are comparable with those from natural gas (see Energy Efficient Strategies et al, 1999). Emissions from loss of soil carbon associated with timber harvesting are reported separately under the NGGI 'forestry and land-use change' sector.

ABARE's projection of residential sector emissions is based on estimates of cost of energy, real household disposable income, technical change, structural change, energy tariff structures and population projections (Bush et al 1997). Figure 1 shows that emissions growth since the early 1980s has been slower than in the 1970s. ABARE expects emissions to peak around 2001, then decline slightly, presumably due to increasing impacts of energy efficiency measures and slight reduction in the greenhouse intensity of electricity. Some wood use is expected to be replaced by gas or electricity.

Figure 1. Greenhouse gas emissions from Australian household fossil fuel use (including electricity) (based on energy data from Bush et al, 1997)

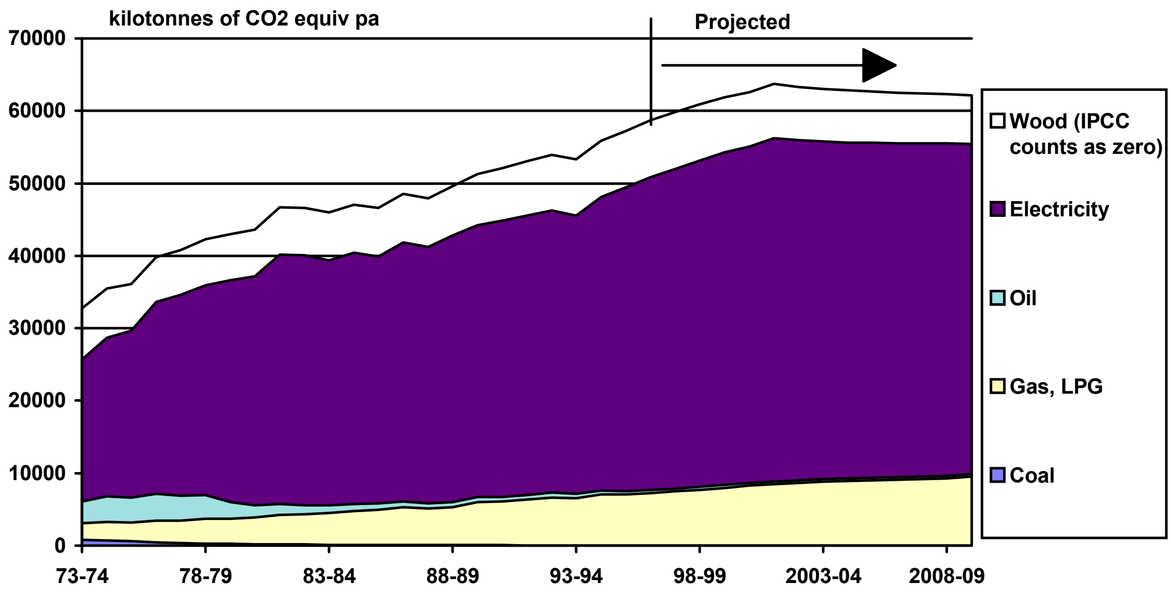


Figure 2 shows that household greenhouse emissions per capita peaked in the early 1980s, declined slightly over the mid-1980s, and rose slightly through the 1990s. ABARE expect them to continue to increase, then peak around the year 2000 before declining. These trends reflect end-use factors such as increasing central heating and cooling and growth of appliance ownership, while the longer term projection may reflect the impact of saturation of appliance ownership and ongoing improvement in appliance and building energy efficiency.

The widening gap between the end-use energy consumption per capita and emissions per capita through the 1970s and early 1980s reflects an increase in the overall greenhouse intensity of energy used in the residential sector, as shown in Figure 3. This indicates an increase in market share of more greenhouse-intensive energy sources such as electricity from fossil fuels at the expense of oil, and natural gas at the expense of wood, as well as an increase in the greenhouse intensity of electricity over that period as generators shifted from oil to coal. The increase in greenhouse intensity since 1994 may be linked to the increase in greenhouse intensity of electricity generation as the share of coal-fired power generation has increased with emergence of the National Electricity Market.

Figure 2. Greenhouse gas emissions per capita from Australian household energy use (based on energy and projected population data from Bush et al, 1997, and past population data from ABS)

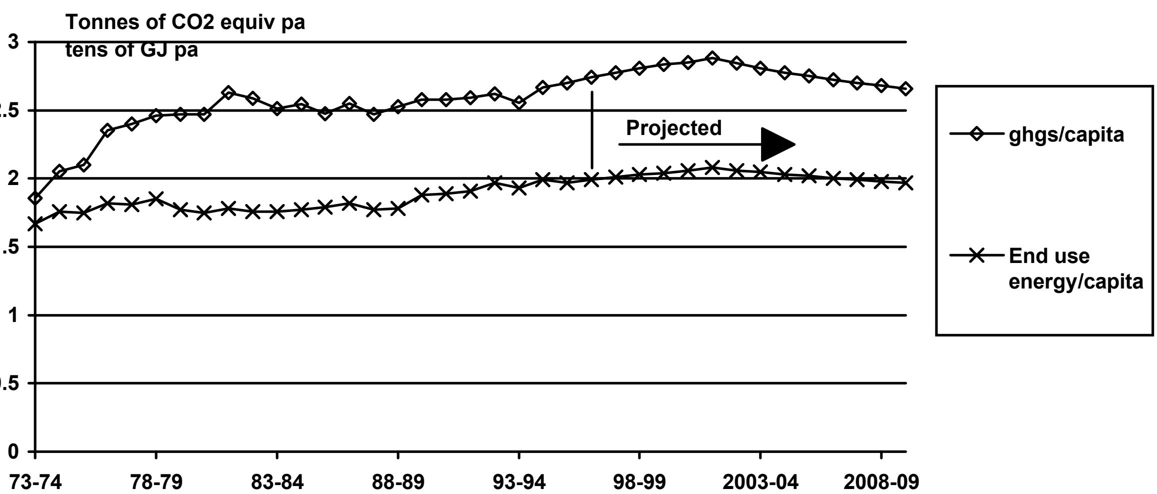
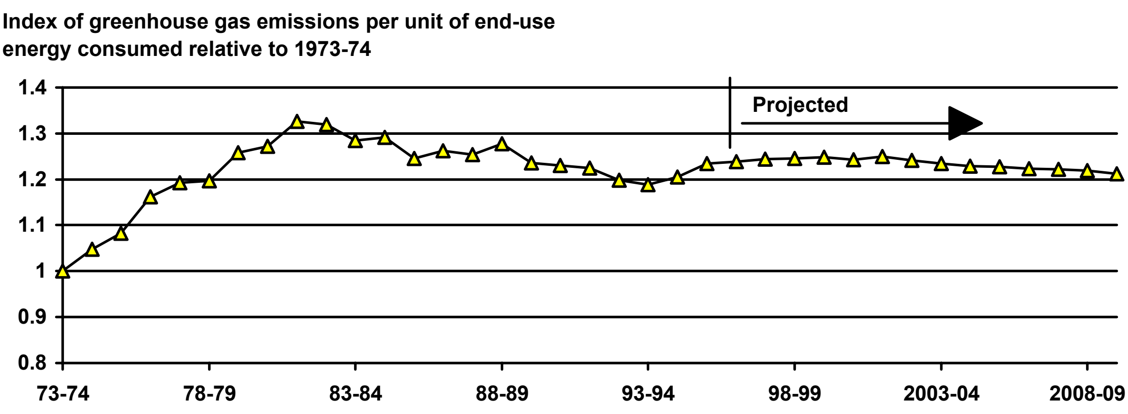


Figure 3. Greenhouse intensity of end-use energy consumed by Australian households, relative to 1973-74 reference value.



Trends by state

Figures 4a and 4b show state-by-state trends in greenhouse gas emissions. It should be noted that national average values of emissions associated with electricity supply (except for Tasmania and Northern Territory) and other fuels were used to prepare these graphs. National energy markets are making state-specific data less relevant for NSW, Victoria, Queensland and South Australia, while the greenhouse intensity of Western Australian electricity is close to the Australian average. It was assumed that Tasmania's electricity was all generated from hydropower (zero emissions) and that Northern

Territory emission intensity was 200 ktCO_2 equiv/PJ until 1991 (the average of 1988 and 1990 values reported by Wilkenfeld et al (1996)), declined to 190 in 1992, then to 167 ktCO_2 equiv/PJ from then on, reflecting the introduction of combined cycle gas-fired power generation . It can be seen that the high growth States over the past decade have been Queensland Western Australia and Northern Territory. This is largely due to greater population growth in those areas, although it also reflects growth in airconditioning loads in these warmer regions. It should be noted that growth in Northern Territory emissions would have been much greater if the mix of fuels for power generation had not changed. The weather-dependence of emissions seems to be reflected in the lower consumption in southern states for 1993-94, a year with a mild winter.

Figure 4a. Greenhouse gas emissions from household fossil fuel use (including electricity based on national average emission intensity except for Tasmania and Northern Territory) by state (based on energy data from Bush et al, 1997)

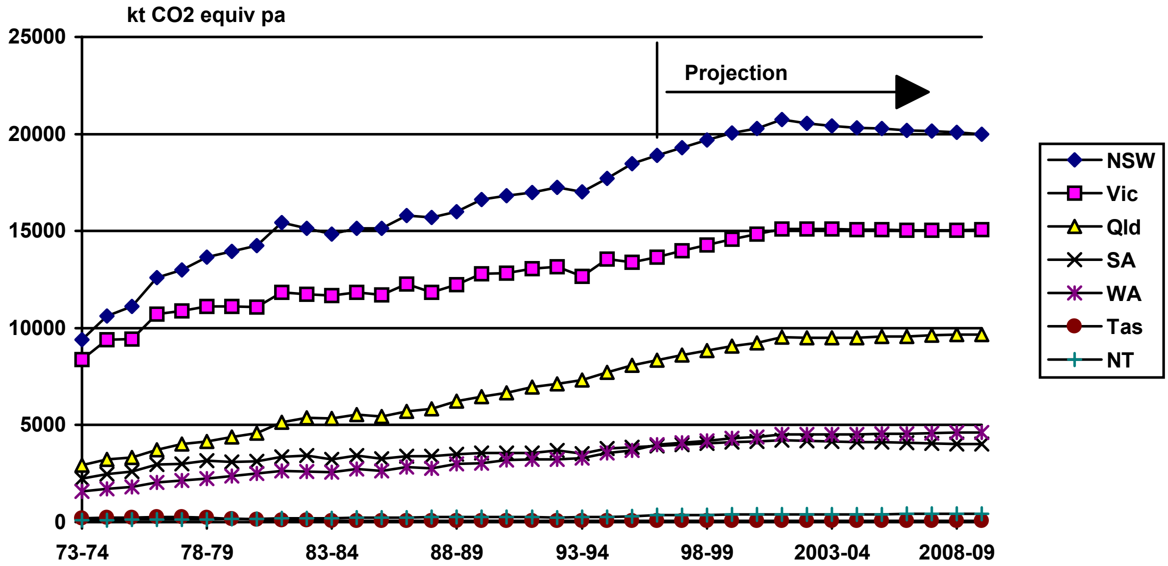
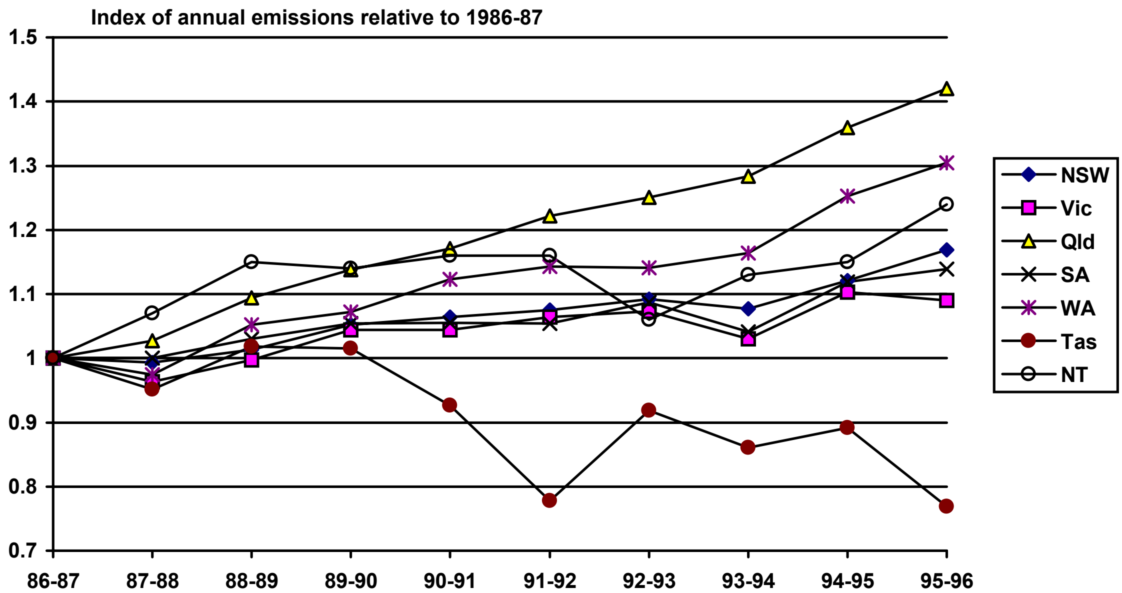


Figure 4b. Relative changes in state-by-state greenhouse gas emissions from household fossil fuel use (including electricity) over the past decade (based on energy data from Bush et al, 1997).



State by State trends in emissions per capita are shown in Figure 5a. It can be seen that the greenhouse intensities per capita are highest for Victoria and NSW. If the higher emissions from Victorian brown coal power stations were allocated to Victorians rather than across Australia, their emissions per capita would be even higher. Victoria's high emissions per capita also reflects factors such as high heating energy consumption, widespread use of large externally-located off-peak electric HWS units (which lose more heat and facilitate higher hot water consumption than smaller tanks) and higher use of clothes dryers, despite a high penetration of less greenhouse-intensive natural gas. The high level of emissions in NSW reflects relatively low penetration of natural gas, and the high level of electric space heating (as demonstrated by the fact that NSW residential electricity demand peaks in winter).

Figure 5a. Greenhouse gas emissions per capita from household fossil fuel use (including electricity based on national average emissions except for Tasmania and Northern Territory) by state (based on energy data from Bush et al, 1997 and population data from ABS)

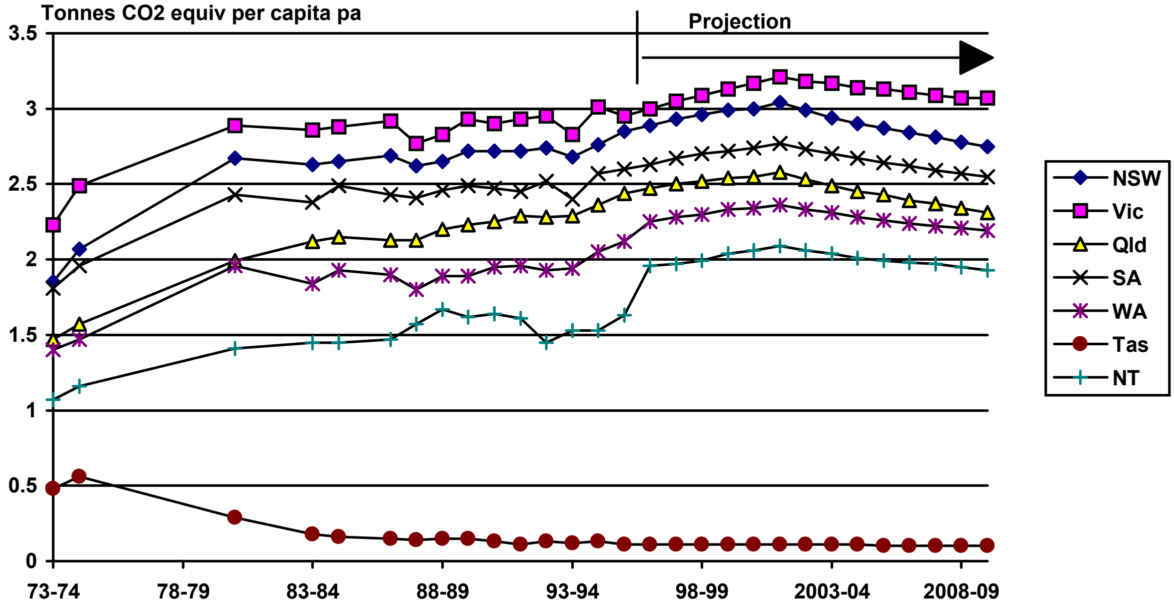


Figure 5b. Relative changes in state-by-state greenhouse gas emissions per capita from household fossil fuel use (including electricity) over the past decade (based on energy data from Bush et al, 1997).

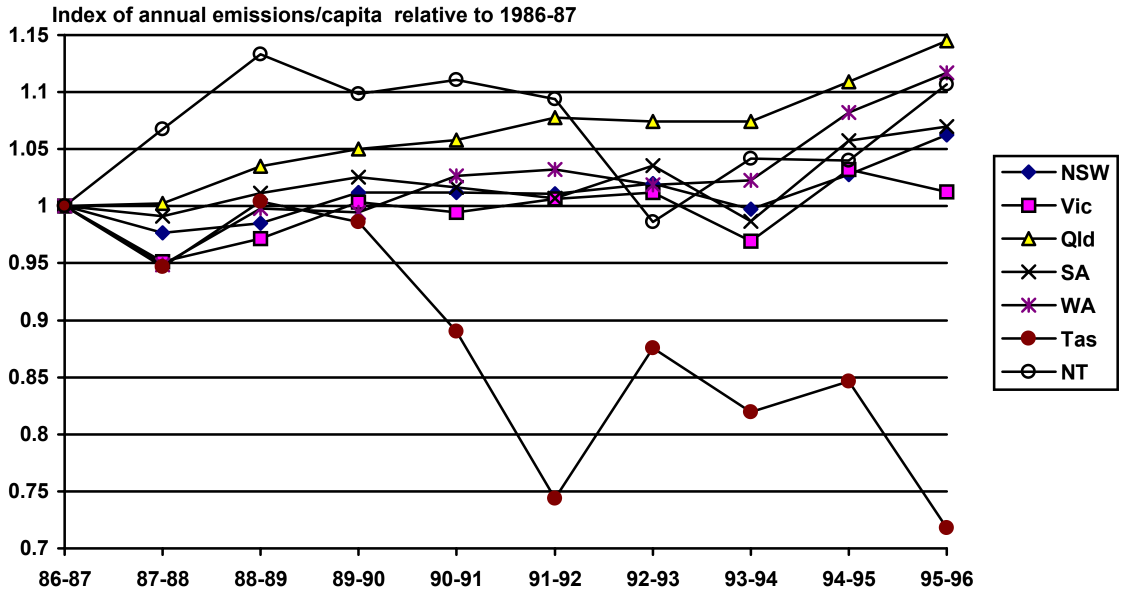


Figure 5b shows trends in emissions per capita over the past decade. The trend in emissions per capita in the Northern Territory over the past few years results from strong growth in airconditioning due to changes in building design, increasing disposable incomes and migration of people from cooler climates, combined with a 17% reduction in greenhouse intensity of electricity in the early 1990s (Kieboom et al, 1998). Above average increases in Queensland, Western Australia, South Australia and NSW are consistent with higher usage of airconditioners and higher ownership of more than one refrigerator, as shown in Figure 18a. Victoria's emissions pre capita have remained relatively constant, despite rapid growth in penetration of central heating and airconditioning: this may reflect the compensating impact of the home insulation regulations introduced in 1991, intensive promotion of schemes such as energy labelling, and ongoing activity of Energy Victoria - until the recent establishment of the better-funded NSW Sustainable Energy Development Authority, the highest profile sustainable energy agency in Australia.

Factors influencing future trends

Household greenhouse gas emissions are dependent on:

- the greenhouse intensity of electricity (which may vary markedly due to changes in the mix of energy sources used to generate it)
- the mix of energy sources of varying greenhouse intensity used to satisfy household energy service requirements
- the types and scale of energy service requirements, which are related to factors such as the sizes of homes to be kept comfortable, the range of amenities desired (eg one television per household or per person), and the quality of service desired
- the amount of energy used to satisfy each energy service requirement, which depends on the efficiency of buildings, appliances and equipment, as well as behaviour of householders
- trends in population, household size and internal migration between areas with varying climates and access to different energy sources

These factors have interactive effects, which can amplify or reduce the overall outcome of trends. For example, if the greenhouse intensity of energy supply declines by 10% while efficiency of energy use improves by 10%, total emissions will decline by 19% (all other things being equal). Also, if household size declines, the number of households for a given population increases, and total energy consumption increases, reflecting loss of economies of scale. It is important to recognise these interactions, as they can lead to larger or smaller than expected impacts on rates of emissions. The potential impact on emissions of each of these issues will be considered later in this report.

ABARE's Business As Usual projections, shown in this section of the report, reflect one informed view on how these factors will influence household energy use and greenhouse gas emissions if present trends continue, including fairly stable energy prices and market conditions. Many factors could influence the actual future outcomes, including the impacts of accelerated greenhouse emission programs, strong consumer adoption of energy intensive or energy saving technologies, changing market behaviour of the emerging competitive energy sector, and so on.

In this report, attention will be focused on strategies that:

- reduce the greenhouse intensity of each energy source, and of the mix of energy sources used by households
- reduce the amount of energy required for each energy service through improvement in the technological energy efficiency of buildings and equipment, and through influencing householder behaviour, including purchase decisions

Chapter 3: The Household Context

Overview

Many factors associated with the characteristics of households can affect their level of energy use and their response to greenhouse response measures. This chapter reviews a number of issues, including:

- variability in energy costs and usage
- variation in cost of energy supply
- home occupancy patterns
- trends in household size and composition

Knowledge of these factors can be used to optimise and target programs. Energy suppliers are beginning to use such information to develop well-resourced and sometimes aggressive promotional strategies (see Chapter 6). It will be important to ensure that such efforts support greenhouse gas emission reductions, rather than driving an increase in emissions. So public sector policy analysts must commit substantial resources to improving their understanding of the forces driving trends in greenhouse gas emissions.

Variation in energy costs and usage

Data on household energy use are usually published as average values. This form of presentation obscures the reality that there is great variability of energy use within households. This variability provides an opportunity to target programs towards groups with greatest scope for emission reductions.

Geographical variation

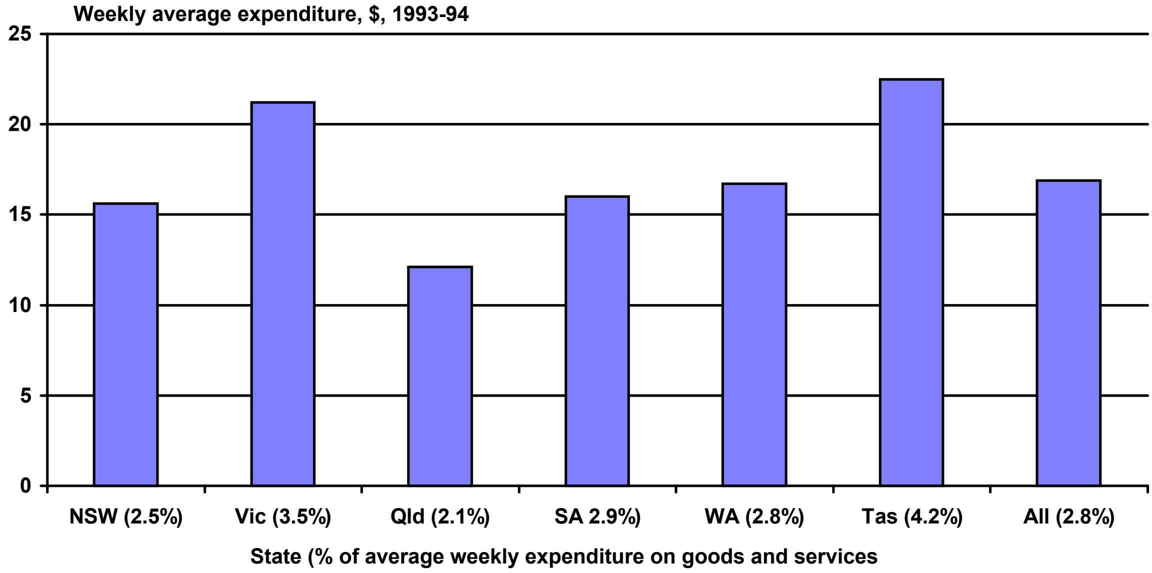
Energy use and greenhouse gas emissions vary with geographical location, due to climate and access to different energy sources. Data from Western Power indicate that average household electricity consumption in Port Hedland (in hot NW Western Australia) is around 10,200 kWh per year, compared with around 3,500 kWh in Perth (which is reduced by the relatively high penetration of gas space heating and solar hot water) and a national average of around 6,000 kWh. Since hot water requirements are reduced in Port Hedland by the warm water supply temperature and high ambient temperatures, and space heating is negligible, this indicates very high cooling and appliance electricity consumption there. This example indicates that regional programs targeting relevant activities, possibly run with local government and/or local energy suppliers, have potential to achieve substantial cost-effective greenhouse emission reductions. Regional operation would minimise waste by facilitating accurate targeting.

Variability in energy use and greenhouse gas emissions on a state-by-state basis is illustrated by the expenditure data in Figure 6 and the emissions per capita data in Figure 5 in the previous chapter. Greenhouse emissions per capita and expenditure on energy on a state-by-state basis do not correlate closely, because of wide variations in types of fuel consumed (eg high gas usage in Victoria), and variations in unit cost of energy (for example, average cost per kWh in Queensland is 9.7 cents, compared with 13.6 cents in Western Australia (ESAA 1995)). It can be seen that Victorian households spend most on energy and are most greenhouse intensive. NSW households are high in greenhouse intensity but below average in expenditure: this reflects their relatively low electricity prices and their greater reliance on electricity from fossil fuels.

All other things being equal, it seems that encouraging migration away from areas with more extreme climates to those with more moderate ones could help reduce household greenhouse gas emissions. However, this position ignores possible increases in transport energy use to visit relatives who move interstate. Further, there is substantial scope for states such as Victoria to reduce household greenhouse emissions per capita to much lower levels through appropriate emission reduction strategies.

Competition between states on this indicator may be a useful motivator for State level greenhouse emission response.

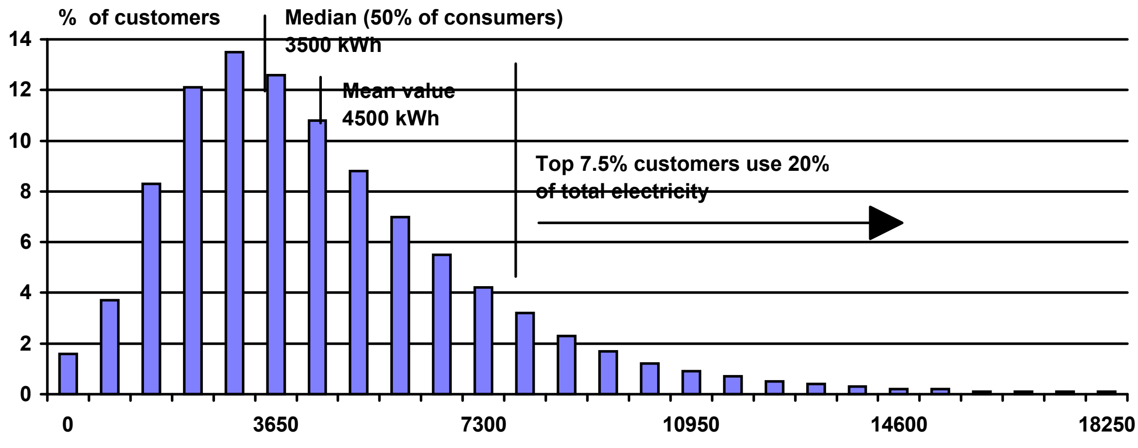
Figure 6. Australian household expenditure on fuel and power on a state-by-state basis, 1993-94 in dollars and as a percentage of expenditure. (ABS 4102.0, 1996)



Variability within geographical regions

There is also wide variation in energy consumption and greenhouse gas emission per household within geographical regions, due to a variety of factors including appliance mix, household size, dwelling characteristics and occupant behaviour. This variation is illustrated in Figure 7, where the 7.5% of households with the highest bills consume 20% of all the electricity used. Further research is required to identify why these households use so much electricity, and it should be possible to develop strategies that target them. High usage households may have energy-intensive equipment, faulty equipment, or may have greater interest in cutting their energy bills - although experience has shown that where households with high bills also have high incomes, they may have lower than average interest in reducing energy bills.

Figure 7. Typical profile of residential sector energy customers by annual electricity consumption, 1997 (anon)



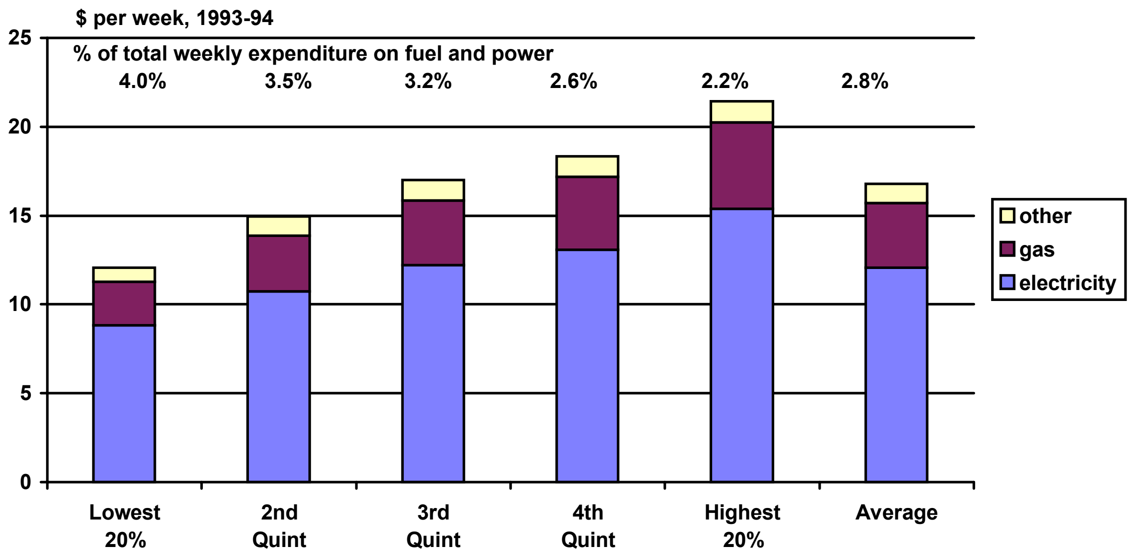
Reducing the greenhouse gas emissions from one household that now consumes 15,000 kWh per year could be more cost-effective and practicable than trying to achieve smaller savings in five or ten households with modest consumption.

Variation with income

Expenditure on energy also varies with income. Figure 8 shows the distribution of expenditures on energy by quintile of income. This understates the variation in energy consumption, because fixed charges or minimum charges for connection to supply are between $1.50 and $5 per week, depending on the electricity supplier and whether gas is also connected.

It should also be noted that low income households include large numbers of small households, including retired people who may be more frugal in their energy use than future retirees, who are used to a wide range of appliances and high standards of comfort. It is unlikely that targeting of greenhouse programs by income group alone would facilitate effective emission reductions, as the diversity of fuel type, appliance ownership, dwelling size and behaviour within each income group is probably great.

Figure 8. Australian household expenditure on fuel and power by income quintile, 1993-94 (ABS 6535.0).



Non-grid-connected households

An important group of households who experience high energy costs are households not connected to the electricity grid These people rely on diesel generation, LPG and/or renewable energy sources for their energy requirements. In some cases, their energy costs may be subsidised. Various sources estimate that up to 20,000 households fall into this category (EGRET 1996).

Although it is often assumed that these households must use energy wisely because of its high cost, this is often not the case. Many users of diesel generators waste energy because they need to create a minimum load for their diesel generator: lightly-loaded diesel generators are prone to cylinder glazing and premature wear, leading to increased maintenance costs. The scope for energy efficiency improvement in these households is illustrated by the outcome of a Queensland project (DPIE, 1996), in which the energy consumption of a rural homestead (Kallalla Station) was reduced by 70% through application of energy efficiency measures. This reduction dramatically cut the capital cost of installation of a renewable energy system, making it cheaper than either diesel generation or grid connection, and reducing greenhouse gas emissions by 95% compared to grid connection.

Caravans and transportable homes

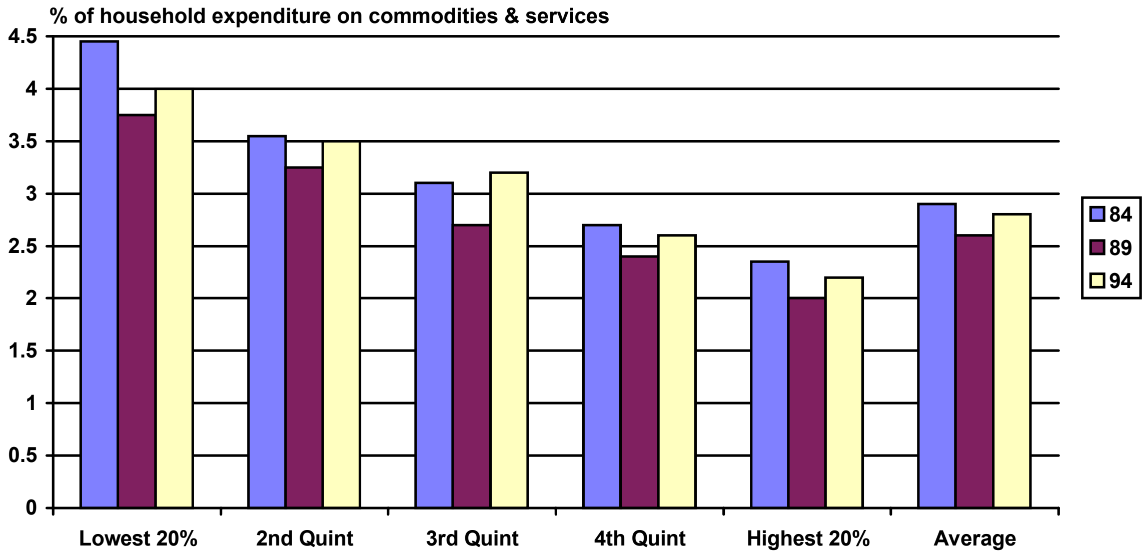
According to ABS, over 77,000 Australian households live in caravans or transportable homes. In many cases, these are small households with low incomes, such as retirees or itinerant workers. It has not been possible to locate data on their energy use, but analysis carried out in Victoria in the 1980s identified them as a group with high energy costs and significant incidence of energy poverty (that is, they experience lower living standards because provision of adequate energy services is too expensive or impracticable, given their accommodation and income).

Since caravan parks do not normally provide reticulated natural gas, these households use electricity or LPG as their major energy sources. Although modern transportable homes are, in many cases, quite well-insulated, most caravans and older transportable homes have little or no insulation and are very difficult to keep comfortable without heavy energy consumption. Further, some of the appliances they use are also expensive to operate and inefficient: for example, LPG and day-rate electric heating and hot water services are widely used, while 'three-way' refrigerators (which can run on LPG, low voltage or mains voltage electricity) which are extremely inefficient, may be widely used.

Variation over time

As background to development of greenhouse strategies, it is useful to look at energy costs over time. If householders believe that energy costs may rise in the future, they may be more likely to place higher priority on energy efficiency in their investment decisions. Figure 9 shows that energy costs have varied as a percentage of household expenditure by up to 0.3 percentage points over the past decade - not a major issue for most households although, in dollar terms, average expenditure has risen from $10.56 in 1984 to $16.77 in 1994. However, this rise occurred in a time of significant inflation and high interest rates, which had a disproportionate impact on the capital-intensive energy sector. Future trends in urban energy prices are unlikely to show significant increases, and may even decline due to low interest rates and market forces. Country households, however, may experience substantial cost increases if subsidies decline.

Figure 9. Trends in Australian household expenditure on fuel and power (ABS 6535.0 and 4101.0)



Changes in tariff structures

The structure of the emerging energy markets may reduce the financial incentive for household energy users to reduce their energy consumption and greenhouse gas emissions. Since control of tariff structures will be relaxed, energy retailers may be inclined to increase quarterly supply charges and reduce marginal unit prices to protect their market position and to reflect the charges levied by generators, transmission agencies and distributors - many of which are not directly related to the quantity of energy consumed. It may be necessary for regulators to specify tariff structures for the residential sector that limit the size of supply charges and prohibit low marginal energy prices, so that significant financial incentives will exist to encourage energy saving and greenhouse emission reduction.

Figure 10. Effects on different types of electricity consumer's annual electricity bill if quarterly charges are increased and unit price decreased.

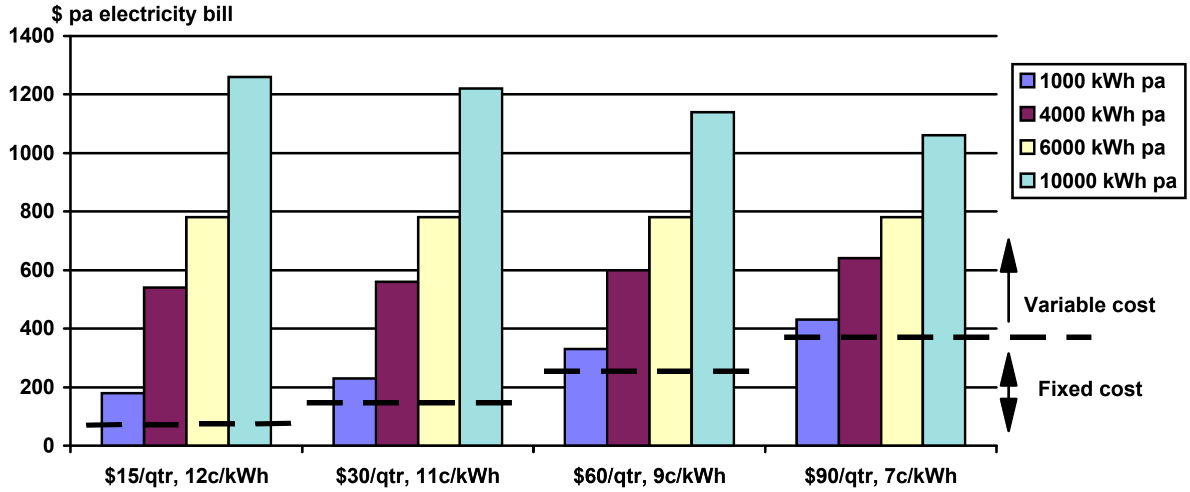


Figure 10 shows the effect of changing the balance between supply charges and unit price of electricity on the annual electricity bills of a small, energy efficient household (1,000 kWh pa), a typical gas-using household (4,000 kWh pa), an average Australian home (6,000 kWh pa), and a large electricity user (10,000 kWh pa). The total charges have been set so that the average home sees no change in its total electricity cost, so that there is no net change in the electricity supplier's revenue. There are dramatic changes in costs for the various households. If the $15/quarter and $90/quarter supply charge scenarios are compared, the following may be noted:

- the financial saving from reducing electricity consumption by one kilowatt-hour declines from 12 cents to 7 cents when the supply charge is increased, a 42% reduction: this reduces the cost-effectiveness of energy efficiency measures and fuel-switching
- for the small, energy-efficient household, annual electricity cost more than doubles, from $180 to $430 per year
- for the large consumer, annual electricity cost falls by 16%, from $1,260 to $1,060
- the unavoidable supply charge reaches $360 per year, and is 84% of the total bill of the small, energy-efficient household, making its average effective electricity cost 43 cents per kWh, compared with an average cost of 10.6 cents per kWh for the large consumer

Clearly, a shift towards higher fixed charges and lower marginal prices would adversely affect greenhouse response, and would also be socially regressive and anti-competitive, as it will impact heavily on the cost-effectiveness of energy efficiency and fuel switching by reducing the avoidable cost of electricity, and it will increase costs for small households. Such changes are not just future possibilities: the Tasmanian HEC introduced a quarterly supply charge of $87.36 and unit price of 6.4 cents/kWh in 1996, but was forced by the Government Prices Oversight Commission (1996) to reduce the quarterly charge to $45. The Victorian Government doubled the quarterly electricity supply charge to almost $34 just before selling off its distribution and retail infrastructure.

The above situation could be made even less favourable for energy efficiency and fuel switching if electricity retailers also reduce the unit charge as consumption increases. For example, the unit charge for the first, say, 1,000 kWh per quarter might be 8 cents/kWh with a reduction to, say, 5 cents/kWh above that consumption level. This type of *declining block* tariff is already used by the Tasmanian HEC, where the quarterly supply charge is now $47.54, the first 500 kWh cost 12.01 cents/kWh, the next 1,000 kWh cost 9.34 cents/kWh, and the balance of consumption is charged at 7.39 cents/kWh (ESAA 1998).

There seems to be a case for Government to ensure that legislation covering the energy sector maintains a role for Government to control tariff structures, so that they cannot be structured in ways that adversely affect energy efficiency and fuel switching.

Variation in cost of energy supply

Apart from off-peak electricity tariffs, variations in the cost of energy supply have traditionally not been visible to most households, due to cross-subsidies between sectors, and between groups of consumers. For example, it is widely recognised that the cost of supplying energy to rural consumers is higher than for urban consumers, due to higher infrastructure and maintenance costs, and greater energy losses in delivery of the energy. One example of the variation in cost (Gilchrist, 1994) for a rural area in NSW showed an electricity supply cost of up to 21.22 cents/kWh compared with an average selling price of up to 14.53 cents. This led to an average annual subsidy of $412 per household on one of the feeder lines evaluated. The results of a study published by the State Electricity Commission of Victoria (1991) indicated that outlying rural residential households paid only half of the cost of supply while residents in country towns paid on average less than two-thirds of the supply cost.

The benefit of identifying groups of households with high energy supply costs is that there is potential to build alliances with their energy suppliers, who often make a loss supplying services to these customers, and State Governments. who may pay subsidies to limit their energy costs. Reduction in greenhouse gas emissions can thus deliver financial benefits to several parties, not just the householder.

However, the framework created by the emerging national energy markets may not encourage energy suppliers to pursue savings. For example, regional averaging of distribution charges has the effect of averaging costs over large areas. The desire of market participants to seek increased market share, even if it loses money in the short term, can also distort the market. These issues are discussed later in this report.

Despite this uncertainty, a number of potentially high supply cost household consumer types and activities can be identified. These may include:

- rural households near the fringe of the grid, particularly those on single wire-earth return (SWER) lines, where up to half of the electricity supplied may be lost through line resistance: so up to twice as much electricity must be purchased and supplied by a retailer as is actually sold. While infrastructure costs for these households are also high, but their loads remain within the capacity of existing infrastructure, there is limited scope for savings
- households in areas of growing population, where the capacity of existing infrastructure is being exceeded. This may include inner urban areas where urban consolidation is occurring, as well as outer urban growth corridors and rural areas
- areas with many holiday homes, which have high seasonal peaks
- appliances or equipment that contribute disproportionately to peak energy demand. For summer peaks, this may include airconditioning, swimming pool filter pumps, day-rate HWS units, etc. For winter peaks it may include space heating, lighting, cooking, etc

Identification of opportunities can require detailed knowledge of consumers' energy use patterns and the energy supplier's infrastructure and costs. Alliances are therefore likely to be necessary to fully exploit these opportunities for greenhouse gas emission reduction.

Home occupancy patterns

The mix of age groups in Australian society influences the types of housing required, trends in household size - which influences the number of dwellings for a given population, and the time spent in the home.

Figure 11 shows that the proportions of people in the age groups of dependant children (0-19 years) and parents of dependant children (30-49 years) are expected to decline, while the proportion aged older than 50 will increase. The groups most likely to live as smaller households (20 to 29 and over 60 years) will increase from 40% to 50% of the population. Also, the number of households with dependant children may increase, as more people have one or two children instead of larger families, and divorced couples share their children across two households. More affluent households may also choose to own holiday homes, further reducing average household size if it is calculated by dividing the population by the number of dwellings.

Figure 11. Distribution of age-groups in the Australian population (Projection A, ABS 3222.0)

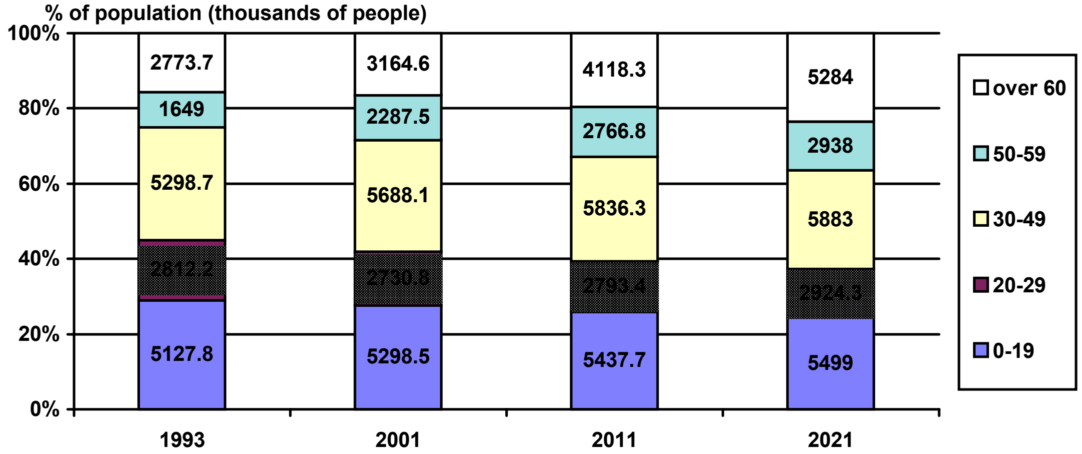
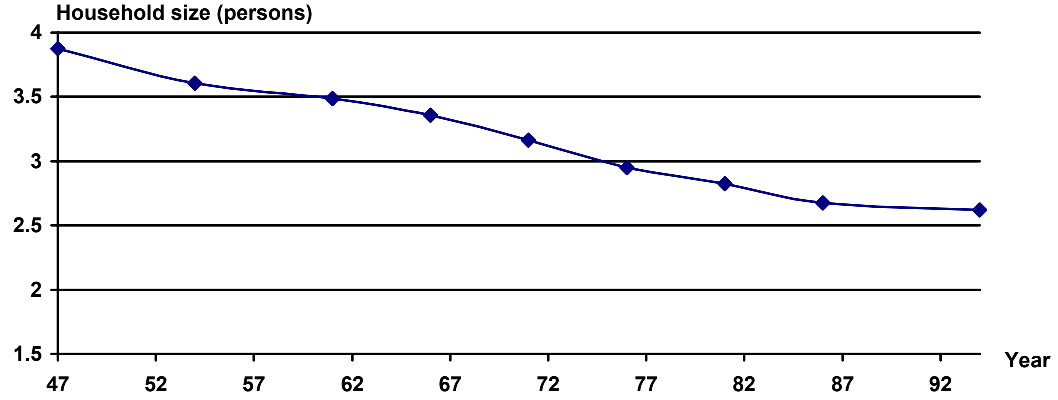


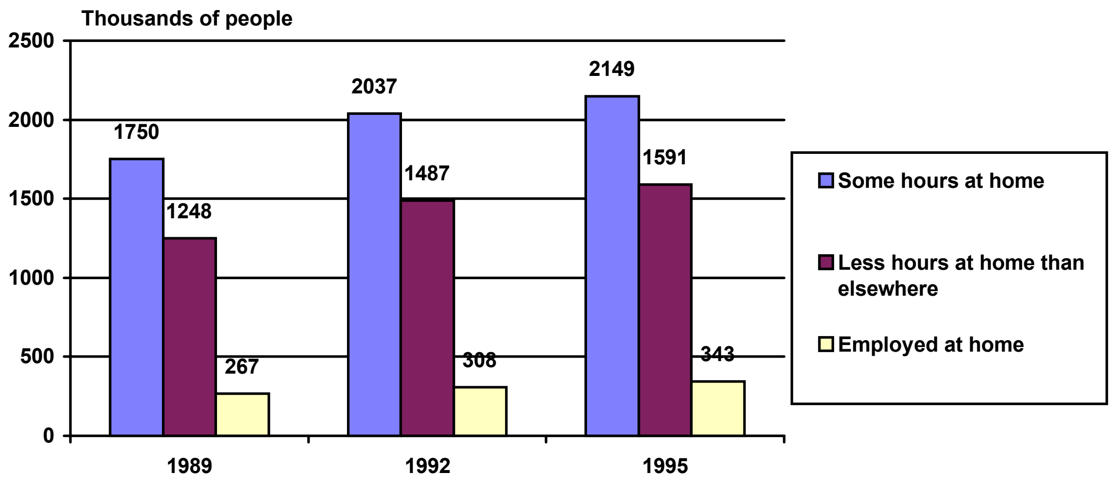
Figure 12 shows the trend in average household size, which shows some signs of stabilisation. It is not clear whether this stabilisation is a long term trend, or whether the factors discussed above will drive household size down further. However, it should be noted that by 1994, 21.8% of households were single people and 25.8% were couples (ABS 6530.0, 1994). When other types of small households, such as single parents with one dependant are included, over half of all households already include only one or two people. So the downward trend should at least slow, if not flatten out.

Figure 12. Trends in household size, Australia (ABS 2417.0, 1992 and ABS 6530.0 for 1993-94 data).



The implications of these trends for household energy use and greenhouse gas emissions are unclear, but potentially significant. Since each house has a minimum rate of energy consumption to provide basic services, even at low occupancy, an increase in the number of households for a given population will tend to increase energy consumption. If the increasing numbers of smaller households occupy medium density housing, which at present comprises only 12.5% of housing but which comprised 25% of new dwellings built between 1986 and 1994 (ABS Yearbook, 1996), energy consumption per household for heating, cooling and lighting may decline. This type of housing is potentially more energy-efficient than detached houses because walls, ceilings and floors are more often shared, floor area is usually smaller than for detached houses, and the number of appliances, such as separate freezers, that can be installed is constrained by lack of space. However, medium density housing has traditionally relied more heavily on electricity instead of gas, so even though energy consumption may be lower, there is no guarantee that this will also lead to lower greenhouse gas emissions.

Figure 13. Home-based employment (ABS Australian Yearbook 1998)



People who spend more time at home in retirement, work from home, and those with part-time care of children, may wish to have access to outdoor space, garages, workrooms etc, so demand for detached homes with backyards may remain high, unless adequate provision for such facilities is made in new medium density development.

The number of hours spent at home seem likely to increase for many households. As noted above, there will be more retirees, and there may be more households with dependant children (with fewer children per household). Also, the incidence of people working at home (see Figure 13) and working part-time -

so they have more time available to be at home, is increasing. For these households, energy use is likely to increase, due to the longer periods of operation of space heating and cooling and lights, more meal preparation, and use of office equipment. For other dwellings, particularly holiday homes and homes of part-time parents, overall occupancy periods may be quite low, but energy use when they are occupied may be high.

These complex trends have important implications for greenhouse response programs. These include:

- more homes will have low, intermittent, or very variable occupancy. This means standby losses from equipment (such as gas pilot lights, heat loss from hot water tanks, power consumed by digital clocks and appliances on standby) will become an increasingly significant proportion of total energy use. It will be important to ensure these forms of energy consumption are minimised. At the same time, HWS units and home heating systems will need to be sufficiently flexible to cope with periods of high usage.
- the potential for increasing adoption of more energy-efficient medium density housing will depend on whether it can provide access to open space (such as shared areas) and other facilities for retirees, children and home-based workers
- it will be important to ensure that new housing uses low greenhouse-intensity energy sources or technologies for hot water, space heating and, as a lower priority, cooking. These could include natural gas or electric reverse cycle airconditioning for heating, and gas, solar or electric heat pump HWS units, as discussed later in this report
- as the population ages, single level medium density homes will be preferable to the now-popular two-storey townhouses, as older people will find frequent use of stairs more difficult. Note that this does not necessarily mean shifting to single storey development, but it could mean a shift back towards multi-storey buildings with single-level apartments in them: this construction is more costly than two-storey townhouses, because higher fire rated floor/ceilings must be installed between residences.

Chapter 4: Greenhouse Intensity of Energy Sources

The greenhouse intensity of each energy source can vary, depending on:

- the mix of energy inputs used by the energy supply industry. For example, the higher the proportion of renewable electricity combined with fossil fuel-generated electricity, the lower the overall greenhouse intensity of each unit of electricity delivered.
- the efficiency of conversion of primary energy inputs to the final form. For example, the efficiency of a power station in converting chemical energy in coal into electricity, or the energy required to extract and process natural gas to pipeline quality
- the losses in delivering the energy to households. For example, energy is required by pumps and compressors to maintain pipeline pressure for delivery of gas

The overall greenhouse intensity of energy used by households (see Figure 3) is influenced by the greenhouse intensity of each energy source, and the share of total energy supplied by each one.

Reduction of the greenhouse intensity of each energy source is primarily an issue for energy suppliers. However, energy suppliers can use a range of strategies to gain support from households to reduce greenhouse intensity, for example by promoting *Greenpower* schemes or by publicising improvements. Such programs can be supported, promoted or regulated by Government.

Householders can be actively involved in selecting lower greenhouse-intensity energy sources, such as natural gas instead of fossil-fuel electricity. However, such strategies should be tempered by the emission-reduction potential of schemes such as *Greenpower* or offsets such as commitment to tree-planting schemes. Also, the efficiencies of end-use technologies can influence the overall greenhouse emissions per unit of useful service delivered. For example, an electric reverse cycle airconditioner using fossil fuel generated electricity can deliver a unit of space heating with about the same greenhouse gas emissions as a standard gas heater, and a microwave oven can cook food while generating less greenhouse gas than a gas cooker. Development of fuel-switching strategies will have to take into account such issues, so that unnecessary dislocation does not occur.

The remainder of this chapter evaluates the role of reducing greenhouse intensity of energy sources, and the scope for achieving reductions within the household context.

Electricity

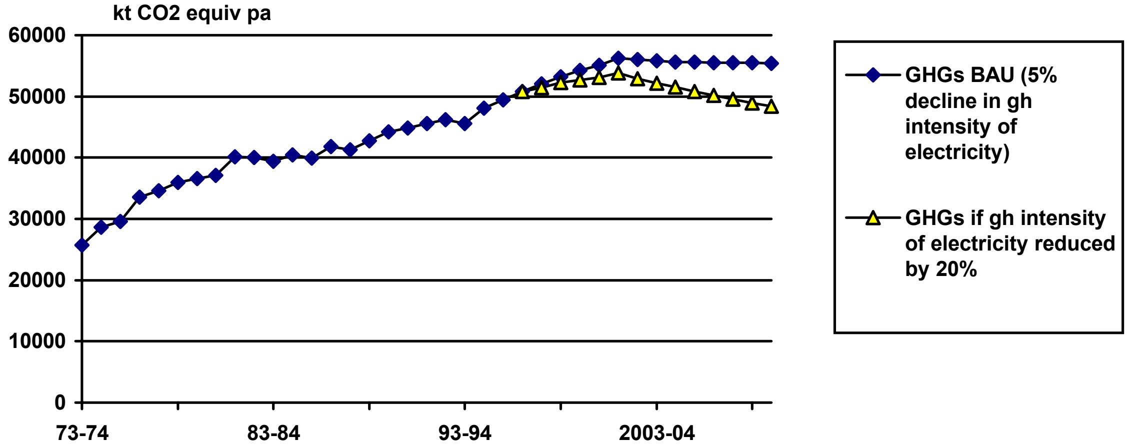
The greenhouse intensity of electricity depends upon the mix of fuels used to generate it, and the efficiency with which it is converted to electricity. At present, close to 80% of the fuel used to generate Australia's electricity is coal. With the strong competition in the newly emerging electricity market, the proportion of coal-fired electricity has increased over the past few years, at the expense of gas and hydroelectricity, leading to a slight increase (1%) in the greenhouse intensity of electricity since 1990 after a decline in intensity of almost 8% over the previous decade. Over time, the greenhouse intensity of electricity is expected to decline due to factors including:

- improving conversion efficiency, through improvements to existing power stations and through new technologies, including fuel cells, integrated gasification and combined cycle coal power stations, etc
- growth in low greenhouse intensity electricity sources, including cogeneration, combined cycle gas and renewables

However, the extent to which these trends occur will be sensitive to Government policy, the rules of the National Electricity Market and State Jurisdictions, attitudes of and strategies pursued by the electricity industry, and relative costs, as discussed below.

Changes in greenhouse intensity of electricity affect household greenhouse gas emissions regardless of the behaviour of householders (unless they change the mix of energy sources at the point of use). To illustrate this effect on emissions, Figure 14 compares the future trend in household greenhouse gas emissions under ABARE's 'BAU' scenario, in which the greenhouse intensity of electricity declines by 5% by 2010 relative to 1990, with the outcome if it declined by 20% over that period.

Figure 14. BAU residential sector greenhouse gas emissions (based on ABARE data (Bush et al, 1997)) and emissions if greenhouse intensity of electricity falls by 20% from 1990 level by 2010 (instead of 5% as in BAU) with no change in end-use energy consumption from BAU.



There is certainly technical potential to reduce the greenhouse intensity of Australian electricity by around 20% by 2010, if support is provided for gas-fired cogeneration, advanced gas-fired power generation, renewables and emerging technologies such as fuel cells. However, the actual future trend for greenhouse intensity of electricity is very uncertain.

In particular, it is unclear how the emerging electricity market will influence emission intensity. On one hand, there is powerful financial pressure for increased utilisation of existing coal-fired power stations (including some old, inefficient stations), for use of cheaper lower grade coal, and for greater long distance transfer of power, all of which increase greenhouse intensity. On the other hand, there are pressures to increase plant efficiency and cut supply losses to increase productivity, and programs such as *Greenpower* and the Commonwealth Government's 2% renewable electricity target and proposed mandatory generation efficiency standards, which reduce greenhouse intensity.

Major uncertainties relate to the rate at which cogeneration, advanced gas-fired power generation and new technologies such as fuel cells and advanced coal-fired generation technologies may penetrate the electricity market. Their market penetration will be very sensitive to the rules applied to the National Electricity Market and, at present, groups such as the Australian Cogeneration Association are expressing concern at the barriers being placed in their path by the structure of the emerging electricity market. It is also unclear how the gas and electricity markets will affect each other.

How long the high level of utilisation of existing coal-fired power stations can be maintained is uncertain, as many generators are being operated outside the limits for which they were originally designed. Some commentators suggest that existing power stations will be repeatedly refurbished and used until the coalfields which supply them are depleted, because this is the lowest-cost option. This would maintain emission intensity at a level higher than would otherwise be the case. Alternatively, owners of these power stations may simply be generating maximum revenue in the short term with a view to gaining market share and shifting to new technologies when they become available, or when the gas market is established: given the high prices paid for coal power stations sold to date, this may be a less likely scenario.

Natural gas

It is most likely that the greenhouse intensity of natural gas will remain stable or decline slightly, as fugitive losses are being cut by pipe replacement programs and improved monitoring of gas flows. This should balance any increase in transmission energy use. CO_2 re-injection may be used to control emissions where gas fields have high CO_2 content.

However, there is potential for the greenhouse intensity of natural gas to increase by up to 20% if:

- gas is extracted from gas fields with higher carbon dioxide content (eg some fields in the NW Shelf region contain up to 10% CO_2)
- LNG is used instead of pipelines - there is an energy penalty of up to 15% in liquefying and transporting LNG, while pipeline energy overheads are typically less than 5% - although this may increase if gas in piped to the eastern states from the NW Shelf. While LNG is usually seen as an export issue, it is already being used for some remote power generation in Northern Territory, and this option could be further developed as a replacement for remote diesel generation
- fugitive losses of methane during extraction and delivery are not controlled: leakage from distribution systems is, at present, significant although most seems to be from old gaspipes

There is scope to reduce the greenhouse intensity of natural gas either directly or indirectly. Direct reduction could be achieved by partially substituting gas from low or zero greenhouse intensity renewable sources, including biogas, landfill gas or wood gasification. Where this involves capture of methane which was previously leaking into the atmosphere, further greenhouse benefits are gained. The renewable gas can either be reticulated via a separate pipeline, blended with pipeline gas at low concentration so it does not excessively degrade average gas quality, or processed to pipeline quality (or close to it) before blending.

Indirect reduction of the greenhouse intensity of natural gas could be achieved by claiming offsets against revegetation. For households, this could prove financially attractive. For example, greenhouse gas emissions from gas space and water heating and cooking in an efficient house might be around 2 tonnes per year, half the emissions of an average family car. In Victoria, the *Greenfleet* scheme offers to plant sufficient trees to offset the emissions from an average car for a (tax deductible) $25 per year. Application of this approach would add less than 5% (after tax deduction) to the annual gas cost, a much smaller increment than that charged for *Greenpower* by electricity suppliers.

Fuelwood

While the IPCC does not count CO_2 emissions from biomass combustion in its inventory, fuelwood production contributes to greenhouse gas emissions through:

- landclearing: according to NGGI (1996a), 24% of all wood commercially harvested from Australian forests is for fuelwood. A Victorian study (VNPA 1997) has suggested that fuelwood removal from Victorian forests is at a rate of 1.5 to 2.5 million tonnes per annum, compared with woodchipping at 1 million tonnes per annum. And VNPA notes that much of the fuelwood involves rarer species such as box, ironbark and redgum. Sale of fuelwood supports the economics of land-clearing.
- transport and processing: some fuelwood is now transported hundreds of kilometres, often in relatively small trucks. Transport over 100 kilometres adds around 1 kilogram of CO_2/GJ of energy content in the wood, which is still small relative to emissions from fossil fuel combustion for home heating (eg natural gas is around 60 kg CO_2e/GJ)
- non-CO_2 emissions: where wood is burnt under sub-optimal conditions, some methane and volatile organics can be produced. For wood burned in closed combustion heaters, the global warming impact is relatively small compared with emissions from fossil fuels - estimated at 4 kg CO2/GJ (EES, 1999) compared with around 60 kg CO2/GJ for natural gas. However, wood burned in an open fire under poorly controlled conditions is estimated by EES at 58 kg CO2/GJ, comparable with that for natural gas on a per-unit-of-energy basis. This is much worse when compared on a delivered heat basis (as up

to 10 times as much wood may be burned in an open fireplace to deliver an equivalent amount of useful heat to one unit of natural gas). Pressure to improve air quality is leading to reduction of these emissions

Inefficient use of wood, especially in open fires, amplifies the greenhouse impacts of wood by increasing the amount (and hence land-use impacts) required to deliver a given amount of useful heat. Even modern sealed heaters are often operated at very poor efficiencies because they are over-sized for the area they heat, and run at low output with limited air supply overnight, so they burn under sub-optimal conditions.

Mix of energy sources

The overall greenhouse intensity of energy can be varied by changing the balance between the quantities of energy supplied by energy sources of different greenhouse intensity. In the extreme, switching from fossil fuels to renewable energy achieves the greatest reduction. This section considers the significance of switching between energy sources.

Switching between electricity and gas

ABARE's BAU scenarios are based on electricity maintaining its share of household end-use energy (at approximately 43%), gas increasing its share from 30.4 to 37.9%, wood's share declining from 23 to 17.1%, and oil and coal declining from 2.9 to 1.1% between 1990 and 2010.

To illustrate the effect of changes in market shares of energy sources, a sensitivity study was done to investigate the impact on greenhouse gas emissions if 10% of the electricity consumed under BAU in 2010 shifted to natural gas. This would involve around a third of households with electric HWS (roughly 20% of all households) switching to gas hot water between 1990 and 2010. It is assumed that 1.5 PJ of gas will be consumed in place of each PJ of electricity, to reflect differences in end-use efficiency. Figure 15 shows that this reduces total household emissions by 3 Mt pa in 2010, a reduction of just over 5%.

For space heating, the impacts of switching from electricity to gas are not so clear. For example, a household with electric space heating may switch to gas central heating, leading to a very large increase in energy use and a much smaller than expected reduction in overall greenhouse gas emissions.

Since around a third of household electricity is used for purposes, including water and space heating and cooking, that could be satisfied by direct use of lower greenhouse intensity energy sources such as natural gas, wood or solar energy, there is clearly substantial scope for fuel-switching from electricity to reduce household greenhouse gas emissions. However, there are indications that some electricity suppliers are implementing marketing strategies aimed at gaining market share from gas in the household sector, and promoting very high greenhouse intensity options such as in-slab electric off-peak heating and large off-peak electric HWS units. So there is a real possibility that fuel-switching to electricity from gas could occur, possibly increasing household greenhouse gas emissions.

This situation will be further complicated by the likely emergence in the energy market of combined energy suppliers, who will retail both gas and electricity: they will promote the option that has lowest supply cost for them. For example, in the 1980s, the State Electricity Commission of Western Australia (SECWA) which sold both gas and electricity, actively promoted use of gas for home heating, cooking and hot water in preference to electricity. The Government of Western Australia (1990) claimed that this strategy saved the state about $500 million in capital expenditure on power plant over five years, while utilising gas supplied from the NW Shelf under a take-or-pay contract.

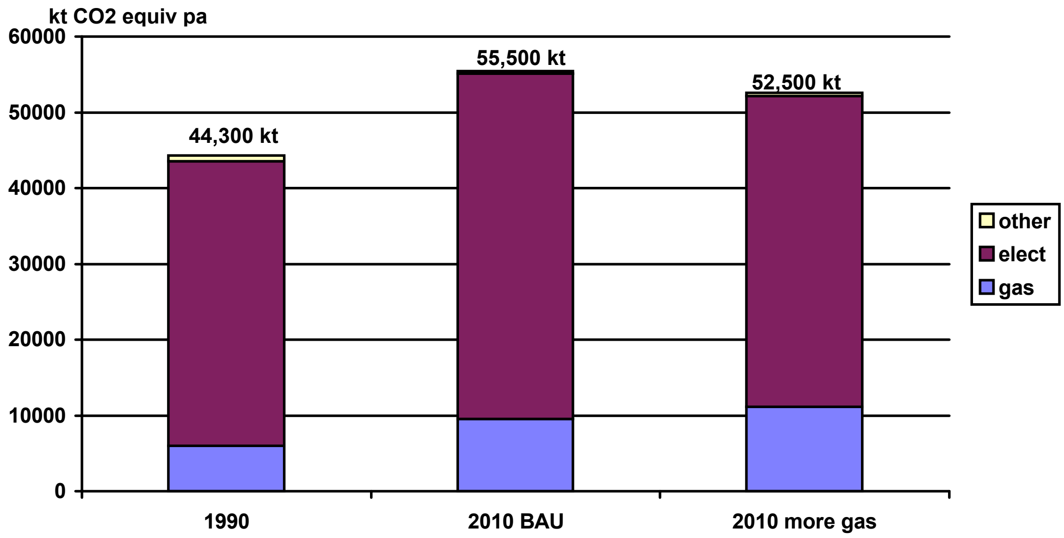
Shifting from wood

If wood maintained its percentage share at the 1990 level of 23% instead of falling to 17%, it would supply 20.6 PJ of additional end-use energy in 2010. If this wood replaced gas consumption - assuming gas is used twice as efficiently as wood, this would displace approximately 10PJ of gas and 0.6 Mt pa of greenhouse gas emissions in 2010, a change of only 1% in total household greenhouse gas emissions. This small impact in comparison to the previous sensitivity study of the effect of substitution of gas for electricity highlights the significance of electricity in determining overall levels of greenhouse gas emissions within this sector. Of course, if wood lost market share to fossil fuel-generated electricity using resistive elements (such as in-slab heating, or electric heat banks), the impact on household emissions could be significantly greater. Also, if existing open fires, which have high greenhouse impacts (see above) were replaced by efficient gas or electric heat pump heating, reductions in emissions could be achieved.

Several factors are contributing to the replacement of wood by fossil fuels. Urban wood use contributes to air quality problems in some areas, and this is leading to strong community criticism, although new wood heaters have reduced emissions. Also, the impacts on animal habitats and forests of fuelwood collection are increasingly being recognising.

Competition from fossil fuels is also increasing. The gas industry is rapidly extending pipelines into regions where wood heating has been popular, such as Melbourne's Dandenong ranges, and inland areas in New South Wales. The electricity industry, responding to the excess base-load generation capacity, is more actively promoting off-peak electric heating systems: these are very high in greenhouse intensity.

Figure 15. Greenhouse gas emissions from household fossil fuel use in 1990 and 2010 under ABARE's BAU conditions, and if 10% of 2010 electricity consumption was switched to gas (with 1.5 PJ of gas replacing each PJ of electricity use)



Changes in end-use technologies instead of fuel-switching

The significance of end-use technologies and their efficiencies can also be illustrated by reference to the above sensitivity studies. For example, if the same number of households with electric HWS units switched to electric heat pump models (which consume between a half and a quarter as much electricity as standard units) instead of to gas, an even larger emission reduction would be achieved, without fuel switching.

Development of same-fuel technology shifts as alternatives to fuel-switching must be given careful consideration in policy development, as this can reduce dislocation, conversion costs, and industry opposition. In the future, the electricity industry may increasingly face a choice between losing energy load to another fuel, or keeping part of that load by encouraging adoption of high efficiency electrical technologies.

Chapter 5: Buildings, Appliances, Energy and Greenhouse Gas Emissions - an overview

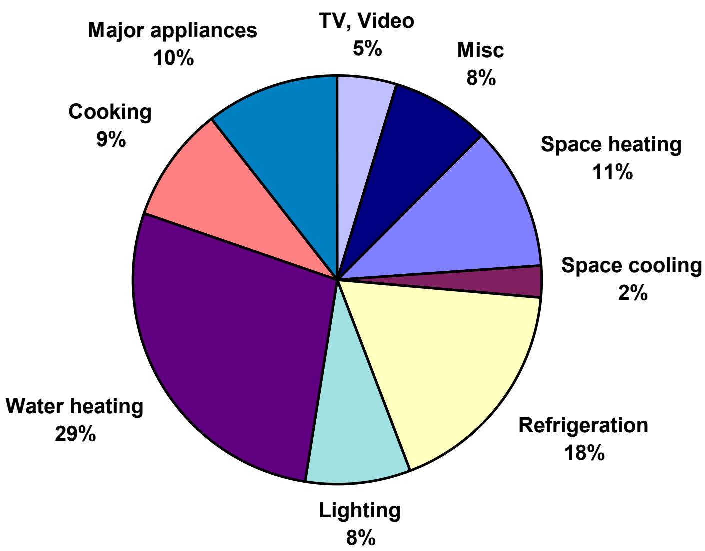
Introduction

Overall trends in greenhouse gas emissions from household energy use were discussed in chapter 2. However, that information does not provide a particularly useful basis for development of specific strategies, programs and measures to reduce household greenhouse gas emissions. Greenhouse gas emissions are generated as householders carry out activities that satisfy their basic needs or discretionary desires, such as storage of food, maintaining comfort, providing light after sunset, and so on.

Analysis of emission-generating activities carried out within households, estimation of the scope to carry out projected levels of such activities in ways that reduce greenhouse gas emissions, and assessment of the scope for change in behaviour, provide essential inputs to the development of effective greenhouse responses.

A breakdown of greenhouse gas emissions from Australian household energy use by activity is shown in Figure 16. However, this breakdown is based on inference, not measured data, so it should be treated with caution. For example, recent studies based on actual monitoring of activities are suggesting that emissions from cooking activity are lower than those shown in Figure 16. Further, as discussed elsewhere in this report, there is great variability in equipment ownership, behaviour, climate and resulting emissions from household to household. Nevertheless, this breakdown provides a useful overview of the significance of each activity's contribution to Australian greenhouse gas emissions.

Figure 16. 1990 Greenhouse Gas Emissions from Australian Residential Sector Energy Use by Activity (Wilkenfeld et al, 1996).

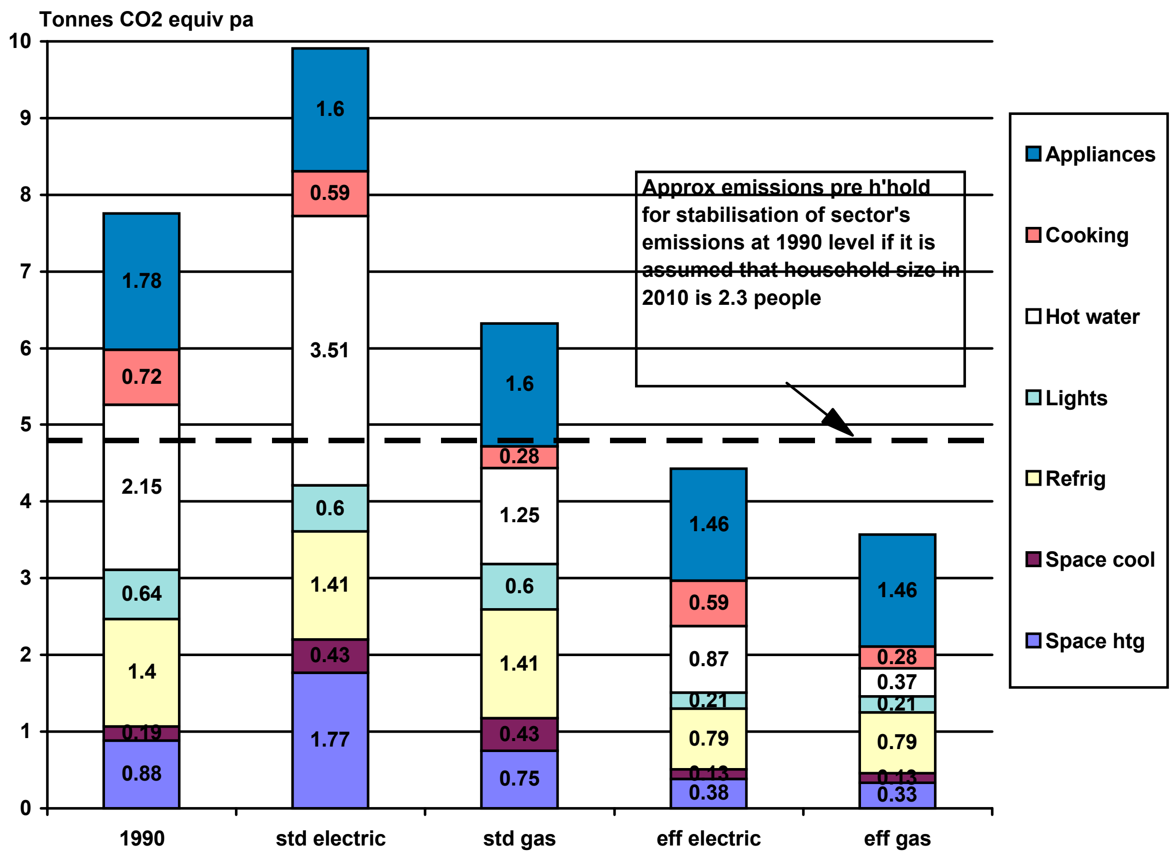


Variability in household emissions and potential for emission reductions

As discussed in chapter 3, there is great variation in the range and scale of activities carried out in different households, and high greenhouse gas emissions can be correlated with ownership of specific types of equipment. For example, in colder areas, space heating may be a much larger part of household emissions, especially if resistive electric heating is used: in-slab electric off-peak heating generates up to 12 tonnes of CO_2 in some areas - 50% more than the average Australian household's total energy-related emissions.

To illustrate the variation due to appliance selection, Figure 17 shows a comparison of greenhouse gas emissions from the Australian average household, as estimated by Wilkenfeld et al (1996) and 'standard' or 'efficient' all-electric and 'all gas' (ie gas hot water, space heating and cooking) 3-person households in Adelaide, using the *Australian Home Greenhouse Scorecard* computer program (Sustainable Solutions 1995). Adelaide was selected as its climate has both heating and cooling requirements, and the level of greenhouse gas emissions per capita from household energy use is close to the Australian average (see Figure 5).

Figure 17. Breakdown of CO_2 emissions from energy use per household for 1990 (from Wilkenfeld 1996) compared with 'typical' 3 person households using standard and high efficiency appliances (already available). The 'all gas' households use gas heating, hot water and cooking.



The standard 'all electric' household's emissions are above the Australian average largely because of its high emissions from water and space heating, which rely on resistive electric technologies. Almost two-thirds of the emissions from the 'all gas' household result from electricity use for appliances and lighting, although its total emissions are below the Australian average.

Both the 'efficient electric' and 'efficient gas' households achieve large emission reductions - to levels below that required for Australian household emissions to decline below 1990 levels, by applying the following changes:

- replace medium-sized inefficient refrigerator and small separate freezer with large 5-star refrigerator-freezer (with similar total storage capacity)
- replace most conventional lights with compact fluorescent lamps (with higher light level)
- replace inefficient top-loading washing machine with 5-star front-loader (but still use normal program on warm wash)

- for space heating and cooling, the existing houses had ceiling insulation. Wall insulation, draughtproofing and shading were added. A high efficiency gas heater was specified in the ‘all gas’ house, and the resistive electric heater in the ‘all electric house’ was replaced by a reverse cycle airconditioner
- for hot water, the ‘all gas’ house switched to a solar-gas HWS, while the ‘all electric’ house switched to an electric heat pump HWS

Much greater emission reductions using technologies already available could have been incorporated into the above model households, for example water-efficient showerheads, cold water clothes washing, a shift to microwave cooking, etc. Further, adoption of much more efficient appliances and improved building performance to levels that should become possible over the next few years will allow even larger emission reductions to be achieved, with annual greenhouse gas emissions per household in the range of 2 to 3 tonnes CO_2 per year being achievable. The actual scope for future emission reductions is discussed in later chapters of this report.

Of course, balanced against the scope for emission reductions are the factors driving growth in emissions. Any growth in resistive electric heating for space or water heating would drive up emissions, as would rapid adoption of inefficient existing-technology digital televisions, heated water beds, airconditioning, electric clothes drying and central heating.

Appliance ownership trends

Each decision to buy an appliance locks-in ongoing greenhouse gas emissions for the life of that appliance. For example, selection of an electric hot water service will lead to generation of 30 to 90 tonnes of greenhouse gas over its life, and will influence the selection of future HWS units by establishing the wiring capacity for a similar replacement. Where all-electric options are chosen, gas supply infrastructure may not even be installed, so it may not be an option for future decisionmakers.

Where an appliance is gaining a significant share of households from a low base, it is particularly important to ensure that early models are energy-efficient, because these products will not be replaced for many years, and they create the norms for expectations. An opportunity to apply this approach exists with the expected launch of digital televisions. These TVs, along with set-top digital-to-analogue conversion boxes, are expected to be left on continuously, so the standby power consumption could create a very substantial electricity demand. Since the rate of adoption of this technology is likely to be rapid, it will be important to ensure that measures are put in place to minimise standby power consumption before the first generation of these products is designed and marketed, or an important energy efficiency opportunity will be lost, and the inefficient products could remain in the marketplace for up to two decades.

So data on appliance ownership trends, and efforts to explain them, provide a basic input to an understanding of future trends in household greenhouse gas emissions, and the actions required to influence them.

Australian households own a wide variety of energy consuming appliances and equipment. There are limited data on the stocks and sales of many of these products, and even less information on their actual energy use. For some products, usage may be very intermittent: for example, many small kitchen appliances spend most of their lives in cupboards. In other cases, small numbers of households may own equipment, but it may be very energy-intensive: for example, swimming pools are owned by just over 10% of households, but their filter pumps often consume large amounts of energy, and may each generate 1 to 4 tonnes of CO_2 each year.

Traditionally, energy analysts have not been particularly concerned about tracking sales and ownership of many types of appliances, as most energy has been consumed by the major appliances associated with space and water heating, food storage and cooking, and clothes washing and drying (see, for example, Wilkenfeld (1991) and Wilkenfeld et al (1993)). However, improvements in the efficiencies of these major appliances, combined with reductions in household size and explosive growth in the numbers of smaller appliances has meant that these other products often use more energy than the traditionally important ones. For example, a family television can consume over 300 kWh per year, almost as much as that used by many households for cooking, and five times that used by a clothes washer using cold wash. And many households now own and operate three or more televisions!

Figure 18. Percentage of Australian households with selected appliances and insulation (ABS 8212.0 1981 and 1987, 1995 and 1998)

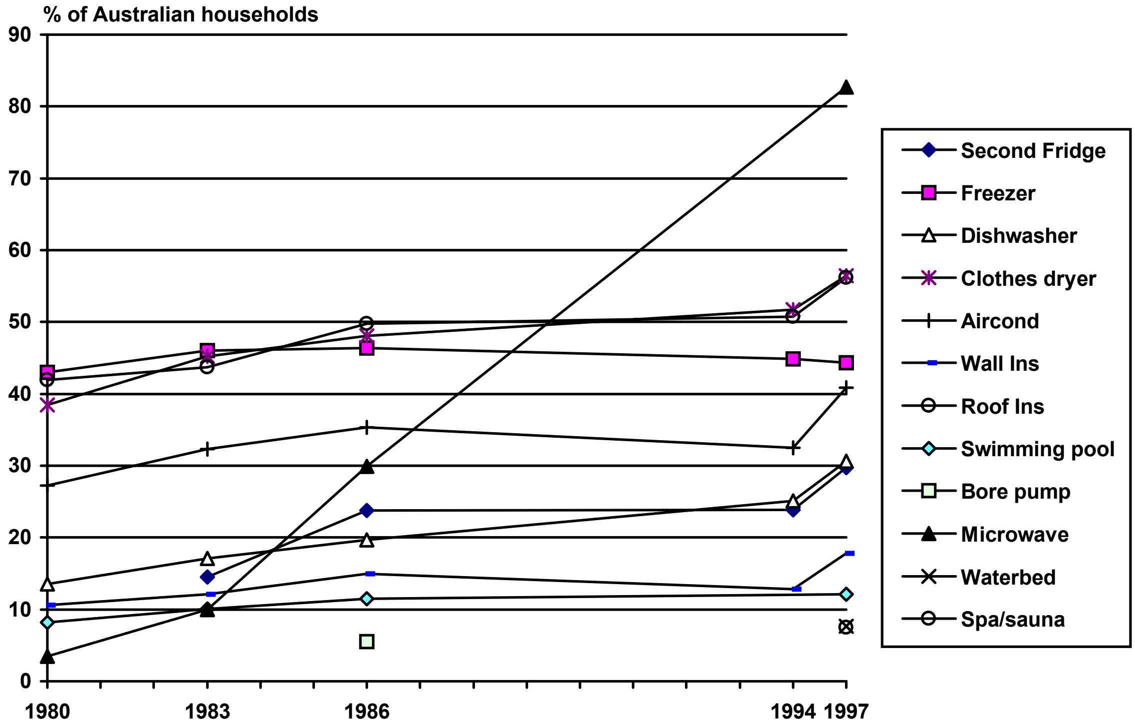


Figure 18 shows ABS data on penetrations of some appliances into Australian households. Data for washing machines and first refrigerators have not been included because they are owned by almost all households. Data for water heaters, space heaters and cookers are shown separately, as they reflect fuel switching trends. Of the appliances shown, only microwave ovens, dishwashers and clothes dryers showed significant growth between 1986 and 1994, but there seems to have been a sudden increase in ownership of many items of equipment since then. This is associated with a dramatic increase in potential peak demand. For example, the extra airconditioners installed between 1994 and 1997 create a potential extra electricity demand of well over 1,000 Megawatts.

Figure 19 shows that gas water heaters are gaining market share, although partly at the expense of types of HWS other than electric ones. What the graph does not show is the trend within the electric water heating market towards large storage tanks, usually operated on off-peak tariffs. The share of the stock using off-peak electricity has increased to almost three-quarters of electric HWS units, from less than 60% in 1990. Also, existing off-peak electric units are being replaced by even larger capacity units. These larger units have greater heat losses at present, but will have to comply with Minimum Energy Performance Standards from 1999, which will reduce their losses to levels comparable with the smaller HWS units they have been replacing. Wilkenfeld et al (1993) shows some national data for 1986 and state data for NSW and WA in 1989 are available: however, this precedes much of the aggressive marketing of larger HWS units, so it is likely to be of limited value in developing greenhouse response strategies.

Figure 20a shows trends in ownership of principal heaters. Again, gas has been gaining market share, while electricity has been rapidly losing it (note that in 1994 many more respondents chose 'no heating', and this seems to account for the exceptionally low score for electric heating that year) . However, this graph does not provide information on market shares of space heaters versus central heaters, nor of electric reverse cycle airconditioners versus resistive heating - critical information for development of greenhouse strategies. For example, growth in heating with reverse cycle airconditioners would have little impact on emissions relative to gas heating, but growth in resistive electric heating would lead to a dramatic increase in emissions.

Figure 19. Shares of Australian households with different types of HWS (ABS)

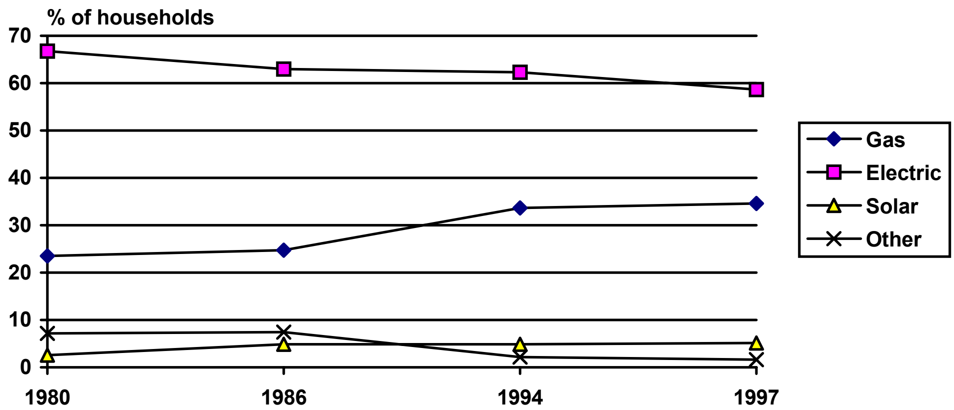
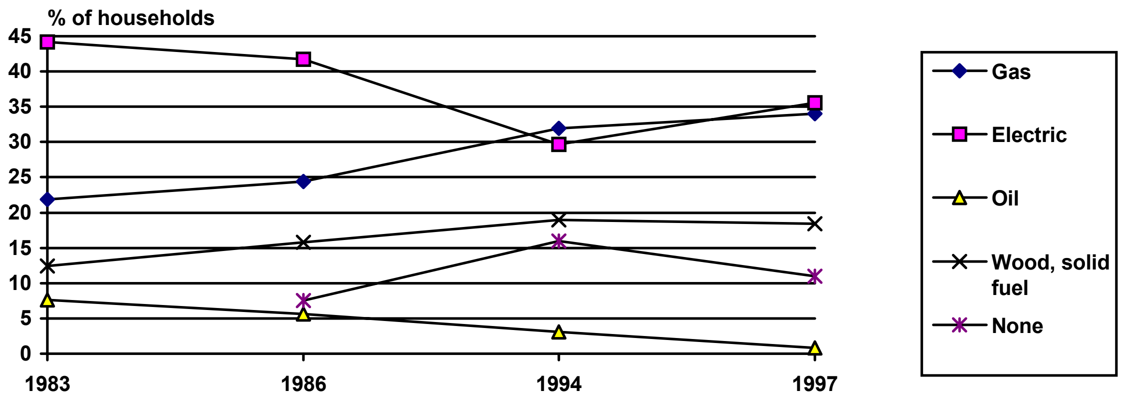


Figure 20a. Shares of Australian households with different types of principal heating (ABS). Note that 16% of households reported that they had no heating in 1994: however, they may have portable heaters, as only 7.5% stated they had no heating in 1986, when respondents were also asked about secondary heating.



Data on ownership of different types of heating and cooling equipment have been collected in several ABS energy surveys, and some results are shown in Figure 20b. It should be noted that the total percentages of homes with gas and electric heating are higher in this graph than in Figure 20a, presumably because some households have several types of heating. Figure 20b shows that the proportion of gas heating provided by central heaters has more than doubled over the decade. For electric heating, all growth in market share has come from reverse cycle airconditioners. Indeed, reverse cycle airconditioners have replaced some electric resistive heating. The greenhouse implications of these trends are complex, and include:

- a shift from electric resistive heating to electric reverse cycle airconditioning reduces greenhouse gas emissions by around two-thirds if the same amount of energy is used. However, this change may also involve a shift from room or spot heating to heating of larger areas for longer periods, which would reduce the emission savings or even lead to increases

- a shift from gas space heating to central heating increases gas consumption: for example, Victorian data suggest that space heating for one home typically consumes 30 GJ per year and central heating 60 GJ per year, generating emissions of 1.8 tonnes and 3.6 tonnes per year respectively. However, a shift to central heating usually leads to a reduction in use of electric secondary heating in bedrooms, but requires increased electricity use for operation of fans or pumps. Overall, the shift to central heating seems likely to increase emissions by at least 1.5 tonnes per year per household.

Figure 20b. Percentages of Australian households with different types of gas and electric heating, 1986 and 1997 (ABS data)

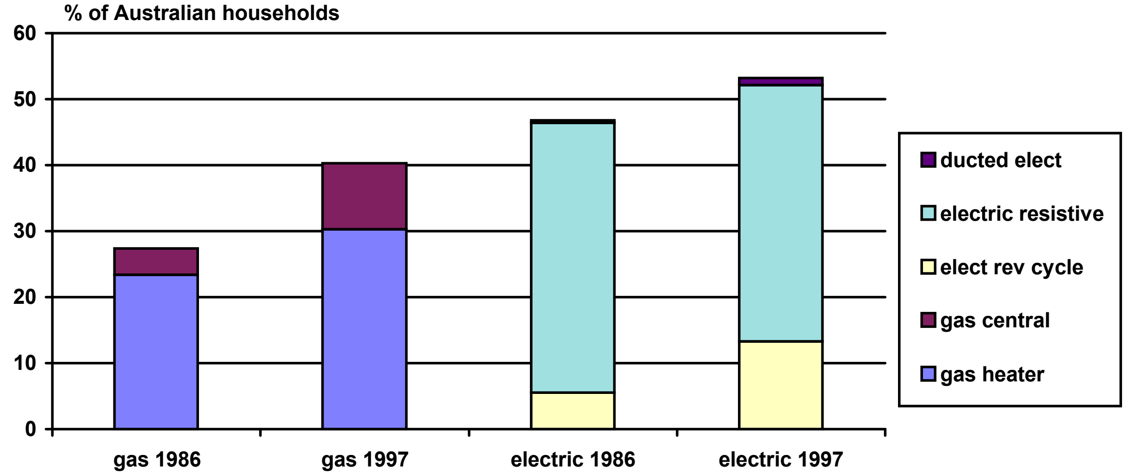


Figure 20c. Shares of Australian households with different types of cookers (ABS)

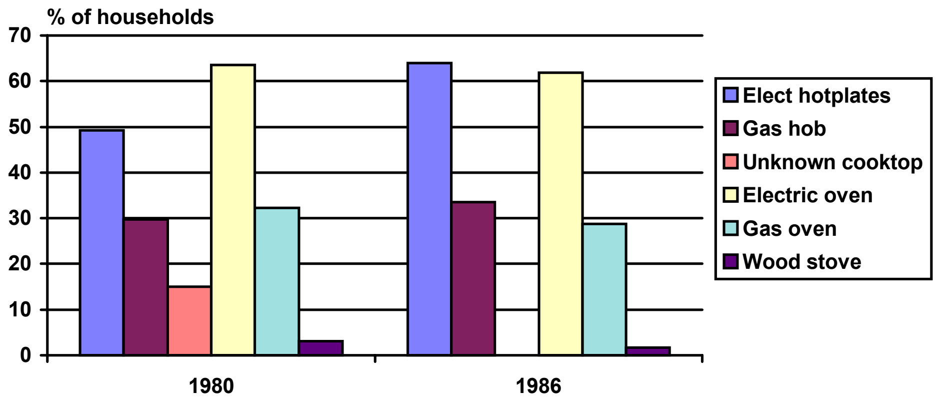


Figure 20c shows limited data on ownership of cookers. Unfortunately, changes in the categorisation of equipment between the 1980 and 1986 surveys make it difficult to draw many conclusions from these data, other than that the share of gas ovens probably declined. This is consistent with anecdotal advice that many people now prefer a gas cooktop and electric oven. It also seems that the popularity of woodstoves declined.

Sales of appliances

Data on sales of appliances are not widely available. ABS collects data on Australian production and exports for some products, but this does not take account of imports. Industry organisations survey appliance sales, but these are either commercially confidential or must be purchased. Table 2 presents data published in Wilkenfeld (1993) collected for a study on Minimum Energy Performance Standards. Note that it does not include estimates of sales of televisions and other equipment now contributing significantly to growth in appliance energy use. Comparison of Wilkenfeld's expenditure data and ABS data suggest that a further $1500 million per year is probably spent on appliances not listed in Table 2.

Table 2 indicates that around three-quarters of whitegoods were locally-made in 1992. However, reduction of import tariffs since then may have changed this proportion.

Table 2. Estimated electrical appliance manufacture, imports, sales and prices, Australia 1992 (Wilkenfeld 1993)

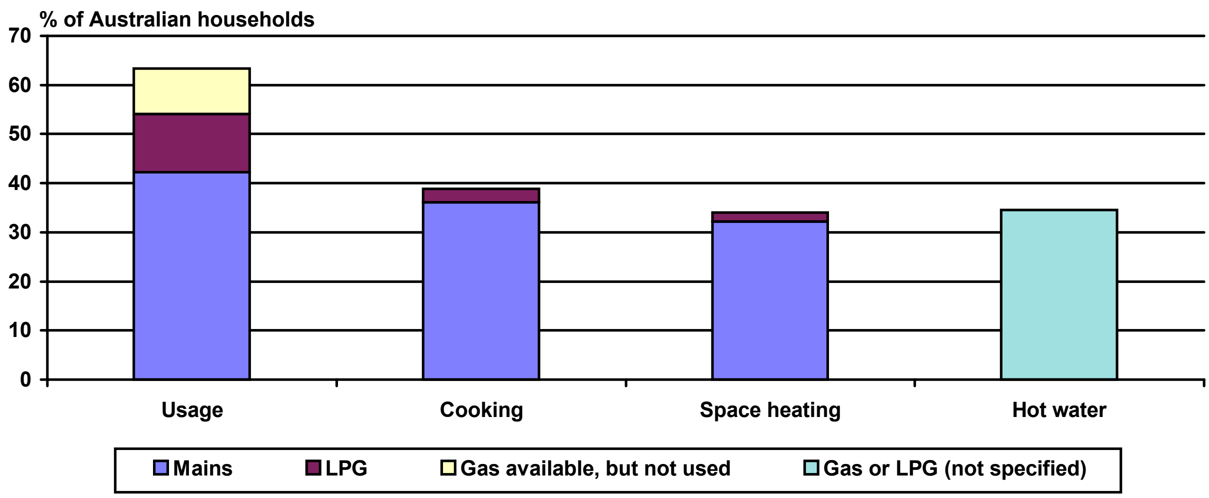
Appliance	Local Prod ('000)	Imports ('000)	Total Sales ('000)	Average Price ($)	Total Value ($M)
Refrigerator	391 (74%)	140 (26%)	531	960	510 (44%)
Freezer	98 (78%)	27 (22%)	125	606	76 (7%)
Dishwasher	89 (77%)	26 (23%)	115	1274	147 (13%)
Clothes washer	325 (71%)	130 (29%)	455	780	355 (31%)
Clothes Dryer	189 (92%)	17 (8%)	206	312	64 (6%)
Total Whitegoods	1092 (76%)	340 (24%)	1432	804	1152 (100%)
Airconditioners	44 (34%)	96 (76%)	140	1362	191
Water Heaters	330 (100%)	NA	330	454	150
TOTAL			1902		1493

Access to natural gas and potential for fuel switching

The latest ABS household survey gives the breakdown of gas connection and gas appliances shown in Figure 21. Even if gas pipelines are not extended, it can be seen that there is scope for 25% more Australian households to use gas or LPG for cooking, and almost 30% more for space and water heating, if all households with existing access to natural gas or LPG used it for all three activities. In addition, the gas industry is extending gas networks in many areas, with an average increase in the number of household customers of 3.5% per year between 1988 and 1993 and an average of 1,800 kilometres of new gas mains and transmission pipelines laid each year over that period (AGA, 1994), 2.5% of the total existing length.

If a third of existing Australian households switched from electric to gas appliances, annual greenhouse gas savings would be at least 5.5 million tonnes of CO_2 per year (based on reductions of at least 2.5 tonnes pa - see Figure 17) - with much larger reductions if homes now using large amounts of electricity for space heating switch to gas. However, similar savings could be achieved if those houses switched to reverse cycle airconditioners for heating, heat pump or solar HWS and best technology electric cooking.

Figure 21. Australian households with access to or connected to gas, and its use for cooking, space and water heating (ABS 1998).



There is a need to analyse the comparative cost implications for individual households and society of switching to gas versus adopting best electric technologies. It may well be that the optimum outcome varies from region to region. This information would assist in selection of appropriate policy directions, although if electricity retailers also market gas in the future, they may promote 'least cost' solutions as part of their marketing strategies. Of course, 'least cost' for the energy supplier may not necessarily be the least cost solution for society.

Building trends

Each year, between 100,000 and 170,000 new homes are built in Australia, 2 to 2.5% of the total housing stock. In 1995-96, $13 billion was spent on new homes and $2.6 billion on renovations (ABS 1998). Over the past decade, an average of a quarter of new homes built have been townhouses, units and apartments, with over 30% of new dwellings built in 1996 being other than traditional houses (see Figure 22a): this trend reflects the adoption of urban consolidation policies, the decline in household size, and increasing interest in living in more convenient locations. Figure 22b shows the actual numbers of dwellings built, and the long-term trends.

Figure 22a. Percentages of new Australian dwellings built by type (ABS Yearbook 1996)

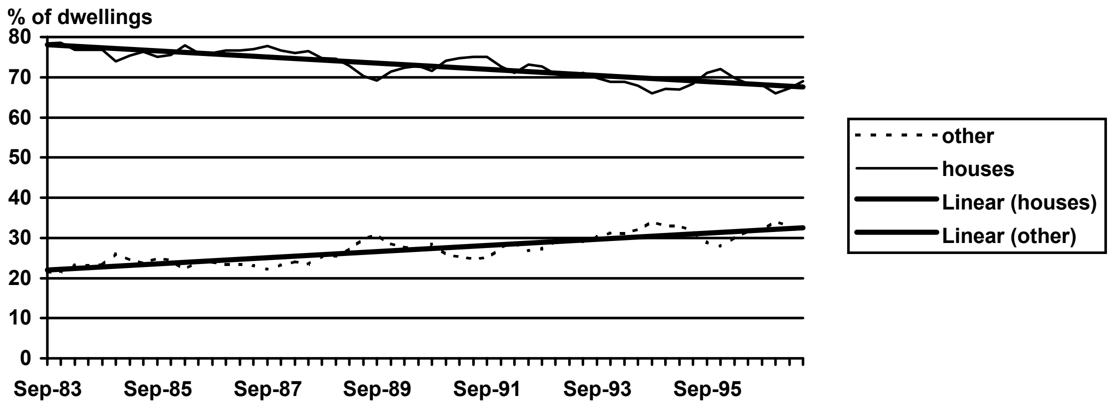


Figure 22b. Numbers of new Australian dwellings built by type (ABS Yearbook 1996)

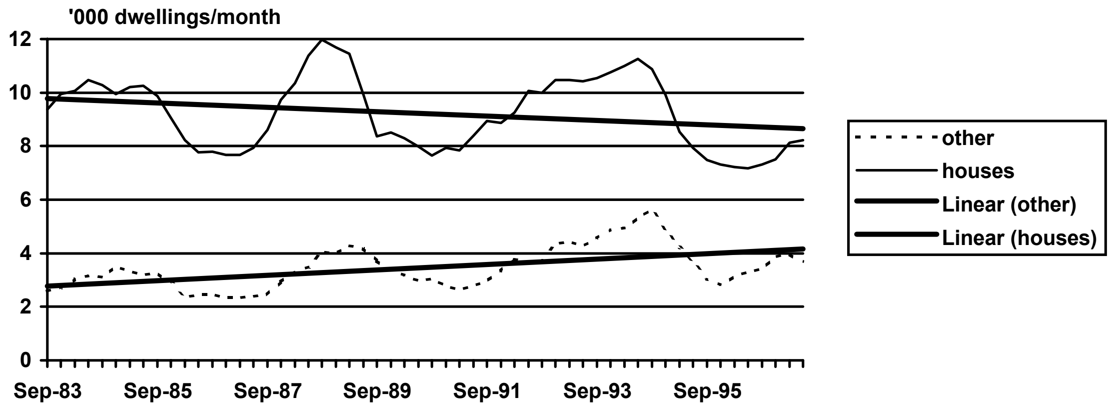


Figure 23 shows the state-by-state construction activity in 1995-96, in terms of dwellings per capita of population. This reflects the high levels of activity in Queensland, Western Australia and Northern Territory associated with their above-average population growth rates. Figure 23 also shows that construction in South Australia, Tasmania and Victoria is directed more towards single houses than in other states, where there is greater emphasis on other types of dwellings, such as apartments and townhouses. Future construction activity will be influenced by population trends and household size trends, which could differ from the recent past. For example, recent migration from Victoria to other states seems to be reversing, while the Asian economic problems may lead to increased international migration to some states.

By 2010, trends in household size could significantly affect housing construction activity. For example, if the projected 2010 population lived in households averaging 2.6 people, 8.03 million households would exist but, if household size was 2.3 people, this would increase to 9.08 million households, increasing demand for new housing by up to 40% and creating a demand for a million additional homes, with their associated embodied energy and operational energy consumption. Of course, this higher rate of construction activity would also provide a greater opportunity to incorporate greenhouse emission reduction features and appliances in many more homes.

Figure 23. Number of dwellings built in each state per thousand residents, 1995-96

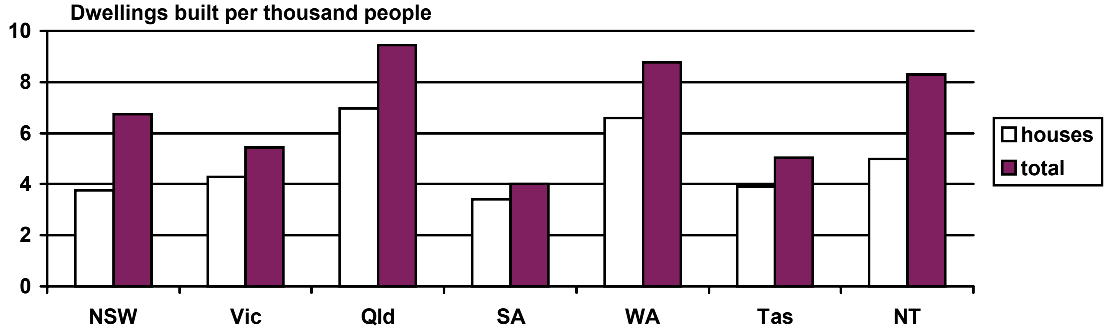
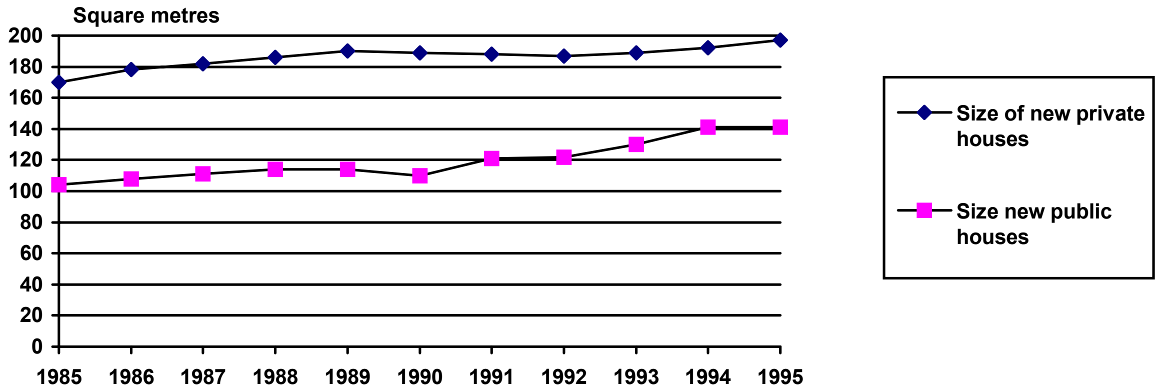


Figure 24a shows the trend in size of new houses over the past decade, which has risen by around 15%. An increase in house size potentially leads to increased greenhouse gas emissions, as a larger area must be lit and kept comfortable, and there are more likely to be additional appliances in operation in the separate spaces in larger homes. However, this potential increase in emissions must be balanced against factors such as:

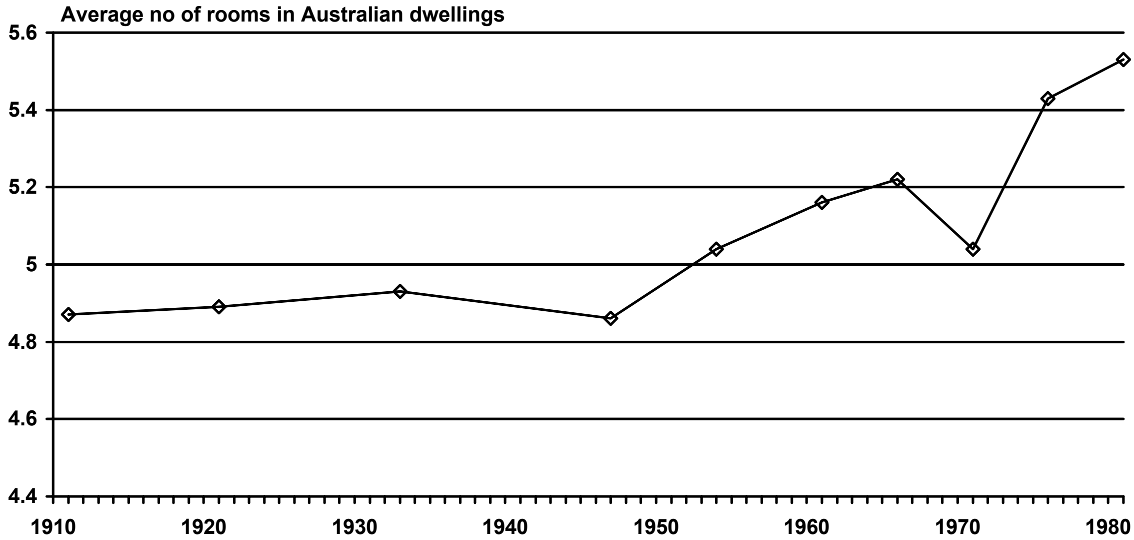
- growth in market share of apartments and townhouses, which tend to be smaller than detached houses: over the past decade, this has probably meant that average floor are per capita in new dwellings has remained fairly constant
- larger homes may be more likely to be two-storey: this not only accounts for part of the increase in floor area (for stairwells), but also leads to a smaller external surface area for a given floor area. These factors tend to reduce energy requirements, although rooms on the top floor may require more heating and cooling because of their greater exposure to the elements
- larger homes have a smaller surface area per unit of wall area, so heat flow per square metre of floor area declines with increasing size
- regardless of dwelling size, there is a trend towards heating and cooling a larger proportion of each home's floor area

Figure 24a. Average size of new Australian houses built, excludes flats etc. (ABS Yearbook 1996)



A longer term picture of home size is provided in Figure 24b, which shows long-term trends in the number of rooms in all private dwellings. This may actually understate the growth in home size, as more multi-purpose rooms (such as lounge-dining rooms) have become popular. On the other hand, there has been a trend towards reduction in size of bedrooms at the expense of larger living areas, so the trend in actual building area may not be accurately reflected by the trend in number of rooms.

Figure 24b. Average number of rooms in Australian dwellings (derived from data in ABS 4140.0)



Renovation activity

Data on renovation activity are not widely available. ABS (1998) shows that alterations and additions to residential buildings valued at more than $10,000 exceeded $2.5 billion in 1996-97, compared with $13 billion spent on new dwellings. However, this understates the level of activity, because many smaller projects, such as kitchen and bathroom renovations, would fall below the $10,000 threshold. The 1993-94 ABS Household Expenditure Survey indicates that the average Australian household spends $18.90 per week (almost $1,000 per year) on home renovation: this is equivalent to $6.5 billion per annum for Australia, half of all expenditure on new homes and more than double the value identified in the ABS building statistics. Also, many renovation projects involve significant amounts of 'sweat equity' invested by the occupants and their friends and relatives, which is not visible in the financial data.

Given the data limitations, it seems that between 50,000 and 250,000 Australian homes are renovated to a significant extent each year. This is comparable with the number of new homes built. And many more homes have minor renovations carried out.

Home renovation activity is an important target for greenhouse emission reduction strategies for several reasons:

- renovation signals, in many cases, a desire to remain in a house in preference to moving, so decisions have greater potential to reflect consideration of long-term costs and comfort because the decision-maker is often planning to benefit from the changes made. So there is greater scope to encourage investment in emission reduction measures that contribute to future financial savings and improved comfort
- renovation activity is often associated with purchase of new appliances and installation of new lighting and other equipment
- the occupant is more likely to be involved in decisions regarding appliances and equipment, so there is greater focus on ongoing costs and quality of performance than on up-front cost, which is more likely if builders and tradespeople make decisions. On the other hand, market intermediaries such as

architects and lighting designers, who may focus on style and image at the expense of greenhouse gas emission reduction, are also more likely to be involved

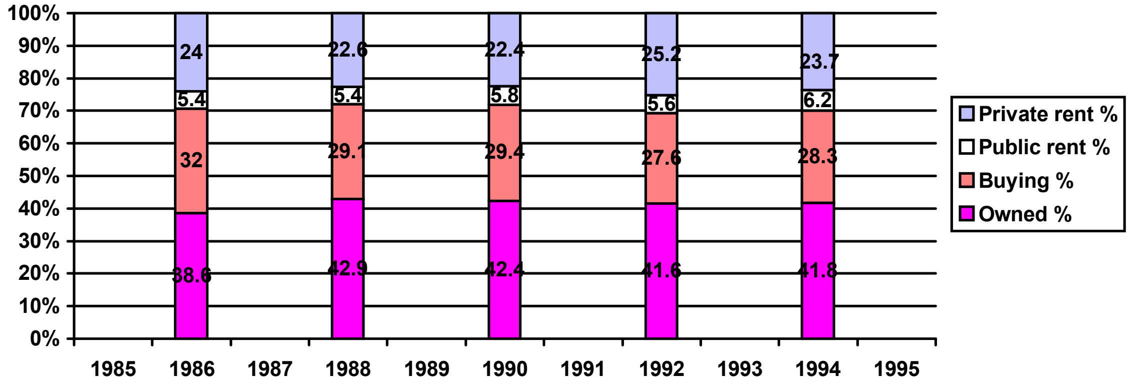
- renovators usually have significant equity in their homes, so they have greater financial flexibility - although the tendency of renovation costs to 'blow out' means they often still feel tight financial constraints. Financial packages that encourage investment in energy-efficient and emission-reducing options could be attractive in these circumstances
- because many renovators already live in the house being renovated, they may be more conscious of the problems that cause discomfort or annoyance, such as excessive summer sun or running out of hot water, so they may be more inclined to respond to encouragement to address these issues. However, they may be inclined to do this in energy-inefficient ways, such as by installing larger HWS units, airconditioners and central heating unless alternative solutions are effectively promoted.

Home ownership

The mix of owned and rented homes in Australia over the past decade is shown in Figure 25. This shows little variation over that period. However, some commentators suggest that Australia's rate of home ownership may decline in the future for a variety of reasons, including increased mobility, reduced job security and less certainty that capital values will increase. These factors increase the sense of risk associated with home ownership.

If the proportion of households renting increases, it may influence the approaches taken for emission reduction strategies. In particular, it will place greater emphasis on dealing with landlords and tenants instead of owner-occupiers. Traditionally, landlords have shown little interest in investments that reduce occupants' operating costs while increasing capital investment. However, as the types of tenants change, or appropriate incentives or requirements are introduced, attitudes of landlords may change. Further, with increasing rates of construction of larger developments, there may be greater emphasis on professional building management agencies, and more landlords with large portfolios of properties. There may be increased scope for creation of business-like arrangements with such property managers.

Figure 25. Percentages of Australian dwelling stock owned or rented (ABS Yearbook 1996)



Conclusion

Overall, it seems that building trends are very difficult to predict, and their impacts on greenhouse gas emissions are also uncertain. The key issue is that large numbers of new dwellings will be built and many renovations carried out. The decisions taken during construction and renovation related to both the building design and selection of appliances and equipment have long-term implications for ongoing rates of greenhouse gas emissions, as well as the amount of energy embodied in their building fabric and associated infrastructure. In almost all cases, the most cost-effective means of reducing greenhouse gas emissions is by ensuring that low emission options are selected when equipment is being purchased and construction activity is being undertaken. Then, only the incremental cost of the emission-reducing option (if there is an extra cost) must be recovered through energy savings or other financial benefits.

Many measures can also be incorporated more easily and cheaply during purchase or construction than later on: for example, installation of insulation, especially in walls and under floors, is much cheaper during construction.

If low greenhouse emitting options are not chosen for new homes and renovations, an important opportunity for emission reduction is deferred until the appliances are replaced and the buildings are either renovated or demolished. Where cost-effective emission reduction options are not chosen for new housing and renovations, this also represents an increased financial burden for Australian households for many years into the future.

It should also be recognised that the majority of Australian homes existing in 2010 have already been built, and many of them will have little renovation work done to them by that time. Many of these houses are thermally inefficient and have inefficient appliances and equipment. This means the rates of greenhouse gas emissions of a large proportion of dwellings will not change significantly by 2010 unless new programs successfully create processes that lead to retrofitting of emission reduction features to significant numbers of those dwellings.

A range of retrofit measures that are potentially either cost-effective or offer valued improvements in comfort or convenience exist, so there is scope for such schemes. These types of programs have been pursued by the Energy Saving Trusts in the United Kingdom and New Zealand, as well as through a range of energy utility and/or government funded programs in the USA. A Home Energy Advisory Service operated in Victoria between 1983 and 1993, and SEDA is developing similar programs. Unless these programs are very carefully structured, program administration and implementation costs can be very high: for example, charities and service groups have received government support to implement programs in some areas, thus amplifying the cost-effectiveness of the programs by using volunteer labour and local social networks.

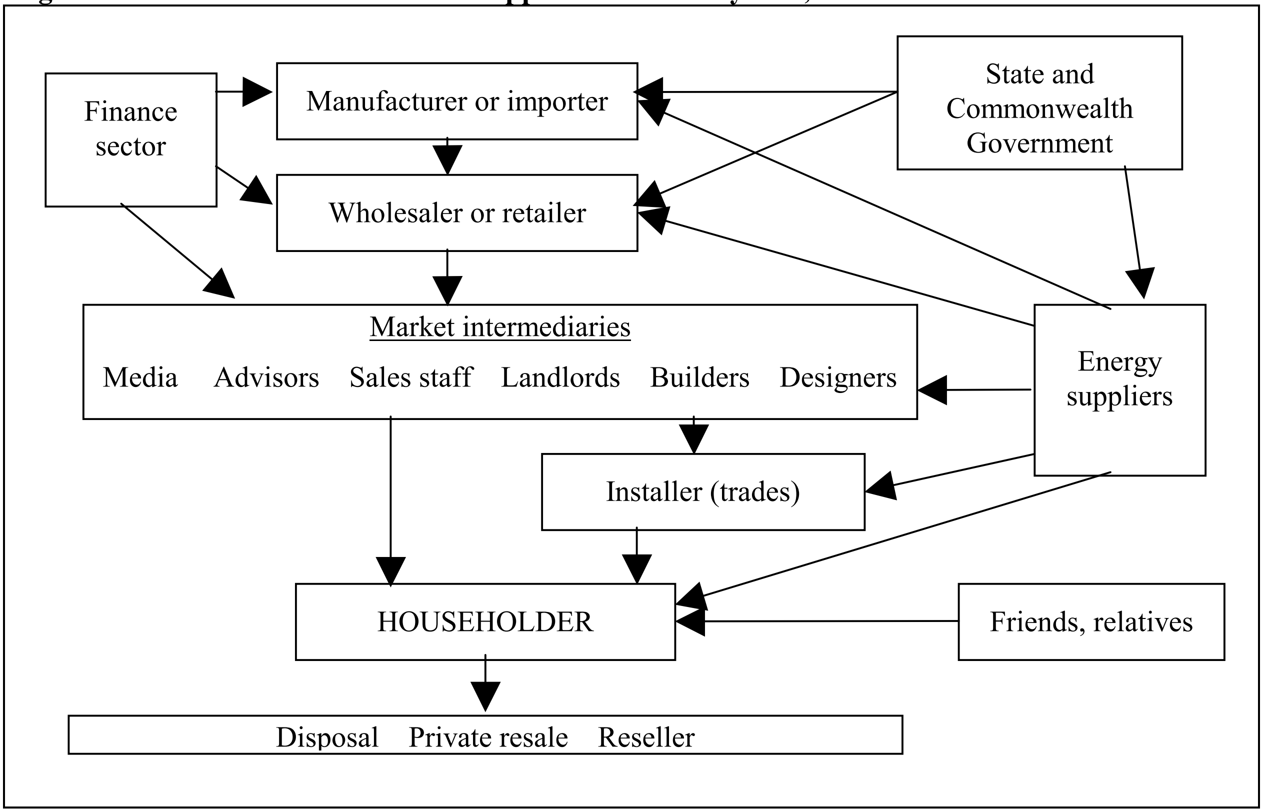
Chapter 6. The Appliance and Building Markets

The nature of the appliance marketplace

The processes influencing the market for domestic appliances are very complex, and they vary from appliance to appliance. For example, the householder may visit a showroom and buy a new refrigerator, influenced by media advertising and images and the sales pitch of a shopfloor salesperson. In contrast, a new hot water service may be chosen by the plumber called in to replace a failed unit under emergency conditions, with little involvement on the part of the householder. Increasingly, builders are including packages of appliances in their houses, with only limited choice being offered to the prospective buyer.

Figure 26 provides a diagrammatic representation of the participants in the appliance market and their relationships. Each participant has a significant role in determining the types of products available, how they are presented to householders, and what criteria will be used in product selection. Each participant has his or her own agenda and priorities, too, which may not coincide with those of the householder, nor the achievement of greenhouse emission reductions. For example, shopfloor sales people are influenced by incentive payments offered by manufacturers as part of their promotional strategies: customers are unaware of these arrangements, yet they shape the way products are presented for sale.

Figure 26. Overview of the household appliance market system,



If strategies are to influence the outcome of the market process, the roles and motivations of the various market participants must be understood, and packages assembled that either create a chain of consistent signals or provide sufficient incentive or pressure for key participants to override the agendas of other market participants. The following discussion highlights some of the key issues influencing the behaviour of the various market participants. The points raised within this limited space may not fully reflect the subtlety of the marketplace, and may unfairly stereotype some participants, but this is a beginning.

State and Commonwealth Government

Governments are involved in the appliance sector via their regulatory roles which cover business practices, appliance safety and certification, and funding of RD&D. They also regulate and promote appliance energy labelling schemes and Minimum Energy Performance Standards. Governments have scope to influence the appliance industry in other ways, by using a range of policy options, including procurement policy, regulation of product performance, financial and taxation incentives, information programs, etc. One option which has been used with other industries, such as the coal and meat industries, is placing a levy on product sales for use by an industry-based body to fund RD&D and industry development.

Finance sector

At present, the finance sector has little direct involvement in directing appliance industry activity towards greenhouse emission reduction. However, the finance sector's policies influence allocation of funds to the appliance industry, and facilitate marketing strategies of retailers, such as 'no interest for six months' promotional strategies.

Home lenders could potentially extend their activities into the appliance sector via more flexible home loans, and this could be linked to investment in low running cost, low greenhouse gas emission products, which improve the householder's capacity to repay loans.

A recent change in the Tax Office's approach to taxing leasing arrangements with households has opened an important opportunity for the finance sector to facilitate investment in emission reducing appliances. Previously, the tax depreciation deductions involved in leasing were lost when equipment was leased to a household, as the tax benefits could not accrue to a non-commercial operation such as a household. Now, however, the organisation leasing equipment to a household can gain the tax depreciation deductions as long as the lessor (Rogers, 1997).

Manufacturers and importers

These market participants are influenced by factors including:

- legal requirements such as safety and, where relevant, energy efficiency standards
- their understanding of the motivation of their target markets
- their technical and financial capacity to supply product into a given market sector
- their perception of their organisation's and product's position in the marketplace

The outcome of these influences may be different from manufacturer to manufacturer, and across product types. For example, a hot water service manufacturer who sees his main target market as builders and plumbers will focus on issues they see as important, such as profit margin, convenience of installation, low initial price, etc, while the focus on the end-user may be limited to ensuring that they are unlikely to complain about running out of hot water or premature failure during the warranty period. At the same time, they may manufacture a 'premium' product line that appeals to the small number of householders involved in purchase of a HWS, and which is also suited to installation in prestige homes. In contrast, a European whitegoods manufacturer may aim to position its products as premium items with superior performance across a range of criteria valued by householders (such as quietness, washing performance, environmental performance etc), so that a high price can be justified.

The priority placed by a manufacturer on energy efficiency and low greenhouse gas emissions is therefore shaped by the above issues. If market research shows customers will place more value on a new colour scheme or a new door handle shape than on improved energy efficiency or greenhouse gas emission reduction, RD&D funds and marketing effort will be adjusted in response.

Traditionally, manufacturers have successfully argued that the technical constraints to energy efficiency improvement have limited scope to achieve rapid gains. However, there is now sufficient evidence to show that technology is not a fundamental barrier (see later sections of this report). The real issues are:

- can I get customers to contribute to the RD&D costs and re-tooling costs by paying a price premium? If not, how can I afford it?
- if I pursue energy efficiency improvement while my competitors cut prices or promote some other feature, will I gain or lose market share?

Industry acceptance of minimum performance standards reflects a view that, if there must be regulatory intervention, it should be done in a way so that there is a 'level playing field'. Then, each manufacturer can feel confident that their competitors must jump the same hurdle. The manufacturer who is most creative in finding ways to achieve the requirement also stands to gain in the marketplace. However, such an approach may still leave local appliance manufacturers disadvantaged relative to international operators, as they have less access to capital and R&D expertise, so they may not be able to respond as quickly, or may have to spread transition costs over a smaller production base.

Customers will only pay more if they perceive some tangible benefit. It is very difficult to convince a tradesperson or builder to pay more for something that offers lower future running costs and environmental benefits unless they are experiencing strong consumer demand from their own customers, they are offered financial or other incentives, or they are required to do so by guidelines or regulations.

Even where householders are directly involved in purchase decisions, many factors are weighed up in a subjective process. These include price, value for money, image, quietness, warranty back-up, manufacturer's reputation, etc. One of the achievements of the appliance energy labelling scheme has been to make energy efficiency a visible factor in showrooms, thereby raising the priority assigned to energy consumption by consumers to a point where, for some appliances and some groups of consumers, it is the most significant purchase factor (ABS, 1998).

An industry levy to be invested back into local emission reduction RD&D and tooling-up activity may be one way to overcome some of the barriers, along with appropriate programs aimed at consumers. This approach has been used in the coal industry and agriculture. It is useful where there are many participants in a market and there is a need for industry-wide action to achieve some objective.

The structured introduction of performance requirements can also be used to limit transition costs: for example, a progressively tighter set of requirements for the sales-weighted average energy efficiency of a manufacturer's products allows the manufacturer to focus effort where it can deliver the most cost-effective return. However, without supplementary requirements for each model, this approach can result in some models becoming very energy-efficient, while others remain inefficient.

Wholesalers and retailers

Wholesalers provide a link between manufacturers and retailers. The deals they make reflect their perceptions of the priorities of the marketplace. Inventory costs are a significant factor for them, so they are interested in both product volume and profit margin per item. The risk of being left with large quantities of unsold stock is balanced against having sufficient supplies to satisfy consumer demand - as delay means customers go elsewhere. Stocking strategies will vary with the image of the retailer, its client base, and the details of each deal negotiated. Manufacturers often attract wholesalers and retailers by promoting the fact that they will be carrying out intensive advertising campaigns to increase demand for their product: this reduces the perceived risk of stocking a product while creating consumer pressure for supplies to be easily available.

While energy efficiency is a factor considered by these market participants for products that carry energy labels, it must compete with other, more powerful factors. On balance, action targeting manufacturers, importers, market intermediaries and householders is more likely to influence the behaviour of this group, as they are heavily influenced by their perceptions of market directions.

Market intermediaries (including installers)

Each type of appliance or product may have its own group of market intermediaries. For example, pool filter pumps are part of a package provided by the pool supplier, then ongoing involvement is usually through a local shop that supplies chemicals, support services etc. Kitchen appliances may be sold via a builder, kitchen designer, or sales showroom.

No market intermediaries have a direct interest in reducing ongoing energy consumption of equipment they sell or promote, as they do not pay the ongoing energy bills. Instead, they may be focused on any of a number of issues, such as:

- does it have good aesthetic features?
- is it trendy?
- will it attract future business for me (by raising my profile, word of mouth promotion, etc)
- will I make more money by selling this instead of something else?
- are there any hassles with selling or installing it: for example, do I have to spend a lot of time explaining its benefits when I could be selling more product; is the design or installation detail difficult; has it a proven reliability record?
- for landlords: will it reduce my tenant turnover, and can I charge a higher rent?

At the same time, many market intermediaries are powerful influences on the purchase decision. Many market intermediaries are seen by customers as experts in their field, and this can be exploited by use of jargon, anecdotes, professional qualifications, authoritative statements, etc. Training in sales techniques gives market intermediaries a wide range of skills with which to influence customers.

The simplest ways of influencing market intermediaries are to:

- make specifying low greenhouse emission options more financially rewarding than other options by offering incentive payments, rebates, etc. This can be done via manufacturers.
- regulate so that all the options available are low greenhouse emission products
- train, educate and provide marketing tools for intermediaries so that they link low greenhouse gas emissions to other features they value and can promote to clients, such as improved comfort, future financial savings, and to simplify decisions and design procedures.
- introduce insurance or other schemes for accredited products to minimise the sense of risk for intermediaries when specifying new technologies

Energy supply industry

Energy suppliers have relationships with most of the participants in the household appliance market, although the nature of the involvement varies from product to product, and the nature of the relationships is changing with the introduction of the competitive energy market.

Many household products require certification for safety and performance before they can be sold. This has traditionally been an energy utility role, although separate organisations such as Victoria's Inspector General are now being established. Utilities have also usually had testing and R&D laboratories, where a great deal of cooperative work was carried out: for example, the Gas and Fuel Corporation of Victoria was closely involved in the development of a number of energy-efficient gas products.

In the past, energy utilities have also had very close links to market intermediaries. The gas and electricity industries have traditionally battled to win the hearts and minds of builders, designers and tradespeople in a variety of ways, including offering attractive financing arrangements, discounted products, promotional support, technical advice and priority service. These activities involve tens of millions of dollars each year around Australia, and dwarf any likely promotional budget that could be envisaged within public sector programs. They are aimed at ensuring maximum long term returns for the energy suppliers involved, and they can be very aggressive. For example, some electricity suppliers have negotiated to exclude gas from new developments (and gas suppliers have also negotiated arrangements to ensure gas HWS units are used in some new developments).

This kind of activity can be expected to increase, and to become even more aggressive in the early stages of the competitive energy markets, especially where new housing development is occurring. The potential directions of energy industry marketing strategies can be gauged from the following examples of topics covered in recent electricity industry conferences:

- leveraging the bill as a targeted marketing tool
- enhancing customer loyalty and service through the contract lifecycle
- the importance of being able to market effectively in your local area
- loyalty marketing
- the process of identifying, analysing and choosing potential marketing partners
- why and how can utilities and telecommunications companies achieve strategic alliances?
- how to obtain marketing advantage through customer billing and metering
- develop powerful tactics to prevent your competition from stealing your customers
- fully exploit potential and existing profitable accounts through effective database management
- data mining techniques to score and rank your high risk customers
- using direct marketing techniques in the acquisition and retention of profitable customers
- development of new computer systems for segmentation and targeting
- what is predictive modelling and behaviour profiling?
- learn which industries are the best with whom to partner
- identifying customers with the highest expected lifetime value

If greenhouse strategies do not develop equally sophisticated and well-resourced programs, and ensure the energy industry's actions are consistent with greenhouse emission reduction strategies, efforts to reduce emissions could be swamped by the activities of energy industry participants.

Energy suppliers install very capital-intensive infrastructure, so they have a strong incentive to increase its utilisation to the maximum as quickly as possible. At the same time, they tend to design for excess supply capacity, to allow for growth in demand, as upgrading supply infrastructure in an existing area is expensive.

While the development of combined gas and electricity retailers will potentially reduce the inter-fuel competition, there will still be disincentives to pursue energy efficiency. For example, when a gas pipeline is installed in a residential subdivision, in most parts of Australia, the bulk of demand comes from hot water services (typically 18 GJ per year, compared with 3 to 5 GJ per year for cooking, and in mild climates, space heating may only reach 10 GJ per year). However, adoption of instantaneous HWS units with electronic ignition or super-insulated storage tanks with electronic ignition would reduce gas consumption of HWS units by around 35%, undermining the financial viability of the gas supply infrastructure. And solar hot water would have an even bigger impact on the financial viability of the gas infrastructure, even if gas was used as the boosting fuel.

The dominance of capital costs for energy suppliers means that their ideal loads are fairly stable, and close to the design capacity of their infrastructure. So they are more interested in load shifting and management than energy efficiency, except where growth in demand, or the decline in performance of existing infrastructure, means total demand is exceeding system capacity. This means energy suppliers have some interest in forms of energy efficiency improvement or fuel switching that limit peak demand, for example shading of windows, but this must be seen in a context of their aims to maintain economic loads and strategic issues. For example, even though electricity industry sources have admitted that they lose money on electric cooking (and that a shift to gas cooking would cut their supply costs), they may not promote this option if it encourages more households to connect to gas and thus increases the risk of losing hot water and space heating loads to gas as well.

Householders also have ongoing relationships with energy suppliers via their energy bills and the provision of energy and associated services. This relationship is likely to be developed under the competitive market, as energy retailers aim to provide 'value added' services to customers in order to retain them. Such efforts may increase or reduce incentives for greenhouse emission reduction, depending on the marketing strategies pursued. For example:

- promotion of *Greenpower* schemes in NSW has already led to significant investment in renewable energy capacity
- some energy suppliers are developing a range of advisory and other services to assist customers to reduce energy use and costs. Some electricity retailers have contracted with a State Government energy advisory service to provide advice for their customers, while a gas supplier provides a staff member for another Government advisory service.
- one Victorian retailer has offered up to $300 worth of free electricity for purchasers of reverse cycle airconditioners. Where these replace resistive electric heating, this could reduce greenhouse gas emissions, but if they replace gas or wood, emissions may increase, while cooling energy consumption will almost certainly increase
- Victorian electricity retailers charge a quarterly supply charge double that which applied before 1992: this allows the marginal price per unit of electricity sold to be reduced. A similar strategy has been adopted by the Hydro Electric Commission in Tasmania
- Eastern Energy, a Victorian electricity distributor/retailer, has stated publicly that it has identified 30 financial products that could be bundled with electricity (Anon, 1998). If this is done, the cost of electricity could be lost among charges for diverse services, so there would be reduced incentive for householders to reduce electricity consumption.

The structure of the energy markets, including requirements related to tariff structures, and how financial returns are generated (for example, in NSW, 'revenue capping' limits the return per customer for distributors, reducing the incentive to supply more energy), will play an important role in shaping the mix of services provided, and determining whether energy suppliers' activities facilitate an increase or decrease in greenhouse gas emissions.

Friends and relatives

Experience and opinions of friends and relatives are often influences on householders' decisions. Testimonials by people who are trusted are very powerful, as they are perceived as both independent and based on real experience. However, such advice can often perpetuate misinformation. Long-term public education and demonstration programs can be used to inform and educate. It is essential to ensure that any negative experiences with emerging low greenhouse emission products are identified quickly, and addressed effectively, or word-of-mouth influence may set back progress. For example, significant numbers of early buyers of compact fluorescent lamps found they produced less light than expected, and that some brands were very unreliable: this has damped public interest.

Householders

The householder is a key element in the appliance system. Not only does (s)he pay for the product, but (s)he pays for the ongoing operating costs and carries most of the risk if problems occur.

At the same time, most householder decisionmakers have limited information and expertise to interpret information, and must balance a large number of variables. Often, they are constrained by lack of capital, emotional energy and time. And, since energy costs are a small component of total household costs (see chapter 3), it is easy for them to be overwhelmed by other, more tangible issues. How can possible future energy bill reductions compete with the luxury of an en suite bathroom or a stainless steel panel on a dishwasher? When you are juggling a builder who is running behind time, a bank that is reluctant to loan extra money to cover cost over-runs, and trying to function at work, it is difficult to make time to ensure that details relating to energy efficiency are properly addressed.

The reality is that most decisions made by householders in relation to greenhouse gas emissions fall far short of the operation of perfect markets. There is far from perfect knowledge, the householder is usually dealing with a skilled expert salesperson in a situation in which (s)he is relatively inexperienced, and future costs are typically heavily discounted.

The positive experience is that appropriately-presented information can make a difference. While surveys in the mid 1980s showed that energy consumption was near the bottom of the list of most appliance purchasers, the energy labelling program has raised awareness to the point that in the latest ABS survey, was the second most frequently chosen factor considered when purchasing appliances (ABS 1998), at 51.5% of respondents. However, it still falls well behind price (73.1%) in importance. Since appliance labelling applies to only a limited range of appliances, there is little or no information available for most appliances on which to base an informed decision. Even with energy labelling, studies showed that the least efficient models, which are often significantly cheaper than good quality products, were not being removed from the market, so Minimum Energy Performance Standards are being introduced for refrigerators to complement energy labelling.

Some market segments may be more inclined towards energy-efficient appliances. For example, surveys of attitudes to appliance energy labelling have indicated that women in the 30 to 50 age range are more inclined to be influenced by energy labels. Also, people planning for retirement may prefer to invest more money up-front in order to reduce their ongoing living costs during retirement.

Disposal or re-sale

A lot of appliances and equipment remain in people's homes because it is too much trouble to get rid of them or 'they may come in handy one day'. Appliance retailers have little interest in trade-ins, as they involve staff time and effort, and it is difficult to market them profitably in competition with trading magazines and charities.

This lack of re-sale and disposal infrastructure means a lot of appliances which are not really needed remain in homes - often using surprisingly large amounts of energy because of their standby power consumption. Alternatively, second-hand appliances are sold through classified advertisement columns or through local networks. Since energy labels do not remain permanently on even the appliances they apply to, the second-hand market operates in complete ignorance of energy efficiency and running cost factors.

Given the low resale value of second-hand appliances, it seems likely that financial incentives of some kind may be required to encourage trade-ins. Bounties could be paid to charities to collect old appliances. Test procedures could be developed to check performance, so that only reasonably efficient models were re-sold, and inefficient models could be disposed of.

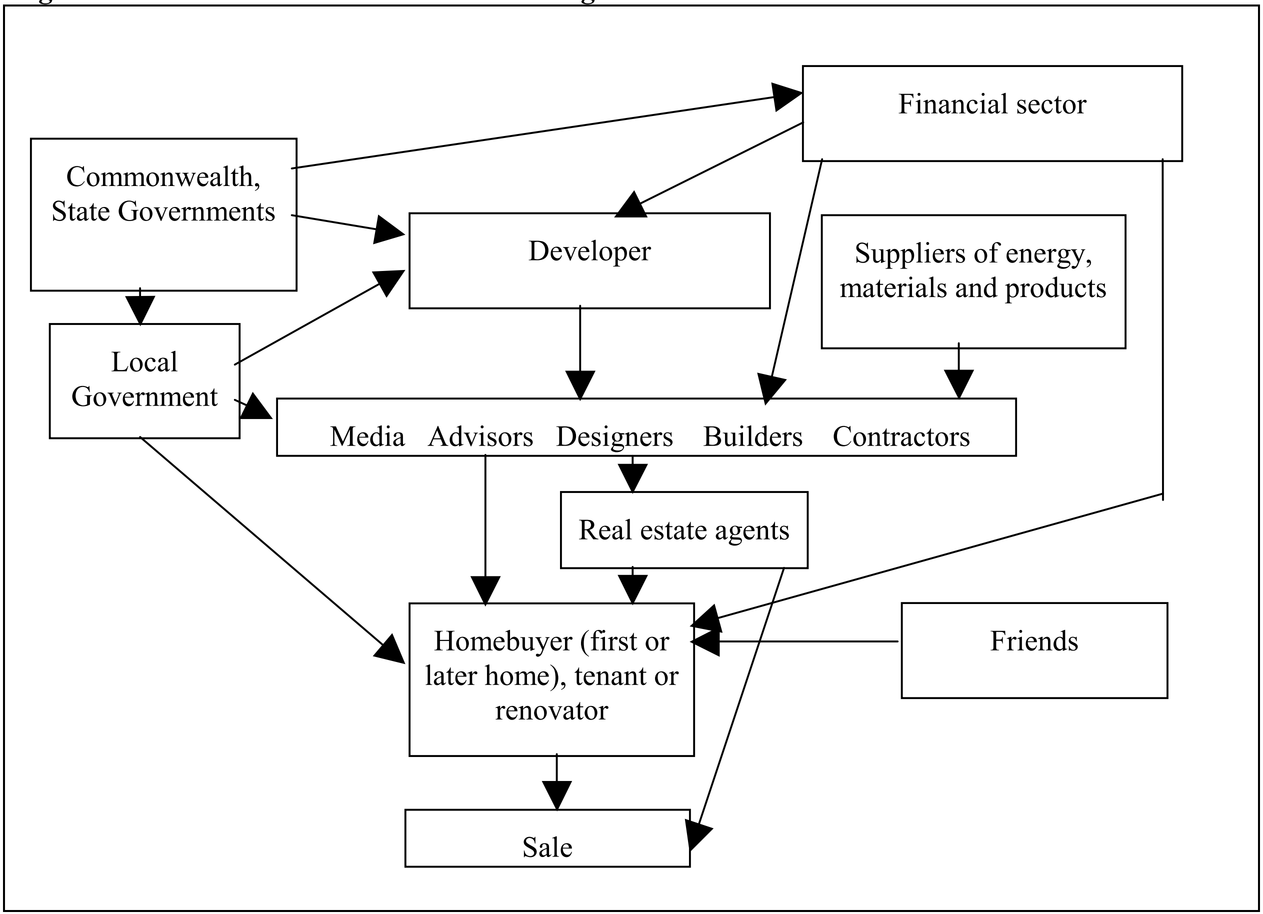
The nature of the housing marketplace

The housing market is, like the appliance market, very complex, with many participants playing a variety of roles. The diversity is vast, including:

- a first home buyer purchasing a house from a large project builder in a new development with very little capital as a deposit
- the second home buyer, who has substantial equity in a first home and is upgrading to a better location and/or type of home
- people who no longer require a large family home shifting to a more compact one in a prime location
- the owner-builder working with individual contractors
- home renovators, who may have substantial equity in their home and are investing in improved quality of life in their existing location
- investors big and small, who may own single or multiple properties.

Figure 27 outlines the broad characteristics of the housing market and its major participants. As can be seen, the situation is even more complex than that for appliances. As in the appliance market, each market participant has its own agenda and priorities, which rarely coincide with those of the householder, and rarely involve consideration of potential impacts on future operating costs or greenhouse gas emissions. The following discussion highlights some of the key issues affecting the behaviour of these participants.

Figure 27. Overview of the Australian housing market



Financial sector

Government policies set the framework within which the financial sector operates, including interest rates, overall economic climate, and regulations for behaviour. In turn, financiers provide capital for developers, builders and home buyers. The guidelines and culture they apply influence the housing solutions that emerge. For example, Newman et al (1992) suggest that financial institutions have been geared towards investment in traditional kinds of housing in greenfield locations, and that this has encouraged urban sprawl. The Australian financial sector has not been involved in programs supporting investment in household greenhouse emission reduction measures.

Overseas, particularly in the USA, the finance sector has been involved in mortgage schemes that favour buyers of energy-efficient houses, on the basis that they will have lower energy bills. Such an approach is not so easily justified in Australia if based just on House Energy Rating scores, because Australian expenditure on heating and cooling energy is usually not the dominant component of energy costs - which are relatively small in any case. Further, as HER scores do not take into account the type of heating or cooling equipment installed, it is still possible for a house with a high HER score to have high energy bills. Nevertheless, discounted financing schemes for a package that includes an energy-efficient building, equipment and appliances could make financial sense.

Commonwealth and State Governments

As noted above, the Commonwealth Government creates the framework for operation of the financial sector. A recent re-assessment by the Tax Office of the tax deductibility of leasing arrangements involving households (Rogers, 1997) may create an opportunity for financiers to take greater interest in the household sector.

The Commonwealth and State Governments also shape Greenhouse policy, which involves measures impacting on the building industry, including development of house energy rating systems and model codes.

State Governments play a major role in urban development policy including, in some cases, funding subdivision of land and public housing. They also set levels of stamp duty, land tax and influence municipal rates, all of which affect housing. State Governments are also key providers of infrastructure, including roads, public transport, and other services. The Commonwealth Government operates the national development of building codes, but each State has a much more detailed involvement in the development and administration of building and planning codes.

At present, only Victoria and ACT have requirements regarding building energy efficiency, with Victoria applying mandatory insulation requirements and ACT applying a performance-based scheme. No urban planning codes protect solar access, and this is becoming an increasing problem as urban consolidation accelerates. For example, in Victoria, the design code allows loss of up to 80% of existing winter solar access if a new dwelling is built to the north of an existing one (Pears, 1994). The code also has anomalies, as it encourages design of new dwellings to incorporate north windows without protecting their future solar access - so those dwellings could be adversely affected if further development occurs on the adjoining site to the north. There is scope to resolve this problem without unduly constraining development, but it requires a more sophisticated approach than that used to date: this is discussed later in this report.

Local Government

Local Government is a key player in the housing market, as it administers planning and building codes. The degree of autonomy varies from state to state. For example, in NSW, SEDA's *Energy Smart Homes* model housing policy (1997) is being adopted by individual councils. Other Councils, such as Armidale, Leichardt and Kuringai have introduced their own energy codes. In Victoria, three councils have trialled voluntary application of an energy checklist developed by Energy Victoria, but there has been a reluctance to attempt mandatory requirements, due to the ease with which developers can win appeals at the State Government level.

Local Government has also experienced severe cutbacks in resources, so they have less capacity to pursue non-core functions. Further, introduction of performance contracts for staff can create barriers where introduction of energy requirements may slow down processing of approvals, as this can lead to salary cuts for the relevant staff.

On the positive side, almost 30 councils have joined the Cities for Climate Protection pilot program which encourages local action on greenhouse emission reduction, including dwelling energy efficiency programs. Armidale Council in NSW offers interest-free loans for insulation and purchase of energy-efficient heaters, although the take-up rate has been relatively low. Moreland Council in Victoria is close to launching an Energy Fund, which is intended to finance local energy-efficiency programs.

There is no doubt that local government has potential to play a leading role in household greenhouse emission reduction strategies. However, it will be important that state-level policies and legislation supports this, and that sufficient resources are made available for effective implementation.

Developers

Developers play a key role in shaping new urban areas. Their decisions regarding density of development, orientation of roads and home sites, road layouts, and provision of energy supply infrastructure all have very long term implications for energy use. Two Victorian studies (Loder & Bayly et al, 1993 and Energy Victoria et al, 1996) have documented these impacts, and have proposed approaches that lead to reduction in emissions. Efforts are being made to implement these approaches around Melbourne.

At the same time, some individual developers have been implementing efforts to reduce energy use within their subdivisions. These include the Olympic Village, the Mawson Lakes (former MFP) site in South Australia, and the Urban Land Authority’s developments around Melbourne’s fringe.

There are some financial benefits for developers to facilitate greenhouse emission reduction where it involves higher density development. However, any constraints on site orientation that limit the number of blocks would lead to higher development costs. Since market positioning is an important factor influencing the profitability of a development, the higher the public profile of energy efficiency and greenhouse emission reduction, the higher the priority developers are likely to place on it.

Suppliers of energy, materials and products

Energy suppliers are potentially very powerful influences on the housing market. They may enter into arrangements with developers and/or builders to promote particular energy sources and appliances, and their market power is therefore substantial. As noted earlier, they have strong financial incentives to increase utilisation of the infrastructure they install in new subdivisions, and to fully utilise existing infrastructure. At the same time, their long-term strategic perspective means they are reluctant to give any ground to competitors.

Suppliers of materials and products tend to respond to the pressures of market intermediaries in most segments of the housing market. In many cases, that means delivering products that can satisfy warranty requirements at lowest up-front price. For renovators, second-home buyers and owner-builders, product suppliers may focus on ‘value-added’ features, including energy efficiency.

Market intermediaries (media, advisors, designers, builders, contractors)

These groups have very diverse motivations, as discussed in the previous section. Unless there is a clear benefit for them, or their clients strongly request greenhouse emission reducing features, there is little incentive for these groups to promote greenhouse emission reduction. Indeed, many have negative attitudes to emission reduction measures, based on the image of 'freezing in the dark', or because they perceive that it will constrain their design freedom.

Real estate agents

Real estate agents play an important role in presenting homes to prospective buyers or tenants. They highlight features they think will facilitate quick, easy sales. So features such as central heating (in cold climates), convenient location, northern aspect (which may, in reality be anything between west and east!), etc may be promoted. But, where a house has no positive greenhouse emission reduction features, the salesperson will focus on other positive attributes. The commission system means a real estate agent's main priority is to achieve a sale with minimum time and effort: this means subtle features that require explanation are less likely to be promoted.

The recently introduced requirement in ACT for all houses being offered for sale to carry an energy rating is one example of a mechanism that will force real estate agents to pay greater attention to energy efficiency issues. But it could also lead them to use the argument that 'energy bills are a tiny part of your living cost - how can you compare that the joy of living in this home with this other feature.....' It should also be recognised that an energy rating does not necessarily bear much relationship to the overall greenhouse gas emissions of a house, due to the impacts of fuel choice, appliances and user behaviour.

The homebuyer, renovator or tenant

The homebuyer is often in a very difficult position, juggling an array of factors including location, home size, access to finance, conflicting requirements of different family members, pressures from real estate agencies and other market intermediaries, and so on. For most Australians, home purchase is an infrequent activity, so they are unlikely to be skilled in this task: this makes them more vulnerable to influence of market intermediaries. Information on energy use, energy bills, building thermal performance and greenhouse gas emissions is simply not available in most cases, so it is difficult to factor them into the equation.

Even where relevant information is available, many householders would have difficulty balancing it against other purchase criteria. This situation provides a rationale for introduction of mandatory requirements, so that homebuyers can be guaranteed a basic level of performance. Financial incentives may also be justified where a low greenhouse impact home reduces the cost of energy supply or reduces the level of subsidy of energy supply, or simply as a form of compensation to balance the market distortions which exist in this area.

Second home buyers and renovators are likely to be better-informed and to have significant capital, so that they may be more interested in investing in measures which reduce ongoing operating costs and improve comfort. People planning for retirement may also be attracted to a more comfortable home that is cheaper to run.

Overview of appliance and housing markets

These markets are characterised by relatively uniformed consumers making complex decisions with long-lasting implications for greenhouse gas emissions. Rational assessment of the importance of greenhouse gas emissions in the overall decisions suggests that they are relatively low in priority, although effective labelling and information campaigns, combined with emphasis on the financial and environmental benefits of appropriate action can influence some segments of the market.

Many market intermediaries are involved in the processes, and none has any particular benefit to gain from emphasising greenhouse gas emissions: indeed, this can make their lives more complicated.

The large number of transactions in these markets makes it difficult to intervene simply and cheaply in these markets.

Chapter 7: Appliance technologies and scope for emission reduction

What proportion of household energy provides useful services?

It is often assumed that most of the energy used by appliances delivers useful services. However, recent studies have shown that this is often far from being the case. Table 3 lists a range of types of losses, with examples of their impacts. These issues are explored in more detail in the sections on appliances later in this report.

Table 3. Overview of types of energy losses from appliances

TYPE OF LOSS	EXAMPLES
Standby energy - used to keep appliance in readiness for use	• heat loss from storage hot water service - up to 60% of HW energy • keeping electronics 'alive' in TV, CD player, dishwasher etc - 10 to 90% of energy use • pilot light for gas heater - around 4 GJ pa
Distribution energy - losses as useful energy is delivered to point of use	• ducted heating or cooling - losses can exceed 30% of energy used • 'dead water' losses - heated water cools in supply pipes, and must be run through the tap before hot water can be delivered - 5 to 50% of energy • lamp shade can absorb up to 80% of light produced by a lamp
Cycling losses - energy required to bring equipment up to readiness when switched on	• in dishwashers, heat required to heat up liner and components can be up to a third of energy used for heating • heating furnaces and instantaneous HWS units that run intermittently cool down and must re-heat before delivering useful energy - variable
Parasitic energy - energy required to run auxiliary equipment required to operate	• electric fans and pumps are used to deliver hot air or water in central heating systems • transformers are used to convert 240 V power to 12V for use by 'low voltage' quartz halogen lamps - these waste up to 15 watts for every 50 watt lamp
Energy conversion losses	• combustion losses in gas, oil, LPG or solid fuel heating appliances - vary from 5 to 60% • compressors in refrigerators or airconditioners fall short of theoretical thermodynamic efficiency by up to a factor of 3
Interactive effects - when operation of one appliance affects the performance of another	• running an exhaust fan removes conditioned air from a house, increasing heating or cooling energy • heat generated by appliances increases the load on an airconditioner

Each appliance is, itself, a system of components, and the appliance may be part of a larger system. This means that different energy losses and inefficiencies often compound to reduce overall system energy efficiency to surprisingly low levels. For example, a gas ducted heating furnace may have a combustion efficiency of 75%, but its overall heat delivery efficiency is often as low as 25%; an electric hot water service may convert electricity to heat at near 100% efficiency, but a large tank in a small household with inefficient water usage may waste 70% of the heat produced.

The nature of systems associated with appliances also means that efforts to improve efficiency may lead to smaller savings than expected. For example, installing a smaller capacity high efficiency burner in a gas central heating system may be expected to reduce gas consumption by 15%, but increased losses from standard ducting (due to longer operating periods) can neutralise the savings. A combination of improved furnace efficiency and improved duct insulation is needed to gain the full savings. Similarly, installing a water-efficient showerhead can cut household hot water consumption by 25%, but total hot water bills may be cut by less than 10%, because losses from the HWS and pipes are a large part of the total bill, and these are unaffected (and, under some circumstances, may even increase). Critics of energy efficiency measures often leap upon these lower-than expected savings as evidence that energy-efficiency cannot deliver large savings, and complex mechanisms such as ‘rebound effects’ and ‘comfort take-back’ are used to explain the outcomes. The author has written extensively on this issue (see Pears 1997).

Trends in energy efficiency improvement

Trends in Australian household appliance efficiency as estimated by Wilkenfeld (1993) are shown in Table 4. It is not known how these compare with trends over more recent years, although there are grounds to expect that those trends have continued and, in some cases, accelerated. For example, the best new large family frost-free refrigerators now achieve around 650 kWh per year; many more dishwashers now achieve 5 and even 6 star ratings; and the market share of more energy-efficient front-loading washing machines is beginning to rise. When the overall impact of these trends is considered, outcomes are complicated by changes in appliance capacity, such as a trend towards larger refrigerators, for which data are not readily available.

Table 4. Trends in Australian household appliance energy consumption, 1980 to 1992 (Wilkenfeld, 1993)

Appliance	Bought 1980 kWh pa	Bought 1992 kWh pa	Annual rate of change, 1980-1992 (% pa)
Refrigerator - single door	650	536	-1.6
- 2 dr cyclic defrost	1100	826	-2.4
- 2 dr frost free	1300	1097	-1.4
Freezer	680	664	-0.2
Dishwasher	620	494	-1.2
Clothes washer	610	575	-0.5
Airconditioner - reverse cycle	1700	1560	-0.8
- cooling only	800	700	-1.1
Electric storage HWS (standing loss only) - continuous tariff	570	460	-1.2
- off-peak 1 element	790	682	-1.2
- off peak 2 element	1000	884	-1.0
- extended hrs o/p	740	607	-1.6

Setting priorities

Key factors affecting appliance energy consumption are:

- market penetration and consumption per appliance
- product design
- model selected
- installation
- pattern and nature of usage of each product

Products with low market penetrations can still be large contributors to greenhouse gas emissions if each unit consumes large amounts of energy, especially if it is electricity from fossil fuels. For example, while only 12% of Australian households have swimming pool filter pumps, their average consumption is 1350 kWh per year, so they use up to 20% of those households’ total electricity and generate an estimated 2.5% of total Australian household energy-related greenhouse gas emissions.

Product design is a critical influence on energy consumption. Each decision taken at the design stage is replicated hundreds of thousands of times, and influences energy consumption for the operational lives of the products. A product’s design also influences the design of competing products, by influencing the criteria used by consumers in purchasing, and by providing an example from which other manufacturers can learn. Intelligent product design can facilitate energy-efficient user behaviour, and can even compensate for poor user control.

The model chosen influences the level of energy use for a given level of usage.

The pattern and nature of appliance usage influences energy use to a greater or lesser extent, depending on the type of appliance and the actual behaviour. On one hand, it may have little impact - for example, opening the door of a refrigerator is responsible for only around 3% of consumption, while washing half loads in a clothes washer can almost double clothes washing energy consumption.

The following sections provide a brief review of the major technology issues involved in reducing greenhouse gas emissions associated with appliances. Heating and cooling appliances are discussed in the chapter on buildings.

Hot water

Overview

Greenhouse gas emissions from energy used to supply hot water are the largest source of household energy-related greenhouse gas emissions, comprising almost 30% of the total. Almost 85% of emissions from hot water supply result from use of electricity for water heating, even though less than two-thirds of households use electric water heating. If household emissions are to be reduced to a significant extent, it will therefore be essential to address hot water and, in particular, electric water heating.

Just over 62% of Australian households have electric HWS units which contribute an average of 3.0 tonnes of CO_2 each year. Almost 34% of households have gas HWS units, which generate on average 1.3 tonnes of CO_2 each year, while 5% have solar HWS units and 2% have other types (most likely wood) (ABS 1994, Pears 1994)). This mix gives an overall average of 2.2 tonnes of CO_2 per year per household for hot water supply.

Around a third of the greenhouse gas emissions from water heating result from heat losses from storage tanks and, for those with gas storage units or small households with large electric units, these losses can exceed 60% of water heating energy. Additional losses (typically 2-5%) result from leakage from pressure/temperature valves and heat losses from pipes. As average household size declines, losses will comprise an increasing proportion of water heating energy, unless different design philosophies are pursued.

Decisions made at the time of purchase of a house, during renovations, and when a HWS is being replaced have the greatest impact on emissions from water heating, as these determine the fuel source and appliance efficiency, types of fittings installed, and lengths and diameters of pipes. Householders have limited involvement in many of these decisions, which are often made by builders, plumbers or designers. These decisions have long-term implications. For example, an electric HWS may generate over 60 tonnes of CO_2 over its life, compared with 25 tonnes for a gas HWS. And the existence of the wiring, combined with the probability that gas supply will not be available near the location of the HWS, means that the replacement HWS is more likely to be an electric unit.

It is difficult to influence the purchase decisions of decisionmakers who are not responsible for ongoing operating costs, and who place a high priority on low up-front cost. For example, a 1990 study by the Gas and Fuel Corporation (GFCV 1990) found that penetration of high efficiency gas water heaters was higher in the replacement market (where householders are more likely to have some influence on decisions) than in the new home market, and that the Corporation (which actively promoted energy rating labels to comply with state government policy) sold a much higher proportion of high efficiency models than did private retailers. The decision to introduce mandatory MEPS for electric water heaters was based partly on the recognition that tradespeople specify most electric HWS units, and would not be significantly influenced by a labelling scheme.

Usage patterns

There is little information on hot water usage by activity. One Perth survey (reported in Wilkenfeld 1991) suggests that 59% of hot water usage was in the bathroom, 28% in the laundry, and 13% for dishwashing. There is wide variation in household water consumption, both between households and from day to day, as shown in Figure 28. Also, occupancy of a given house varies over time, leading to long term variation in hot water requirements. And the possibility of running out of hot water is a major concern for many households. All this leads to the conclusion that HWS units must be able to efficiently satisfy a wide range of consumption patterns, regardless of the type of housing in which they are installed: Existing products often fail to deliver this outcome.

Figure 28a. Daily quantity of hot water consumed per person for 13 households (Allwood et al 1995)

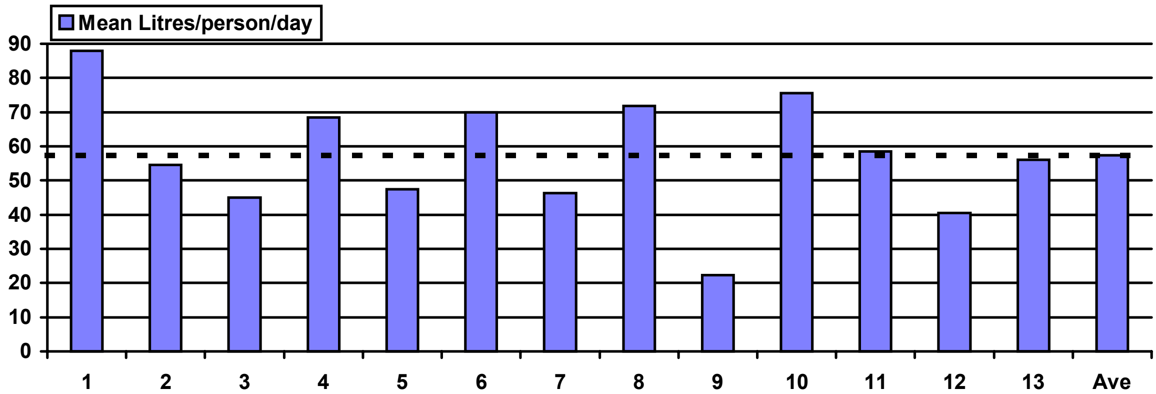
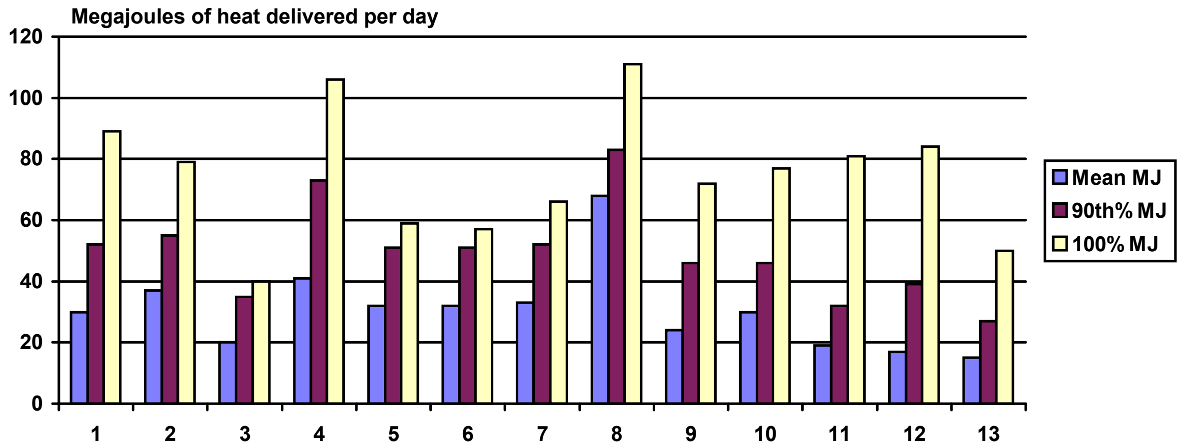


Figure 28b. Daily average and peak heat supplied by HWS for a sample of households (Allwood et al 1995)



Trends in hot water energy use

A number of trends related to hot water are influencing levels of greenhouse gas emissions. These are listed in Table 5.

It is not clear what the net outcome of the trends listed in Table 5 is, due to the lack of monitored end-use data. It is desirable that this inadequacy be remedied if informed strategies are to be implemented and their outcomes evaluated.

Table 5. Trends influencing household water heating greenhouse gas emissions

TRENDS INCREASING GHGS	TRENDS DECREASING GHGS
Larger storage tanks (gas and especially electric, as large off-peak units are encouraged to replace small continuous tariff units and to upgrade capacity of o/p units to comply with new tariffs)	improving gas HWS efficiency (especially new instantaneous models), MEPS to be introduced for electric HWS
Increased ownership of spas and saunas	clothes and dishwashers using less hot water, and shift from hot to warm or cold clothes wash
Increased installation of mixer taps (which draw water from hot water pipes, even when users are not aware of using hot water)	trend away from baths to showering
More frequent, longer showers	adoption of water-efficient showerheads
	increasing share of gas HWS (see Figure 9)

Scope for savings

To evaluate savings, it is necessary to consider the overall system used to deliver hot water, as well as the end-use requirements of users. These elements include:

- supply water (the temperature of which varies seasonally and geographically
- hot water service
- distribution pipes
- tap and shower fittings, and hot water-consuming appliances
- user behaviour

Unless all of the elements of this system are optimised, savings may fall short of predictions, as discussed in the previous section.

Scope for savings with HWS units

While the greatest savings come with replacement of a HWS, a number of actions can be taken to improve the performance of existing units. These are summarised in Table 6.

Table 6. Scope for emission reduction for retrofit options for average existing hot water services in tonnes per year per household, based on 1.3t pa for average gas HWS, 2.3t for day-rate electric, and 3.5t for off peak electric HWS

ACTION	INCREASE	DECREASE
Replace pressure-temp valve with new design (not yet available) that avoids dumping hot water, cuts heat loss	up to 0.07	up to 0.2
Re-set thermostat (where adjustable - reduces effective capacity)	up to 0.07	up to 0.2
Add extra insulation to cut heat loss from storage tank - day-rate electric HWS		-0.3
Add extra insulation to cut heat loss from storage tank - o/p electric HWS		-0.3 to -0.7
Add extra insulation to cut heat loss from gas HWS		n/a (pilot light may cause overheating)
Convert electric HWS to gas		up to 2.5
Rectify plumbing faults (eg shorten pipes, replace 20mm pipes with 15mm pipes, insulate exposed pipes)		very variable - 0 to 40%

The following discussion amplifies the options shown in Table 6:

- the pressure-temperature valve fitted to all mains pressure HWS units dumps 2-5% of the volume of water heated. It also loses heat directly, and from the attached drainpipe via conduction, convection and radiation. In many cases, faulty P/T valves leak even more water, a situation which is often undetected because the leakage is drained away via a pipe. An improved design solution is needed, and could possibly be retrofitted to existing HWS units to achieve worthwhile savings
- resetting the thermostat to a lower temperature reduces the temperature difference between the stored water and the environment, thus reducing heat loss. However, this also reduces the quantity of heat stored in the tank, so there is a greater chance of running out of hot water. This approach can be used with gas HWS units, but many electric units do not have adjustable thermostats. In households with young children or elderly occupants, lowering the thermostat setting can reduce the risk of scalding, providing a safer situation.
- the greatest savings from adding insulation to large off-peak electric tanks are gained for units installed in homes where hot water consumption is low. The less hot water drawn off, the less cold supply water enters the tank, so the hotter the average temperature of the tank over the day, and the more heat it loses. In colder climates, the temperature difference between the heated water and the environment is higher, so more heat is lost. For new electric water heaters, reduction of heat losses through improved insulation and reduction of thermal bridging across the insulation is being pursued via MEPS, but units of 80 litres and smaller have been exempted, and even higher standards of insulation can be justified.
- there is scope to convert existing electric HWS units to gas by installing an external gas burner, or to add solar boosting or pre-heating to existing gas or electric HWS units. Conversion to gas is likely to cost several hundred dollars per unit, which may limit its appeal. Gas suppliers who are extending their pipelines to new areas may find conversion of electric HWS units to gas useful to increase gas load (and hence revenue streams) more rapidly than would occur if they wait for existing electric HWS units to fail, so they may finance such modifications. Simple solar pre-heaters may be installed cheaply, and could improve the performance of existing HWS units by reducing the likelihood of running out of hot water, as well as reducing energy costs
- many existing homes have serious inefficiencies in their plumbing systems. Dripping taps and leaks from pipe joints are significant contributors, but long lengths of pipes exposed to the weather are also wasteful. Where old HWS units have been replaced, plumbers may have left unnecessarily long lengths of pipe in place or, where a gravity fed unit has been replaced by a mains pressure one, 20mm pipe may not have been replaced by 15mm pipe, which holds half as much water. In one extreme case, the author found that unnecessary pipework was doubling one household's hot water bill.

Replacement of an existing HWS, or installation of a HWS in a new dwelling provides an opportunity to make major greenhouse savings. Table 7 shows the greenhouse impact of existing technology options.

Table 7. Scope for emission reduction (or increase) for replacement of average existing hot water services in tonnes per year per household, based on 1.3t pa for average gas HWS, 2.3t for day-rate electric, and 3.5t for off peak electric HWS

ACTION	INCREASE	DECREASE
Replace day-rate electric HWS with standard gas		-1.0
Replace o/p electric with standard gas		-2.2
Replace day-rate electric HWS with off-peak electric	+1 to 1.5	
Replace 250 L o/p electric with 400L o/p electric	+0.3	
Replace o/p electric with solar-electric or heat pump		-2.0 to 3.5
Replace standard gas with 400L o/p electric	+2.5	
Replace standard gas with 5 or 6 star gas		-0.2 to 0.3
Replace standard gas with solar-gas		-0.7 to 1.3

Table 7 shows that the largest savings come from replacing resistive electric units with lower greenhouse impact options such as solar, heat pump or gas units. Since average HWS life is of the order of 12 years, the majority of Australian HWS units will be replaced by 2010, so there is scope to use appliance replacement strategies to achieve significant change by 2010. It should also be noted that over 25% of the electric HWS units installed in homes are small capacity units, operating on relatively expensive tariffs: these comprise a key target group, as they are costly for consumers and they contribute to peak demand costs for electricity suppliers.

When replacing or installing new HWS units from now on, it will be important to factor in consideration of long term strategies, or short term gains could undermine achievement of long term objectives. For example, the gas industry is extending the lives of storage tanks by using stainless steel and improved vitreous coatings. However, these gas products, which are up to 20% more efficient than standard models, still use pilot lights and have substantial heat loss. Widespread adoption of these units would undermine any future strategy to retrofit solar pre-heating or upgrade insulation, because the pilot light would tend to overheat the water if insulation was improved, and the losses are so large that solar pre-heating would make a small contribution. This situation provides a rationale for accelerating HWS design to 'best feasible' design within cost-effectiveness limits as quickly as possible.

Table 8 shows the effect of replacing today's standard HWS units with the best feasible technologies.

Table 8. Savings potential of 'best technology' HWS units, in tonnes CO_2 per year per appliance

BEST TECHNOLOGY	SAVING *c/f* STD GAS (tonnes CO_2 pa (% saved))	SAVING *c/f* Off-Peak ELECTRIC
Super-insulated gas storage with electronic ignition and high efficiency burner OR high efficiency instantaneous unit with electronic ignition	0.4 (35%)	2.6 (75%)
Super-insulated electric HWS	increase of 1.5t pa	0.7 (20%)
Solar (low loss tank, high efficiency collector)	0.9 - 1.3 (70-100%)	2.5 - 3.5 (70-100%)
Electric heat pump (COP 5, super-insulated tank, solar input)	n/a	2.8 (80%)
Greenpower or Greengas	up to 100%	up to 100%

The following discussion amplifies the options in Table 8:

- for gas storage units, the fundamental energy waste is associated with tank standby losses and pilot lights. The gas industry has been slow to adopt electronic ignition, because this has been considered to be expensive, while also requiring attendance on-site by an electrician to provide a powerpoint. Both these issues have been resolved: Bosch uses a battery powered electronic ignition, while Solahart uses a low voltage power supply plugged into an internal power point (as unqualified people can run the low voltage lead to the HWS). In both cases, the cost is now within acceptable levels. For storage units, it will still be necessary to substantially upgrade insulation, and probably to use an external burner and automatic damper, so heat loss from the tank can be controlled. Substantial improvement in burner efficiency, from today's best of 80 to 85% to 94% is feasible.
- gas instantaneous units (also called 'continuous') with electronic ignition and high efficiency burners have been on the Australian market for over five years. During that time, their price has fallen by 40%, so that they are now competitively priced. For small households, they can deliver savings of up to half on water heating bills, because they have negligible standby losses. However, these products can suffer minor but annoying temperature variations when operating at low flowrates in warm weather, so they are not ideally suited to use with water-efficient showerheads unless their flexibility is further improved. The heat-up time means they take a little longer to deliver hot water when a tap

is turned on, too. Nevertheless, these units never run out of hot water, which is a big attraction for many households, and their outlet temperature can be controlled so that the risk of scalding is avoided. Substantial improvement in burner efficiency, from today's best of 80 to 85% to 94% is feasible. If located at a distance from the gas meter, these products require a large diameter gas supply pipe to deliver sufficient gas for their high capacity burners. Some instantaneous units are also used to supply hydronic space heating as well as hot water, which improves their economics.

- Reducing the heat loss from an electric HWS cannot achieve the scale of improvement really needed where significant amounts of hot water are consumed, as the actual heating of water generates large quantities of greenhouse gas emissions. The practical options available seem to be either their removal from the role as a major household heater in favour of heat pump, solar or gas appliances, or requiring resistive electric HWS units to be sold only with a *Greenpower* tariff arrangement for their lives. This would involve the consumer paying the greenpower surcharge on electricity used by the off-peak HWS (which could receive an insulation upgrade, along with water-efficient shower etc, to cut usage). While the electric HWS would continue to create an off-peak load, the electricity supplier could invest the extra revenue in renewable electricity sources that helped reduce more costly peak and intermediate demand, thus reducing pressure to build new fossil-fuel powered plant in the short term. SEDA's *Energy Smart Homes* policy (1997) incorporates a points system which effectively excludes conventional electric HWS from compliance: it would be useful to evaluate market reaction to this approach.
- solar HWS units are well-proven in most parts of Australia. However, there is scope for further improvement through reduction of heat losses from the collectors, pipes and tank, and through more efficient collector design. Summer overheating of water is being dealt with in a number of ways. In cold areas, frost protection increases the cost of solar HWS units. When solar HWS is electrically boosted, it may generate as much greenhouse gas as a standard gas HWS in less sunny climates - although design improvements could reduce emissions in future.
- electric heat pump HWS units are now well-proven, and cut greenhouse gas emissions by 50 to 85%. Products are available from a number of suppliers. On an annual basis, they are claimed to reduce energy requirements by around the same amount as do solar HWS units, however their winter performance is superior: one recent monitoring project in South Australia achieved a 62% reduction in water heating energy. Because they heat water to a specified temperature, they do not overheat in summer. In winter in cold areas, they are not prone to failure due to freezing of water, because they use a refrigerant which remains liquid. However, heat pumps work more efficiently during daytime, when electricity suppliers are less likely to offer discounted tariffs. Further, where electricity is generated from fossil fuel, greenhouse emissions from heat pump HWS may be comparable with those from a conventional gas HWS.
- *Greenpower* and *Greengas* involve either replacing fossil fuels with renewable alternatives, or investing in offsets such as tree-planting. These are discussed in chapter 4.

Off-peak electric hot water is considered by many in the electricity industry to be a strategically important load, as it creates demand overnight when other loads are small, allowing output of less flexible coal-fired powerstations to be utilised. Indeed, some industry participants argue that off-peak electric units should be credited with lower greenhouse gas emissions, because they use electricity generated with steam which would otherwise be vented to the atmosphere by base load power stations that cannot be shut down overnight. This argument has little validity (see Box 1 for discussion), but it may mean that some major participants in the electricity industry actively oppose efforts to encourage fuel-switching.

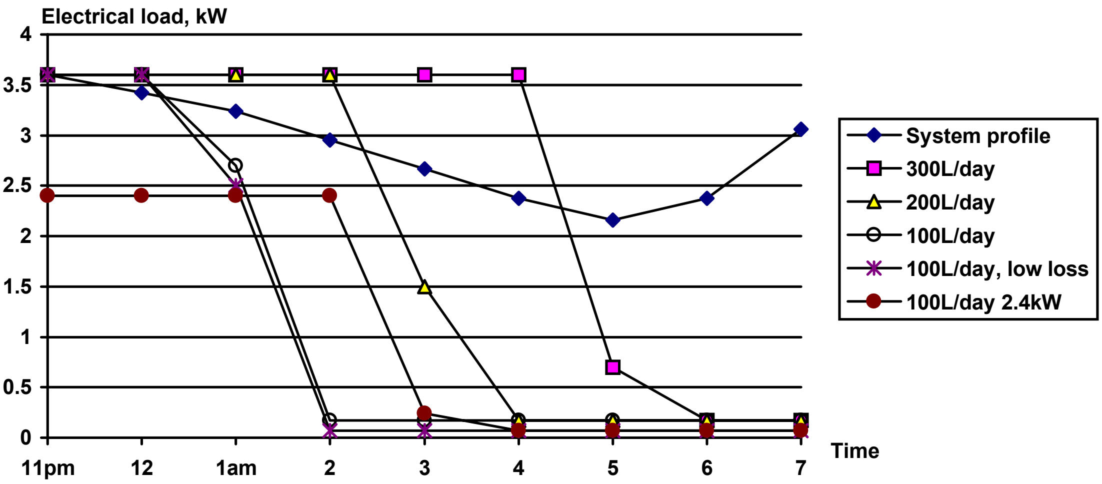
It will also be important in tactical terms to balance the impacts on the electricity industry against those on the gas industry: part of the electricity industry's resistance to MEPS for electric HWS was because MEPS increased the purchase cost of electric HWS units while leaving gas HWS prices unaffected. If gas HWS units were required to switch to electronic ignition and higher insulation standards while electric units had to meet new performance standards, the balance of the competitive situation could be maintained. As we move towards integrated retailing of gas and electricity, this may become a less difficult issue.

BOX: The off-peak hot water dilemma

The off-peak electric hot water market is considered by many in the electricity industry to be a strategically important load, because it creates demand during the early hours of the morning, when demand from other sources is low. This provides a load for relatively inflexible coal-fired power stations, so their output can be utilised more effectively. It also reduces the load due to day-rate electric HWS units, which can be a significant contributor to peak electricity demand. However, the validity of this argument is declining for a number of reasons:

- technological developments mean that even coal-fired power stations are becoming more flexible
- new plant such as combined cycle gas is more flexible
- options for load control are expanding
- electricity storage technologies are rapidly approaching commercialisation
- most important, time-switched electric HWS units are becoming less likely to deliver load at the times it is most needed, while they can contribute to local system peaks early in off-peak period (see Figure B1)

Figure B1. Electrical load for re-heating an electric HWS for varying hot water consumption, based on 3.6 kW heating element and 4 kWh/day heat loss from tank (low loss tank 1.7 kWh/day)



It can be seen from Figure B1 that the ideal off-peak storage electric HWS would have a heat-up cycle delayed until the latest possible time, but capable of completing re-heat by around 6.30am. A Melbourne University academic (Dr I Cochrane) demonstrated a simple system to achieve this some years ago. A nichrome wire next to the storage tank senses the total amount of heat stored in the tank, as its resistance varies with temperature. This resistance is then used by an on-site control system to delay the reheat cycle or, alternatively, the information could be sent to a central control system which could manage reheating to match reheating activity to electricity supply system loads. Such an approach would allow reheating to be carried out at other times of the day, improving customer service.

This concept was rejected by the State Electricity Commission of Victoria in the mid-1980s in favour of installing larger tanks with higher capacity heating elements which started reheating at 1am instead of 11am. A cheaper tariff was offered to encourage adoption of this approach. This decision has led to higher electricity consumption due to increased heat loss from the larger tanks, and has had only a temporary impact on the overnight load problems. Further, households taking up this option have not experienced significantly lower overall bills, because the higher tank heat loss has increased consumption by about as much as the effect of the tariff reduction!

Scope for savings through reducing hot water consumption

Hot water consumption can be reduced by a number of measures, including:

- water-efficient showerheads and tap fittings
- water-efficient clothes washers and dishwashers
- smaller diameter, shorter pipes
- recovery of waste heat from warm or hot water running to waste

The water industry has developed a rating system for water-efficiency of showerheads. However, the more efficient models have a reputation for not providing enjoyable showers. Improved design has largely overcome these problems, but it will take time and effort to win acceptance. In any case, it is clear that water-efficient showers are less satisfactory than traditional showerheads in cold, draughty environments. The common practice of installing an exhaust fan above the shower recess and switching it on with the room light creates a very difficult situation, as cold air is drawn over the user's wet body. Practical advisory materials that address the key issues are needed.

Many promoters of water-efficient showerheads overstate the likely savings. The Australian Standard test is carried out under full mains water pressure, equivalent to having the tap turned on fully, so standard showerheads can deliver over 20 litres per minute in tests. Using these results, enormous savings can be claimed. However, standard shower flow rates are usually in the range of 8 to 15 litres per minute, so water-efficient showers offer smaller savings under typical conditions. Other factors which further reduce savings include longer showers (where previously shower time was constrained by running out of water) and slightly hotter shower temperature (to maintain comfort with lower water flow in cold conditions). Nevertheless, water-efficient showers can deliver substantial cost-effective savings. Future developments, such as air-assisted showers and micro-sprays, could see further reductions from today's AAA-rated 7.5 litres per minute to as little as 3 litres per minute.

Many activities which require hot water are time-dependent, so a low flowrate tap uses less water for these tasks. However, the lower flowrate increases the time delay before hot water is received, as replacing the cold water in the pipes with hot water takes longer at a lower flowrate. Smaller diameter pipes can be installed to solve this problem and, as discussed below, they save energy, too.

Mixer taps, which are becoming increasingly popular, waste hot water: when operated in the most natural middle position, these taps draw 50% of the water from the hot supply, even when the user only wants cold water. Improved design could easily overcome this problem.

Front-loading washing machines and/or cold water washing can deliver significant hot water savings. A conventional clothes washer on hot wash may use up to 40 litres of hot water per wash. A front loader can halve this consumption, as can warm water washing. Cold wash virtually eliminates water heating energy - although some models have heating elements to raise the water temperature from the supply temperature (sometimes as low as 10C in cold climates) to 20C, but this is still a modest energy requirement

Water-and energy-efficient dishwashers may also save hot water. However, most dishwashers are connected to the cold water supply only, so they heat water with electricity but, because this is not delivered by the HWS, it is not observable as hot water consumption. Low temperature dishwashing detergents are being developed, and these will contribute to further savings.

Losses from water pipes can be reduced by reducing pipelengths, using lighter pipes, and insulating them. Smaller diameter pipes than now generally specified may also be used for pipe-runs for low flowrate taps. For example, the pressure drop per metre in a 10mm pipe with a water flow rate of 5 litres/minute is approximately the same as in a standard 15mm pipe with a flowrate of 12 litres per minute (Rheem, 1992), so the smaller pipe (which would have half the 'dead water' losses) could provide satisfactory pressure if it supplied a water-efficient tap.

Heat recovery from waste water also offers potential savings. Where hot or warm water is being drained while more hot water is required, there is scope for heat recovery. Such systems are being developed for use with clothes and dishwashers, and a US-developed system for recovery of heat from showers has demonstrated capacity to recover up to 60% of heat energy. Heat recovery from shower water has the potential to reduce total hot water requirements by up to 30%, but would require installation of automatically-adjusting mixer controls in showers, to maintain constant temperatures. This could be promoted as a safety device, to limit temperatures to safe levels for children and the elderly.

Hot water-saving measures such as those discussed have potential to cut hot water consumption by at least 40 to 50%, saving up to a tonne of CO_2 per year for average electric HWS units. However, trends towards longer showers and spa baths may eat into these savings. An important benefit of hot water efficiency improvement is the potential for down-sizing hot water services and pipes, thus reducing their capital cost.

Overall hot water savings

By adopting water-efficiency improvement options and best technology gas HWS units, Australian households could reduce their average annual greenhouse gas emissions to around half-a-tonne of CO_2 per year using gas HWS (and to below a quarter of a tonne with solar-gas), while resistive electric HWS units could cut emissions to less than two tonnes per year. If resistive electric HWS units were replaced by heat pumps, solar or gas HWS units, their emissions could also fall to around half-a-tonne of CO_2 per year.

Pro-active strategies addressing hot water would make a major contribution to reduction of household greenhouse gas emissions, with a potential reduction of 75% or more in emissions from hot water.

Refrigeration

Overview

Australian households have quite a lot of refrigeration equipment - almost two appliances per household on average, as reflected in the fact that refrigeration is the second largest contributor to household energy-related greenhouse gas emissions. ABS estimates that, in 1997, 30% of Australian households have at least two refrigerators (up from 24% in 1986), and 44% had freezers (close to the 46% that had them in 1986). Wilkenfeld (1996) estimates that electricity consumed by an average household's refrigerators generates around 1.4 tonnes of CO_2 each year - around 9 Mt per year in total. This is equivalent to approximately 1400 kWh per household per year. Survey data indicates that an average household refrigerator consumes around 950 kWh per year, a second refrigerator uses 830 kWh, and a freezer uses 650 kWh.

In Australia, most household refrigerators are purchased by householders themselves, so information programs such as appliance energy labelling have been relatively successful at influencing the market.

Refrigerators use more electricity in warmer weather, due to greater heat flows, lower compressor efficiency and higher usage. Summer consumption can be 30 to 40% higher than winter consumption. Thus household refrigerators are a disproportionately large component of summer peak electricity demand, which is a major problem for electricity suppliers in several States.

Trends in energy use

The best mass-produced Australian family-sized refrigerators consume around 1.5 kWh/litre/year, comparable with the best Japanese 1995 models. The best European and US 1995 models achieved 1.0 kWh/L/year (Meier, 1997). New mandatory standards to be introduced in the USA will reduce consumption by a further 30%. The most energy-efficient 450 Litre refrigerators on the US market consume less than 200 kWh per year - 0.43 kWh/L/year. These are limited production, relatively expensive models, but they demonstrate that there is substantial scope for improvement.

The best new Australian refrigerators are significantly more energy-efficient than those of previous years (see Table 4), due to the impact of appliance energy labelling. Trends influencing greenhouse gas emissions from refrigeration energy consumption are listed in Table 9.

The trend towards larger refrigerators, especially two-door models with large long-term freezers may not lead to net increases in greenhouse gas emissions. One large appliance may replace separate refrigerator and freezer, and increased storage capacity may reduce the amount of transport energy used for shopping by reducing shopping frequency. Increased capacity to store pre-cooked food may also facilitate reduction in cooking energy consumption. The decline in household size and changes in home design (such as reducing size of laundries) may also be limiting use of separate freezers. This area requires further research.

Table 9. Trends influencing household refrigeration greenhouse gas emissions

TRENDS INCREASING GHGS	TRENDS DECREASING GHGS
Larger refrigerators, more with two doors, and more households have a second fridge	Slight decline in share of homes with separate freezer (see Figure 18)
Shift to frost-free from cyclic defrost	Improving energy efficiency within each type and size (but rate of improvement may have slowed since early ‘90s due to ‘5 star’ limit being reached and diversion of effort to CFC replacement)
Warmer homes in winter (raise heat load)	Homes may be cooler in summer
Additional features such as ice-makers, more than two doors, chilled water dispensers etc	Limited space in medium-density housing constrains size and number of appliances
Population growth greater in warmer regions, where refrigerators use more energy	

Scope for savings

Calculation of the theoretical amount of energy actually required for cooling of food for three people, at the theoretical maximum coefficient of performance (about 3 times more efficient than existing compressors) indicates that the theoretical minimum energy required to operate a perfectly insulated refrigerator-freezer is around 25 kWh per year. When heat flows through highly insulated cabinets are considered, family-sized refrigerators have the technical potential to achieve a consumption level of around 150 kWh per year over the next few years.

The technological development contributing to refrigeration efficiency improvement includes:

- more efficient compressors (especially small ones, which have traditionally been very inefficient) with very high efficiency motors and variable speed capability (which cut cycling losses)
- high efficiency variable speed fans
- intelligent control systems that defrost only when necessary and optimise appliance performance
- improved door seals (up to a third of heat gain can be via poorly-designed door seals)

- improved insulation materials - although evacuated panels have been developed, there seems to be a preference for multi-layer metallised plastic modules filled with low conductivity gas, which seem to be more reliable over the long term: this technology is reaching commercialisation
- improved Power Factors from existing levels of around 0.6, to reduce electricity supply losses.

There is substantial scope for further refrigerator efficiency improvement. Over the next decade, consumption of the best family refrigerators could decline from around 700 kWh pa to 350 - 400 kWh if they match good US practice, while it is feasible for the best models to achieve close to 150 - 200 kWh per year. A saving of 350 kWh per year gives a saving of $500 or more over a 15 year life, which should be sufficient to justify any likely extra cost of measures required to achieve the savings. For comparison, US estimates suggest that cutting consumption of a 450 litre refrigerator to 400 kWh per year would add US$150 to its cost (Turiel et al, 1995): this extra cost is easily recovered within the life of the appliance.

As an illustration of the scope for efficiency improvement, a small Albury-Wodonga-based company, Davy Industries, modifies 310 litre Email refrigerators with an energy rating of 700 kWh per year by replacing the motor with a high efficiency alternative designed for operation by renewable electricity systems. The modified unit is claimed to consume between 220 and 290 kWh per year under conditions similar to the Australian Standard test - at least a 60% reduction from the standard unit.

Installation and user behaviour are also significant influences on refrigerator energy use. For example, poor ventilation around a refrigerator can increase energy consumption by 15%, high rates of ice-making can increase consumption by 10%, and setting thermostats too low can increase consumption by 5 to 10% per degree. Information and education programs can influence these factors.

The improvement in refrigerator performance in the USA over the past decade has been most striking. It has been driven by a combination of strategies including:

- strong commitment to public sector RD&D work, including computer simulations and construction of prototype high efficiency products that have been used to demonstrate to the industry and consumer what is possible (eg USEPA 1993)
- strong performance standards which have driven market improvement: for example, when the 1993 standards were announced in 1989, few existing models could meet them, so manufacturers were required to invest serious effort into efficiency improvement
- incentive programs such as the widely-known ‘Golden Carrot’, which offered a reward of $30 million for a model that used 30% less than 1995 models. The reward was paid to the winning manufacturer on the basis of actual sales, not as a lump sum.

There is no doubt that this combination of strategies has worked, and extensive studies have shown that the outcomes have been very cost-effective for householders and society, and that proposed ongoing improvements should also be cost-effective (see, for example, Nadel and Pye (1996), Greening et al (undated), Levine et al (undated)).

In Australia, the rate of energy efficiency improvement seems to be constrained by:

- small market size, which means RD&D and tooling-up costs must be spread over small numbers of sales, and model upgrades occur less often
- relatively low expenditures on energy-efficiency RD&D
- reluctance of purchasers to pay significantly higher prices for energy-efficient products
- perceptions among manufacturers that wall-thickness should be minimised (to maximise storage capacity in a given cabinet size), which makes them reluctant to increase the thickness of insulation - one of the easiest ways of improving refrigerator efficiency. However, development of multi-layer reflective insulation panels may allow insulation to be upgraded while walls remain thin.

Options for action

If greenhouse gas emissions associated with household refrigeration are to be reduced, efficiency improvement of new products should be accelerated, as this is technically feasible and cost-effective. However, efforts in this area must take account of issues affecting our relatively small market. Intervention will be required to either increase the market pressure for energy efficiency, or to increase the incentives to focus RD&D activity on energy efficiency. There is also a case for funding publicly-accessible RD&D work via universities and research organisations, to increase the pool of expertise and free up access to information on the potential for improvement.

It may be possible to introduce funding for manufacturers as soft loans, to be repaid from sale of high efficiency products. Alternatively, a rebate scheme which increases with appliance efficiency (paid to the manufacturer and possibly the retailer, not the buyer) could provide an effective incentive. However, this would have to be linked to a baseline efficiency which improved over time, so that an ongoing subsidy was not established. The advantage of paying a rebate to the manufacturer is that its impact on production cost is amplified up the marketing chain, due to the practice of applying percentage mark-ups. Further, a manufacturer can choose to use some of the money to provide incentives to retailers to increase sales of high efficiency models, so that rebate income increases. The rebate should increase with product efficiency, to reflect the fact that the savings to society are greater, and that the cost of large improvements is often greater.

When new refrigerators achieve high efficiency levels (say 400 kWh pa or better), incentives could be provided to encourage households to replace their old refrigerators with new ones, using the argument that the energy savings will pay for their new appliance over its life (for example, if a 350 kWh unit replaces an average refrigerator and freezer, annual savings would exceed 1,000 kWh, or $100, giving a lifecycle saving of around $1500). Note that adoption of such a scheme now would create a barrier to greenhouse emission reduction in a few years, because people would be reluctant to prematurely replace the 5-star fridges they bought in the belief that they were energy-efficient.

An obvious target for action is the large number of second refrigerators and freezers in people’s homes. These seem to be responsible for over a third of refrigeration-related emissions and, from observation, they are often poorly utilised and exposed to extreme environmental conditions. In the USA, utility-funded programs have removed more than a million old refrigerators from households, but there have been some concerns that this has included a fairly high ‘free rider’ effect. Other options for removal of old, inefficient appliances could include:

- establishing arrangements with charities for collection of old refrigerators from households, possibly by offering a ‘bounty’ for each working appliance collected, and funding publicity campaigns to encourage householders to appreciate the cost of keeping unnecessary appliances operating. The charities could also test units they collect, and make those that are efficient available to low income households. Others could have CFCs removed and be recycled.
- encouraging appliance retailers to collect trade-in appliances, possibly by extending the ‘bounty’ to them
- making manufacturers and importers of refrigerators and freezers responsible for their collection and disposal at the end of life, consistent with waste management regulations being introduced in some European countries
- running an information/education campaign (eg via segments on home improvement shows and in magazines) to highlight the running cost of second fridges, and the importance of correct disposal

When old refrigerators are disposed of, there is potential to capture CFCs from their refrigeration systems and from their foam insulation: this increases the justification for establishment of effective recovery systems (See Appendix 1), and means there may be scope for some cost-sharing.

A small proportion of households operate "three way" caravan refrigerators (which can run on LPG, 12 volt electricity or 240 volt electricity). These are very inefficient when running on 240V, using at least three times as much electricity as conventional refrigerators, so their use should be discouraged.

Small bar refrigerators, which are almost all low in purchase cost and imported, are mostly very inefficient - some use more electricity than models with more than double the capacity. This is partly due to low cost construction and compressors, but also reflects their large surface area relative to their storage volume, and the technical difficulties in making small compressors energy-efficient.

In areas where peak electricity demand occurs in summer, there is a stronger argument for refrigerator energy efficiency programs based on savings for electricity suppliers, because of the higher consumption of refrigerators in hot weather. Electricity suppliers should contribute to funding of these programs, because they stand to gain significant benefits. Possibly these contributions could be encouraged by a commitment by Government to mandate tough Power Factor standards for refrigerators (and other equipment) in exchange for a commitment to contribute. If individual organisations will not do so, there is a case to levy the industry, or at least those industry participants who will benefit. There is a potential co-ordinating role here for the ESAA, associations of electricity distributors, or other industry groups.

There is scope to utilise waste heat from refrigerators for pre-heating of domestic hot water, although the amount of energy available is limited when the refrigerator is efficient, so it may be difficult to achieve cost-effective solutions. One option may be to use waste heat from the refrigerator as a heat source for a small heat pump or in-line electric HWS supplying hot water for kitchen use. This would provide the additional advantage of reducing dead water losses (due to cooling of heated water left in long lengths of hot water pipe after each draw-off) from kitchen hot water usage, which could magnify the financial benefits of such a system. If 200 kWh per year of heat is recovered, this is sufficient to supply 30 litres of lukewarm water (30 to 35C) per day, around a third of average kitchen hot water requirements: this could be 'topped-up' by a small heat pump or electric element. Since kitchen hot water usage often involves frequent draw-offs of small quantities of hot water, the supply of hot water from a nearby source instead of from the more distant central HWS may significantly reduce losses from hot water pipes, improving the cost-effectiveness of such a solution.

Since much of the extra demand for refrigeration capacity, and much of the door-opening activity, results from the requirements of householders for cold drinks, development of energy-efficient options for delivery of cold drinks may contribute to a long term reduction in refrigeration energy use.

Development of refrigerators that use alternatives to HFCs for both their refrigeration cycles and blowing of foam insulation will be an important step towards minimising total lifecycle greenhouse gas emissions from refrigerators. CO_2 and other replacement gases are already being used for some foam-blowing. In Europe, hydrocarbons are being adopted for some applications, but there is debate about safety issues in the USA.

Cooking

Cooking is an energy-intensive activity which contributes disproportionately to evening peak energy demand. Surveys suggest that average household cooking consumes 600 to 700 kWh per year for electric equipment (over 10% of average annual electricity consumption), or around 5 GJ if gas is used (almost 15% of average annual gas consumption). Recent trends in greenhouse gas emissions from cooking are shown in Table 10.

Cookers are normally included in new homes, where they are often specified by the builder, with little involvement from the homebuyer. Because they are often built-in and have long lives, cookers are usually replaced as part of a kitchen renovation, when the householder often has some influence on the decision. Views on types of cookers are often strongly held (eg gas has quick response, electricity is clean), so it is not necessarily easy to encourage fuel switching in this area.

There is little or no information available for purchasers on relative energy efficiencies or greenhouse gas emissions of different models of cooker, despite evidence of significant variation in performance. There is scope for substantial efficiency improvement: for example, gas burners with low NOx emissions and efficiency up to 50% better than conventional models have been developed. Ovens can be better insulated, with pre-heating of inlet air, and their thermal capacity can be reduced by light-weighting. Some electric oven manufacturers (eg AEG) allow the size of the oven cavity to be varied, thus reducing energy requirements. Most existing grillers are relatively inefficient, and there is scope for substantial improvement.

Table 10. Trends influencing household cooking greenhouse gas emissions

TRENDS INCREASING GHGS	TRENDS DECREASING GHGS
Shift to electric ovens, even when gas available	More meals eaten away from home
Shift from radiant electric elements to solid elements reduces efficiency	Changing diet towards pre-prepared foods and meals that require less cooking
Increasing use of range-hoods and exhaust fans may increase heating and cooling energy by increasing air infiltration - but they play an important role in maintaining indoor air quality	More use of microwave ovens and specialised appliances which are more efficient than conventional cookers
When cooking for a smaller household, not much less energy is used than for a larger household, so decline in household size increases cooking energy consumption for a given population	Fan-forced ovens, advanced glazing for oven windows, improved controls reduce oven energy use
	Improving cook-top efficiency for both gas and electric types

User behaviour is a major factor influencing cooking energy use. Apart from decisions about the type of meal to be cooked, actions such as leaving lids off and boiling hard instead of simmering can easily double energy consumption. Melting fat for deep frying or boiling large quantities of water for meals such as pasta can also consume large amounts of energy. Use of pressure cookers and well-designed pots and pans can cut cooking energy significantly. It is feasible to design better-insulated cookware but many cookers lack sufficiently precise controls to take advantage of such advances.

Energy-efficient cooking equipment will be increasingly important as homes become better-insulated and more of them are airconditioned: an inefficient oven used for an hour or so can easily overheat the kitchen in an energy-efficient house, causing significant discomfort.

Options for action

Provision of information on energy use of ovens, grillers and cooktops based on authoritative testing is an important first step in reducing greenhouse gas emissions from cooking. Development work on better-insulated cookware is also needed, but this probably needs to be linked to development of (and possibly performance standards for) burners and hotplates that can operate at low heat output rates. Energy rating of ovens, grillers, cooktops and cookware may be appropriate, although attempts to implement this in the past have had limited success.

Authoritative comparative data on the energy consumed by various approaches to cooking are also needed, and this could be incorporated into information kits and educational curricula. Training in energy-efficient cooking techniques could also be included in relevant curricula.

There is also scope for optimisation of shrouds around range-hoods (to effectively remove cooking odours, moisture and combustion emissions), automatic control of rangehood fans, and automatic dampers (to stop unnecessary air leakage).

Existing RD&D information could be drawn together, and Australian cooker manufacturers encouraged to utilise it to develop and market 'best practice' cookers.

Lighting

Traditionally, lighting has been seen as a relatively minor contributor to household energy use and greenhouse gas emissions, although it is typically responsible for 400 to 750 kWh per year - 5 to 15% of electricity consumption.

Trends in lighting

Since the popularity of incandescent downlights and spotlights in the 1970s and the low voltage downlights and spot lights of the 1990s, lighting energy use has increased dramatically in many homes, particularly those designed by architects and interior designers. In the UK, surveys are said to have shown a doubling in lighting energy consumption in new households compared with older homes, but no such surveys have been conducted in Australia. In the USA, growth in energy consumption from widespread use of halogen 'torchiere' uplighting lamps with 300W or 600W globes has cancelled out the savings achieved by adoption of compact fluorescent lamps, and has created serious fire risks in many houses: energy-efficient, safe compact fluorescent alternatives have now been developed.

The hidden power consumption of transformers used to run low voltage lamps (up to 30% of power consumed) further increases consumption.

Trends in household lighting energy consumption are listed in Table 11.

Table 11. Trends influencing household lighting greenhouse gas emissions

TRENDS INCREASING GHGS	TRENDS DECREASING GHGS
Increasing use of large numbers of low voltage quartz-halogen lamps with inefficient transformers	Compact fluorescent lamps are improving in performance, becoming more widely available, and costs have moderated
Increasing lighting levels (due partly to use of narrow beam low voltage lamps)	Circular and tubular fluorescent lamps have improved fittings and better colour rendition, making them more suitable for use in homes
More outdoor lighting for security, safety, recreation and aesthetics	Replacement of incandescent downlights by low voltage lamps (modest saving only)
Larger houses and central heating require lighting of larger areas	Increasing use of skylights and skytubes to provide daylight
	More efficient low voltage Q-H lamps are becoming available (eg new Osram 35W replaces a 50W standard lamp)

A survey by Melbourne University students found that most family living rooms had light levels of around 50 lux or lumens per square metre (compared with 320 lux in an office), and that people used task lamps where they required more light. Yet many homes with low voltage lamps have light levels close to those of offices, which leads to energy consumption per unit of floor area of up to double that of an office lit with fluorescent lamps.

Experience with staff in lighting shops, architectural offices and lighting designers indicates widespread ignorance of energy efficiency issues, and of appropriate light levels for homes. For example, some advisors believe that 'low voltage' is synonymous with 'low energy', so they believe they are addressing energy efficiency issues when specifying massive amounts of inefficient lighting! In a recent project, a householder went to four lighting designers before finding one who could assist with an energy-efficient lighting design for a new house. The focus of most designers is on creating exciting and interesting lighting effects, not optimising energy efficiency. Low voltage lamps have an up-front price advantage over most other lighting systems, which is also a driving factor for their adoption.

Lighting is a classic example of equipment with low initial cost and high operating cost. A $20 low voltage downlight will use electricity costing 10 times its purchase cost over its 15 year life (assuming 5 hours use per day). Replacement lamps will add a further $100 to $200 to that cost. Information showing lifecycle cost may help to shift consumer preferences.

The vast majority of domestic light fittings available are not suited to compact fluorescent lamps, and high wattage low voltage lamps are routinely specified in kitchens and living areas. It would not be surprising to see lighting energy consumption continue to increase unless strong action is taken to drive developments in more energy-efficient directions.

Scope for savings

Energy-efficient lighting technologies can achieve quality home lighting with around 3-5 watts per square metre of installed lighting, compared with the 10 to 20 watts per square metre installed in most homes.

There are many exciting developments in lighting which have potential to contribute to significant savings over the next decade. These include (from Turiel et al, 1995):

- much more efficient incandescent and halogen lamps, with efficacies (a measure of output efficiency) of up to 50 lumens/watt (compared with 10 to 20 today)
- further improvements in compact fluorescent technologies, including dimming capability and heat sinks to stabilise operating temperatures (which improves efficiency by 15 to 20%)
- ultra-high efficiency lamps with efficacies of 130 to 180 lumens/watt, compared with 60 lumens/watt for compact fluorescent lamps
- light distribution systems which will allow central high efficiency light sources and daylighting systems to deliver light throughout a house

If these innovations can be promoted and are adopted, household lighting energy consumption could decline significantly. However, if present trends continue, it will increase.

Options for action

Given the increasing variation in lamp efficacies (from 10 to 100 lumens/watt already, with further evolution likely), and that similar-looking lamps may vary widely in efficiency, it will be important to change labelling of lightglobes and lamps from watts to a measure that reflects their actual light output and indicates their efficiency. Labelling could also state average life. For example, lumens could be used to indicate light output, and a star rating could be used to indicate lamp efficiency (ie lumens/watt).

Practical information guides on domestic lighting are desperately needed, including:

- strategies to reduce the energy consumption and improve light distribution from existing installations of low voltage halogen downlights
- appropriate ways of using compact fluorescent lamps - for example, US studies have shown that almost 80% of the light from a typical compact fluorescent lamp installed in a traditional standard lamp is absorbed by the lightshade - so it provides sub-standard lighting. Also, the angle at which a compact fluorescent lamp is installed can vary its light output by 15%, due to sub-optimal distribution of the mercury in the lamp.
- guidance on how much lighting is appropriate in various parts of a home, the importance of separate switching of lamps, etc.
- lifecycle costs of various lighting options.

Intensive public information, training of architects and designers, and promotion would be necessary to overcome the present culture regarding lighting.

There is a severe shortage of attractive light fittings for compact, circular and tubular fluorescent lamps suitable for use in homes. Competitions, incentives for light fitting manufactures, and information catalogues of good examples could be used to overcome this problem.

A rating system for home lighting, to be incorporated with House Energy Rating schemes, could be developed. For example, the Green Home Guidelines developed by the Australian Conservation Foundation (Sustainable Solutions, 1993) simply limit installed lighting (including ballasts and transformers) to 3 watts/square metre: this rating provides a good standard of lighting if fluorescent lamps and efficient light fittings (ie that allow most light to pass through) are installed in most parts of the house. Different star ratings could be allocated for varying power ratings per square metre (eg 3 W/sqm is 5 stars, 9 W/sqm is 3 stars, etc). In practice, it would be desirable to specify appropriate lighting levels (eg 50 lux for living areas, 40 lux for halls, etc) as well as the power rating, so that adequate lighting was guaranteed. To apply such a system may also require testing and rating of the effective efficiency of light fittings, as they can substantially reduce the amount of light delivered from a lamp. Even if such a system were introduced in an advisory or voluntary scheme, it would begin to influence the market.

There is a case to introduce Minimum Energy Performance Standards covering energy losses and power factors, and/or a rating system, for transformers used with low voltage halogen lamps. Many of the cheaper models are extremely inefficient, and generate large amounts of heat, which makes them a potential fire hazard under some circumstances.

Clothes washing

Almost all Australian homes have a clothes washer. If warm or hot wash is used, most of the energy used by a clothes washer results from heating of water: around 1.5 kWh/load is used to heat water for a normal program in a top loader (Turiel et al 1995, Wilkenfeld 1992). Operation of motors and pumps consumes less than 0.2 kWh per wash (Wilkenfeld 1992), less than 75 kWh per year if a load is washed every day. *Choice* magazine (ACA, 1997) tested front loading machines on warm wash, and found their total consumption fell in the range of 0.4 to 0.84 kWh, while top loaders (which washed 50% more clothes per wash) used from 1.4 to 2.1 kWh. In practice, particularly in a small household, keeping the electronics energised (typically 35 to 50 kWh) may consume as much energy as actual operation of a washing machine using cold wash!

In 1994, ABS found that 61% of households used cold wash, 28% warm wash, 6% hot wash and 5% varied the temperature of their wash. In the Northern Territory and NSW, around 70% used cold wash, while in Victoria and South Australia only 48% used cold wash: this may reflect the lower temperature of water supply in cooler parts of Australia. The ABS survey also indicated that an average household washes 5-6 loads per week.

An interesting point is that the energy used to produce detergent is now significantly greater than that used for cold water washing. Data from Greene (1992) indicates that greenhouse gas emissions from energy use to produce detergent and its packaging is more than 1.2 kg CO_2 per load for a top-loader, and 0.6 kg CO_2 per load for a front loader, 3 to 6 times the emissions from energy use for a cold wash. The amount of detergent required is proportional to the volume of water in the washing part of the cycle - as little as 20 litres for a front-loader and often 40 litres for a top loader, so front loaders usually require less detergent than do top loaders. In theory, this should cut running costs. However, if premium detergents are used, according to *Choice* (ACA, 1996), the detergent costs are similar for both types of machine.

Spin drying uses more energy in the washing machine, but cuts clothes drying energy requirements. According to Turiel et al (1995) spin drying can remove 60 kg of water per kWh of electricity consumed, compared with almost 1 kg of water per kWh for a conventional clothes dryer. E-Source (1997) suggest that spin drying is 19 times more efficient than conventional clothes drying.

Scope for savings

For existing washing machines, switching to the lowest temperature wash that provides a satisfactory outcome is the most important action. Ensuring the machine is fully loaded, and that the correct amount of detergent is used will also minimise energy consumption. Switching off the machine at the power point when not in use will also save a significant proportion of clothes washer energy use if it has electronic controls, although it may mean programmed settings are lost.

Where warm or hot washes are used, it is important that the hot water is supplied from low greenhouse intensity hot water sources: these are discussed under hot water.

When buying a new machine, front loaders are, in principle, more energy and water efficient, and have higher spin speeds. However, some frontloaders use much more water than others, and some also heat their own water (sometimes to surprisingly high temperatures) as can be seen from the variation in test results quoted earlier. Some new model top loaders have quite high spin speeds, too. So care must be exercised when selecting a new model. Front loaders are usually more expensive than top loaders, but the price gap has been closing as top loaders become more sophisticated and front loaders gain economies of scale from higher sales.

Future improvements in clothes washer energy efficiency may include:

- intelligent controls, which can optimise washing performance with estimated savings of up to 20% (Turiel et al, 1995)
- more energy-efficient motors (typical existing motors are only 65% efficient) and pumps, and low flow resistance water pipes
- reduced water consumption: this is easier for front loaders than for top loaders, which must use sufficient water to immerse the clothes. However, Sharp and others are developing 'bubble wash' top loading machines which avoid the need for an inner and outer drum, cutting water consumption by around 30%. Front loaders can use sprays to reduce water consumption
- higher spin speed to remove water more effectively.

Overall, these strategies should allow energy consumption of front loaders to be reduced by up to a further 30%. Ongoing improvement in cold water detergents, and developments in fabric manufacture and treatments, should mean that the trend towards lower washing temperatures can continue, reducing water heating energy consumption.

Options for action

- promote the benefits of cold washing by publicly demonstrating the effectiveness of cold water detergents and highlighting that disinfection of clothing is performed more reliably by soaking in (oxygen-based) bleaches and disinfectants than even washing at high temperatures: it is important to wear down myths
- continue to promote the energy, water and detergent saving benefits of front-loading washing machines, but focus on the best performers
- focus attention on improving the energy efficiency of laundromats, which may attract increasing custom as more households move to medium-density housing and household size declines
- encourage Australian manufacturers to continue to improve the performance of their products
- consider introducing a mandatory standard for spin dry effectiveness, set close to 'best practice'

include energy consumed on 'standby' in energy star ratings and consumption information on energy labels, and consider other proposals to address standby power consumption.

Clothes drying

Over 55% of Australian households own clothes dryers. Dryers typically consume around 1 kWh per kg of water removed, compared with a theoretical requirement of 0.64 kWh/kg, so they are relatively energy-intensive appliances when they remove large quantities of water from washed clothes.

Energy use for clothes drying is sensitive to climate. Surveys in New South Wales have indicated that a clothes dryer typically consumes around 125 kWh each year, while surveys in Victoria suggested an average of 230 kWh (SECV 1984). However, changes in working patterns, trends towards medium-density development, and changes in technology (such as combined washer-dryers) may lead to higher usage of clothes dryers. In the USA, average 1992 dryer consumption was around 900 kWh per year (Schipper et al, 1997), and drying all of a family's washing could consume more than 1500 kWh per year (if a traditional top loading washing machine with relatively low spin speed is used). So clothes drying energy consumption could increase dramatically if large numbers of households move away from traditional methods of clothes drying.

Dryers work by heating fresh air, and forcing it through clothes which are tumbling around in a rotating drum within the dryer. As the temperature of the air rises, its capacity to absorb moisture increases exponentially, so the hotter the operating temperature the more water a given volume of air can remove. Dryers can operate at quite high temperatures of up to 175C, but excessive temperatures can damage clothes. The moisture is blown out of the dryer, either into the room or outside, via a flexible duct.

Over time, there is likely to be increasing interest in condensor-dryers (which remove moisture from exhaust air - at the expense of higher energy use, due to additional fan energy consumption in the heat exchanger) and automatic controls (which may reduce consumption by optimising moisture removal processes and avoiding over-drying).

Scope for savings

The spin dry effectiveness of the clothes washer is an important influence on drying energy use. Older machines leave up to 1.3 kilograms of water in each kilogram of clothes, while most newer models can reduce this to 0.8 kilograms of water. Best practice models can reduce this further, to around 0.5 kilograms of water per kilogram of clothes.

Existing technology can be improved to come closer to the theoretical maximum efficiency of 0.64 kWh/kg of water removed by:

- recycling some exhaust air which can save 6% (E-Source, 1997)
- using exhaust air to pre-heat inlet air (although avoiding fluff build-up in the heat exchanger is a problem)
- operation at lower temperature, which cuts consumption by up to 10% but extends drying time
- intelligent control, which optimises temperature at different stages in the cycle

Dryers using microwave technology are close to commercialisation. EPRI has developed such a product, which saves up to 26% relative to conventional dryers (Turiel et al, 1995). Apparently the microwaves vaporise water within the fabric, while conventional dryers rely on moisture flowing to the surface of the fabric before it can be evaporated. Microwave dryer efficiency is still considered by most researchers to be constrained by the energy required to evaporate the water and the inefficiency of the magnetron which produces the microwaves. Some authorities argue that microwaves also gain efficiency by vibrating tiny droplets of water from the clothes by mechanical action, so it may be possible to improve efficiency beyond the level required to evaporate all the water if magnetron efficiency can be further improved.

Heat pump clothes dryers have potential to reduce energy consumption well below that required to evaporate the water from clothes, because the latent heat of evaporation can be recovered at the heat pump's evaporator. Instead of working with inlet air from a room, the heat pump recirculates air. Air is first heated at the condensor, then it moves through the clothes absorbing moisture. It then passes over the heat pump's evaporator, where heat is absorbed from the exhaust air and by condensing the moisture in the air. This cool, dry air is then reheated as it passes over the heat pump's condensor.

A major advantage of the heat pump dryer is that it does not exhaust moist air into the building, so there is no need for exhaust ducts or extra room ventilation. This attribute may provide a useful marketing advantage to justify its higher price, as the only other dryers that can achieve this are the condensing dryers which actually use more energy than standard dryers, and are quite expensive because of their extra complexity. One heat pump design has achieved a COP of 2.6, giving energy savings of 50 to 68% at an estimated extra cost of US$300 (Turiel et al, 1995). For a household that dried all of its clothes electrically, annual savings could be around $80, so this could be cost-effective.

In Japan, clothes dryers have been built that use heat from the HWS to warm air. However, this type of unit runs at a lower temperature and requires installation of a hot water return pipe to the HWS. Gas clothes dryers generate much lower greenhouse gas emissions than those using electricity from fossil fuels, but their high cost, and the requirement to install a gas connection in the laundry, has meant that they have had little market success in Australian homes - although they are widely used in commercial laundries.

Combined washer-dryers are available, and are attractive for households living in small dwellings. When used in the combined mode, they hold reduced capacity, because a dryer with a given sized drum has lower capacity than a washing machine with the same sized drum. Such a unit with heat pump drying could be popular if marketed appropriately: you could load your dirty clothes in the morning, then remove the clean clothes when you arrived home from work. The scope for sharing the motor, pumps and heat pump between two tasks could make the overall package financially attractive.

Options for action

- promote or require provision of protected spaces for outdoor clothes drying in new housing (except multi-storey apartments), encourage design and marketing of improved clothes drying racks for use inside houses
- educate householders on the importance of spin drying clothes, and avoiding use of clothes dryers where possible
- encourage ongoing improvement in dryer energy efficiency via energy labelling and financial incentives
- develop low greenhouse intensity drying solutions for apartments, such as specifying gas connections or hot water loops in laundries, or centralised gas dryers (with heat recovery) or heat pump dryers
- fund RD&D to develop more cost-effective high efficiency solutions, including simple solar dryers

The capital barrier for adoption of heat pump or gas dryers seems likely to be a major barrier to their adoption, yet these are the options most likely to achieve major savings if people do require mechanical drying. Special financial incentives may be necessary to allow production to gain economies of scale.

Dishwashing

By 1997, 31% of Australian households owned a dishwasher. Although earlier studies have suggested that dishwashers use around 900 kWh per year (eg SECWA, 1991), a recent NSW monitoring project estimated consumption at 230 kWh per year. This lower value is partly explained by the improvement in product efficiency since the mid 1980s, but may also reflect the fact that previous studies used regression analysis rather than actual measurement. There is anecdotal evidence that people with dishwashers may use more hot water to rinse dishes before putting them in their dishwasher, and the regression analysis may have included this energy use with that used directly by the dishwasher. If this is the case, there is a clear need for consumer education on the energy cost of rinsing dishes under running hot water, and to highlight the fact that modern dishwashers are actually very good at cleaning dirty dishes!

In the USA, dishwashers are estimated to consume only 165 kWh per year (Schipper et al, 1997). However, most US dishwashers draw their hot water from the hot water service, and including this component would increase their consumption considerably. German data for 1992 show a value of 310 kWh, which is similar to the NSW value if adjustment is made for the colder water supply temperature.

Comparisons indicate that a well-managed dishwasher uses similar amounts of energy to washing up in the sink. However, it usually heats its own water with high greenhouse intensity electricity, while households with gas or solar hot water wash up with water from a lower greenhouse intensity source. In Victoria, around a third of dishwashers are connected to the hot water supply, but this means they use heated water for their whole program, instead of just for the one or two fills that would be heated if the internal heater was used. Ideally, dual connections should be used, so hot water can be used for the appropriate parts of the program, and cold water for the remainder. Dual connection increases the product cost, so it has not been particularly popular.

Scope for savings

The best dishwashers now use less than 1.3 kWh for a normal wash (for 12 to 14 place settings), and they can perform satisfactory washing using as little as 0.7 kWh per wash. Further improvement, to 0.5 kWh per load or better, is certainly feasible through:

- further reduction in the amount of water heated
- more efficient pumps
- heat recovery
- use of low temperature washing detergents
- reduced standby consumption by electronic controls
- use of a heat pump or gas to heat the water used
- lighter, better-insulated cabinet liners

Use of lighter dishes can also make a surprisingly significant contribution to reduction in energy consumption.

In theory, use of gas or solar-heated water for the part of the cycle that requires hot water should reduce greenhouse gas emissions relative to fossil fuel-generated electricity. However, this requires a dual connection appliance, which is more costly. Also, ‘dead water’ in the pipes connecting the dishwasher to the HWS can reduce the advantage from this strategy. As dishwashers become more water-efficient and operate at lower temperatures, the advantage from using gas or solar heated water will decline. Developments in small heat pumps may mean that such a device could be installed for a similar cost to dual connection - and this could supply hot water for the sink as well, using waste heat from the refrigerator to improve efficiency even further. It may also be possible to utilise waste heat from the refrigerator directly to supply warm water for a dishwasher.

With the decline in household size, we may see an increase in the market share of smaller dishwashers. At present, these use more energy per place setting than larger models, but there is scope for improvement. Further, there is a greater probability that they will be run fully loaded than a larger model in a small household, which may be run partly loaded for hygiene reasons, or because the household is running out of dishes, so overall energy consumption may be lower.

Options for action

- adjust the energy rating system to encourage further efficiency improvements, and to include standby electricity consumption in the rating

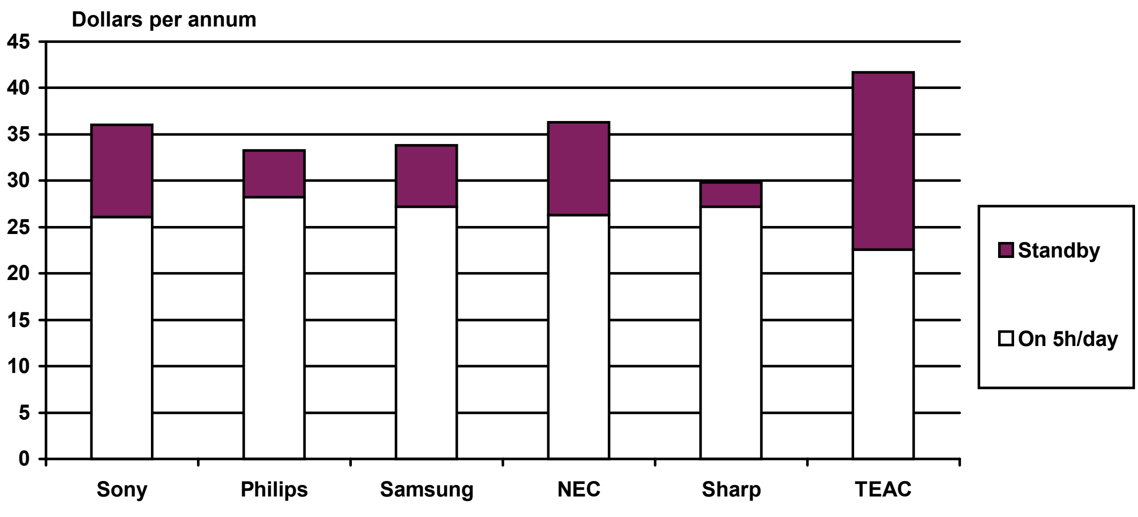
- consider MEPS to remove low efficiency models from the market (which are often purchased by builders for new homes)
- consider financial incentives for development of ultra-efficient models, including models designed for smaller households

Electronic appliances

Electronic appliances have traditionally been seen as minor contributors to household energy consumption. However, the proliferation of equipment, and the fact that much of it is left on 'standby' continuously, means that it is an increasingly important issue. Figure 29 shows data for a sample of televisions tested by the Australian Consumers Association. When used for 5 hours per day, they consumed around 300 kWh per year: many Australian TVs run for much longer periods, and many households have more than one TV operating at a time, so TVs could consume more than 10% of many households' total electricity. Figure 29 also shows the significance of 'standby' power consumption for these models, with the worst one consuming 20 watts of power while doing nothing. It has also been found that the Power Factors of most appliances in operating made and, even more so in standby mode, are poor.

Looking beyond 'standby' power, many items of equipment use much more power when left switched on but not operating than when they are switched to standby or turned off at the wall socket. One example is shown in Figure 30. These results are for a $750 CD/tape/radio unit sold under a well-known brand name. While operating, it consumes around 50 watts. When the CD finishes, power drops to 33 watts and, when switched off at the unit consumption drops to 13.5 watts. If left on when not in use, this product would waste 230 kWh, costing more than $25 worth of electricity each year. If every Australian household had one, they would waste $150 million worth of electricity and fully occupy over 200 megawatts of electricity generation capacity for no useful purpose.

Figure 29. Annual operating costs of 68cm televisions during operation and on standby, based on 5 hours per day operation and 12 cents per kilowatt-hour (Choice Jan 1997)

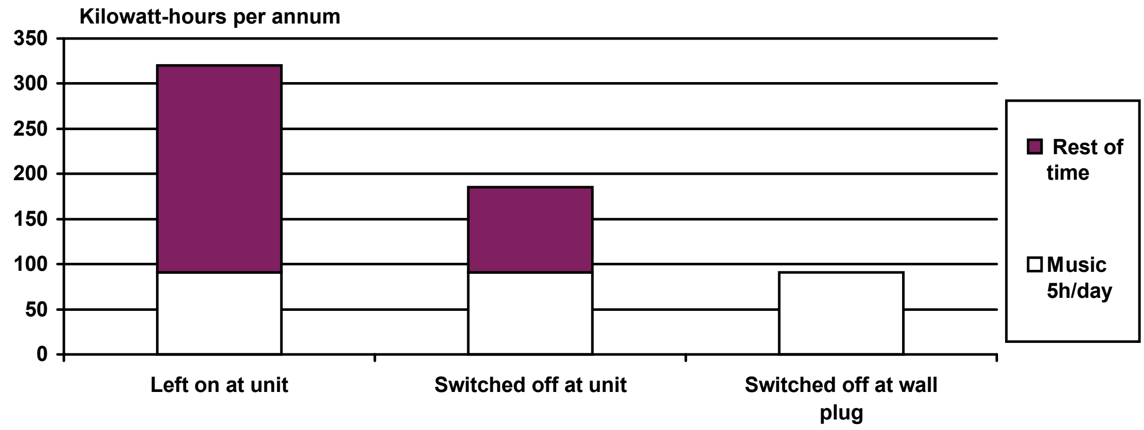


Measurements have shown that other products have similar characteristics. One VCR measured consumed 24W while running a tape, 16W while left on (so its remote control could be used to operate the TV) and 8.5W when switched off at the unit (with the digital display showing the time).

The significance of standby power consumption can be seen from Table 12. This shows that a family can easily consume 600 to 1500 kilowatt-hours per annum for this purpose. US data suggest that the average household's electronic equipment consumes 400 to 500 kWh per year on standby, and it seems likely that Australian households are similar. Average Australian household electricity consumption is around

6,700 kWh, making this component potentially responsible for more than 6% of total household electricity consumption.

Figure 30. Annual electricity consumption of a $750 CD/tape/radio stereo system under various operating conditions.



Scope for savings

For owners of existing equipment, it can be quite difficult to reduce standby power consumption. Where convenient, it can be switched off at the power point. Also, it is important to ensure that equipment is switched off at the unit, so even more energy is not wasted. This requires discipline, as it is usually not very obvious that equipment has been left on.

Table 12. Electricity consumption by household equipment on standby (estimates from an unpublished report prepared for Energy Victoria, based on testing by the author)

	Consumption - Watts		Elect tariff	0.126			
Appliance	Low end	High end	Annual low kWh	Annual high kWh	Number of items	High $	Low $
Plug pack	2	5	17.52	43.8	5	27.59	11.04
TV (standby)	1	8	8.76	70.08	2	17.66	2.21
Clock-radio	3	5	26.28	43.8	4	22.08	13.25
modem	3	6	26.28	52.56	1	6.62	3.31
microwave	3	5	26.28	43.8	1	5.52	3.31
inkjet printer	4	12	35.04	105.12	1	13.25	4.42
radio-cassette	2	4	17.52	35.04	3	13.25	6.62
thermal fax	8	20	70.08	175.2	1	22.08	8.83
VCR	5	10	43.8	87.6	2	22.08	11.04
dishwasher	2	5	17.52	43.8	1	5.52	2.21
clotheswasher	2	5	17.52	43.8	1	5.52	2.21
light sensor	0	4	0	35.04	3	13.25	0.00
oven display	2	5	17.52	43.8	1	5.52	2.21
electronic ignition -gas	2	5	17.52	43.8	1	5.52	2.21
					Total $	185.43	72.85
					Tot kWh	1471.68	578.16

US studies (Meier, 1998) have determined that household appliances should be capable of remaining on standby while consuming less than one watt, using existing cost-effective technology. Efforts are being made through the International Energy Agency to introduce this as an international Standard. The proposed requirements could also include minimum Power Factor values, too.

Where items of electronic equipment, such as televisions or computers, are used for long periods of time, their operational energy consumption may also be substantial, as illustrated by the example of televisions, quoted above. There are already significant variations in consumption between models, but this is not obvious to potential buyers. For example, Philips recently released a 51cm television that consumes only 55 watts, compared with 80 to 100 watts used by most models of that size. Samsung has recently developed new tube technology that may allow brighter screens to be generated while less energy is consumed. Flat screen televisions which use much less energy than traditional models are moving towards commercialisation, and these will provide further energy savings, although if they are coupled with inefficient stereo systems, savings will be reduced. The imminent introduction of digital TV provides an excellent opportunity to set energy efficiency standards to apply from the date of introduction, to avoid unnecessary energy waste.

Options for action

Initially, it seems reasonable to require manufacturers of all electronic equipment to publish accurate information on the energy use of their equipment under all operational modes, and to include this on the nameplate of the product itself and in advertising materials. Where an item of equipment is likely to use more than, say, 100 or 200 kWh per year under typical operating conditions, there is a case for introducing a simplified form of appliance energy labelling.

Standby power consumption seems best addressed via international Standards, and Australia could actively support the present US initiatives. As an alternative, it should be possible to modify electrical approvals regulations to specify maximum allowable standby power and Power Factors for all electrical equipment permitted to be used in Australia.

Since most electronic equipment is imported, Australia can have little direct impact on its design. However, requiring publication of relevant information, and publicising comparative information, is likely to influence major manufacturers. If necessary, Minimum Energy Performance Standards could be introduced.

Other equipment

Other equipment which is known to contribute significantly to Australian household energy-related greenhouse gas emissions includes:

- swimming pool pumps (owned by 12% of households, with each, on average, generating around 1.3 tonnes of CO_2 per year
- bore pumps, owned by around 5% of households, and generating around 0.35 tonnes of CO_2 per year (SECWA 1991), although these data are relatively uncertain
- heated waterbeds, owned by almost 8% of households, which on average generate around three-quarters of a tonne of CO_2 per year
- heated aquaria, which can generate from half to several tonnes of CO_2 per year
- ceiling fans, which consume up to 80 watts each, and can operate in several rooms for long periods in homes in hot climates, generating up to half a tonne of CO_2 per year
- water coolers, which are becoming more popular as increasing numbers of people stop drinking tap water: these can generate a third to half a tonne of CO_2 per year
- saunas and spas, which can generate several tonnes of CO_2 per year, depending on how they are used.
- central heating fans, which can generate a third to half a tonne of CO_2 per year
- plant growing lights and root heaters, which can generate from half to several tonnes of CO_2 per year

Each of these technologies can be made much more energy-efficient via cost-effective strategies. For example, sensors which monitor pool water condition, more efficient motors and pumps, larger diameter pipes and use of low pressure drop filters can cut pool filter energy consumption. The Northern Territory University's Professor Dean Patterson has developed an energy-efficient ceiling fan which consumes less than a quarter as much energy as conventional models. And so on. So there is plenty of potential for savings.

In a number of cases, these technologies are distributed through specialist networks, so there is scope to work with manufacturers and market intermediaries to improve energy efficiency. However, in some cases, mandatory Minimum Performance Standards may be required: for example, inefficient ceiling fans are sold at extremely low prices, and efficient models would have great difficulty competing, even though they have potential to be cost-effective if mass-produced.

Chapter 8: Buildings, and heating and cooling equipment

Overview

Much to the surprise of many people, space heating and cooling is responsible for less than 15% of household energy-related greenhouse gas emissions (see Figure 16): on average, this is around 1.1 tonnes of CO_2 per year per household. This lower-than-expected outcome reflects a number of factors, including moderate climates, tolerance of discomfort, widespread use of low greenhouse intensity fuels such as wood and natural gas, and efficient technologies such as electric heat pumps, for heating and cooling. However, it should be noted that if all homes heated with wood switched to fossil fuels, the proportion of household emissions generated from heating and cooling would rise by several million tonnes of CO_2 per year, making it the second largest contributor to household greenhouse gas emissions, after water heating. If the land clearing impacts of fuelwood use were also considered (see Table 1), emissions associated with home heating and cooling would be even greater.

There are wide variations in both energy consumption and fuel selection from one climatic zone to another. Changes in climate due to global warming may also lead to significant changes in heating and cooling energy use patterns, as households respond to more extreme weather events, warmer summers and milder winters.

The community's strong focus on buildings and space heating and cooling issues seems to come at least partly from the fact that many householders place high value on comfort and amenity, and architects, building designers and specialist media focus a lot of attention on design aspects of houses. Also, public sector programs have tended to focus on the building envelope, possibly because this issue is less controversial than the debate over fuel selection, which can provoke strong reactions from powerful energy suppliers.

Australian homes do not rate high for energy-efficiency or thermal performance. The former leader of the International Energy Agency program on heating and cooling, Anne Grete Hestnes, expressed extreme surprise at the size of our heating consumption when she visited Melbourne in 1994. She made the point that, if our homes were built to appropriate standards of thermal performance, we would need little or no heating. This position is supported by both computer simulation and experience with a limited number of houses built to high standards of energy efficiency in Australia.

According to ABS (1998), only 56% of Australian homes have insulated ceilings, while 18% have wall insulation (see Figure 18). From the ABS 1994 survey, ACT (77%), South Australia (70%) and Victoria (69%) have most ceiling insulation, while only 26% of Queensland homes have ceiling insulation. In the Northern Territory, only 43% of homes have ceiling insulation while 76% have airconditioners, which indicates significant energy waste, and may explain the rapid increase in energy consumption in NT over the past few years. In Queensland in 1994, only 18% of homes had airconditioners, compared with an Australian average of 33% at that time, which means there could be large increases in energy use in future if airconditioners become more popular there. It has also been suggested that Australian homes experience higher rates of air leakage than do homes in many other countries.

Around 35% of Australian households rely mainly on electric heating, of which about a third use reverse cycle airconditioners and two-thirds use greenhouse-intensive resistive electric heating (see Figures 20a and 20b). Around a third of households use gas for their main heating, around a quarter of which have central heating. Space heated homes often use significant amounts of auxiliary electric heating, so their greenhouse gas emissions are often not much lower than those from centrally-heated homes. Almost 20% of households use wood as their main heating fuel. After a sharp increase from 33% since 1994, 41% of Australian households now have airconditioners, of which a fifth are relatively energy-efficient evaporative coolers.

Accurate data on home heating and cooling energy use is difficult to come by, due to lack of monitoring of end-use activity. Most data therefore rely on regression analysis or other estimation methods. The situation is also confused by the significant year-to-year variability of weather. Table 13 summarises data collected for this study. Clearly, more research is required to establish more accurate and comprehensive data on heating and cooling energy requirements throughout Australia.

The cost and difficulty of data collection and analysis has been one factor driving the development and use of computer simulation models for evaluation of heating and cooling energy issues. This approach allows many variables to be fixed and assumptions to be specified, so that policy development can proceed. However, small changes in assumptions and specified values can lead to large changes in estimates of energy requirements. This has led to extensive debate on these issues, as these judgements markedly change the cost-effectiveness of energy-efficiency options, and can therefore affect policy positions.

For example, one study of houses in Sydney showed that, for an intermittently heated house, ceiling and wall insulation would reduce heating requirements by only 5.3 GJ per year for an intermittently-heated home, while savings of 14.7 GJ were achieved for a home kept comfortable 24 hours each day. For cooling the difference was even more extreme, with an annual reduction in cooling requirement of only 2.5 GJ for the intermittently cooled house, compared with 14.9 GJ for the continuously cooled home. Clearly insulation is far more cost-effective when the house is heated or cooled for longer periods.

Table 13. Various estimates of heating and cooling energy requirements throughout Australia. Sources are noted at the end of the Table.

STATE	GAS HEATING (GJ)	ELECTRIC HEATING (kWh)	COOLING (kWh)
NSW	9.5 (1) 12.9 (2)	resistance main htg 519 (2); 996 (3) rev cycle htg 771 (2); 698 - 1026 (3) secondary htg 185 - 262 (2)	a/c 504 - 556 (2) a/c 216 (3)
ACT	22.4 (1)	resistance main htg 2648 (2) rev cycle htg 3161 (2) secondary htg 983 (2)	a/c 924 (2)
Victoria	36.7 (1) space htg 30 (4) central htg 60 (4)	in-slab storage htg 12,000 (6) o/p heat bank 3,000 (6) elect fan heater 912 (6) rev cycle, ducted 5610 (6) rev cycle, room 980 (6) secondary heaters 250 (6)	a/c 200 (6) evap cool 80 (6)
Queensland	7.6 (1)		
South Australia	10.2 (1)		
Western Australia	8.9 (1) room htg 8.2 (5) aux htg 2.5 (5)	resistance main htg 422 (5) rev cycle htg 146 (5) secondary htg 248 (5)	a/c 420 (5) evap cool 221 (5)
Northern Territory	2.0 (1)		

Sources:
1. Energy Victoria, 1997
2. Fiebig and Woodland, 1991
3. Pacific Power et al, 1996
4. Gas and Fuel Corporation of Victoria, 1990
5. SECWA, 1991
6. SECV, 1984

Evaluations are also very sensitive to the methodology applied to assessment of costs and benefits, particularly the selection of discount rates and whether utility costs are considered. There is still little consensus in this area, and the differences constitute a significant barrier to progress in policy development. To develop a higher level of policy consensus could require serious effort over a significant period, including end-use monitoring, extensive analysis and demonstration projects.

The situation is complicated by the fact that many decisions regarding building energy efficiency, such as installation of wall insulation, are most cost-effectively implemented during construction, yet they have implications for energy use over the fifty year (or more) life of the building. It is difficult to predict the energy use patterns and comfort expectations of possible future occupants of a house, and it is also difficult to convince someone building a holiday home that they should insulate it because some future owner may wish to make it a permanent home. Further, the costs and benefits are distributed across a number of beneficiaries, including:

- the first and subsequent occupants (through savings on energy bills, improved comfort and smaller capacity heating and cooling equipment)
- energy utilities (through savings on supply infrastructure)
- society (through improved health, improved urban air quality, higher disposable income, reduced welfare costs, reduced greenhouse gas emissions, etc)

Development of a consensus method of estimating the full costs and benefits on building energy efficiency measures could be a useful path to pursue, as this would create a framework within which the range of views could be worked through. If a position was taken that, in principle, a building is intended to be maintained at comfortable temperatures at all times, and that heating and cooling equipment purchased will be fully utilised, very high standards of energy-efficiency could be justified. If the existing approach, in which the circumstances of households who heat and cool intermittently are used as the basis, there will be ongoing rejection of best practice energy-efficiency standards.

Cultural attitudes in different parts of Australia affect not only the views of policy makers, but the level of interest and support from the community. These positions do not necessarily reflect the energy, financial and greenhouse implications of the actual circumstances, as reflected by the high ownership of airconditioners and low level of insulation in the Northern territory. A major barrier to improvement is the lack of familiarity of most people with what it is like to live in an energy-efficient, comfortable house: even those who live in such houses may attribute their comfort to other factors or just accept it as ‘normal’. Many anecdotes illustrate these situations, for example:

- a couple who moved from a traditional cavity brick house Melbourne’s seaside suburbs (where the climate is moderate) to a solar house in the much more severe climate of the Dandenong Ranges claimed that the climate in the Dandenongs was much milder than down in Melbourne
- a couple who moved from their (unwittingly) well-oriented house to a new home with large areas of south and west glazing were bemused when they received winter energy bills double what they were used to
- many people involved in design of their own passive solar homes tend to overglaze the north facade, creating serious overheating problems, because they cannot conceive of winter overheating being a problem in cool climates such as Melbourne
- many people in Queensland and Western Australia claim that winter is a trivial issue, yet they huddle around electric heaters in uninsulated and draughtly homes for significant periods in winter: this is particularly obvious to visitors from colder areas, who often complain that houses in ‘hot’ climates are too cold in winter

The importance of focusing attention on energy-efficient house design and selection of low greenhouse impact heating and cooling systems is enhanced by the fact that many other energy and greenhouse-related decisions are made at or around the time when a home is being purchased, built or renovated. Decisions related to lighting systems, cookers, hot water services and other major appliances may therefore be influenced if the profile of energy efficiency is raised at this time.

Education, information programs and demonstrations for both householders and the building industry are needed to re-shape attitudes and understanding, and to develop support for energy-efficient housing strategies. Training of tradespeople and designers is critical. A long-term perspective must be applied to implementation of strategies, in contrast to the stop-start approach that has been pursued in many areas.

Trends in heating and cooling

Major factors underpinning recent trends in space heating and cooling are shown in Table 14. Data illustrating these trends has been presented earlier in this report. It should be noted that global warming will, itself, begin to influence heating and cooling requirements of dwellings being built now over the coming decades. This provides a rationale for moving in the direction of higher energy-efficiency.

Paths to building energy efficiency

To minimise heating and cooling greenhouse gas emissions involves taking a systems approach, so that all the elements work together to achieve savings. This includes consideration of the following factors, which are discussed in following sections:

- location
- micro-climate, including access to winter sun
- building envelope design
- selection and installation heating and/or cooling technology
- user behaviour
- maintenance

Table 14. Trends influencing household space heating and cooling greenhouse gas emissions

TRENDS INCREASING GHGS	TRENDS DECREASING GHGS
Increased cooling	introduction of building energy rating systems
trend to central heating	mandatory insulation/ performance standards in Victoria and ACT and, recently, *Energy Smart Homes* policies by 28 local councils in NSW (but overall, little increase in insulation penetration -see Fig 18)
larger homes	trend away from resistive electric heating to gas heating, electric reverse cycle heating
promotion of in-slab electric heating	more efficient heating and cooling technologies (eg electronic ignition, high efficiency burners for gas, higher star ratings for rev cycle a/c
wood heating losing market share to fossil fuels	more medium density housing - shared walls and floors/ceilings facilitate energy efficiency
longer periods of occupancy in some homes	

Location

Geographical location has a significant impact on building energy requirements in several ways:

- space heating and cooling requirements are affected by temperatures, solar radiation levels, wind and humidity
- hot water requirements are influenced by cold water supply temperature and, where solar heating is used, availability of solar energy
- lighting is affected by the length of the days, brightness and position of the sun

Data shown earlier in this report (see Figure 5) indicate that households in parts of Australia with mild climates generate less greenhouse gas per capita from energy use, despite lower levels of insulation and greater reliance on electricity for heating.

Micro-climate, including access to winter sun

The micro-climate around a building can significantly affect its thermal performance. For example, AS2627.1, which recommends levels of insulation, uses a method which assumes solar radiation falling on a building raises average ambient temperature by around 3 degrees Celsius. A house that is shaded from the sun thus suffers a colder winter environment, but is protected from the summer heat. Windows exposed to winter sun can be used to collect solar energy to heat a home. The better the solar access, the more energy can be collected by each square metre of glazing. However, where solar access is constrained, a range of measures can be used to compensate for the reduction in solar gain, as discussed below.

Exposure to wind not only creates a cooler (or hotter) environment, but it increases the rate of air leakage into a house, increasing the rate of heat flow.

US research has shown that the shading and transpiration from trees and vegetation can significantly reduce cooling energy requirements, by modifying the micro-climate.

Building envelope design

Many books have been written on this topic, so it is not possible to adequately address all the relevant issues in a short section of a report. As noted above, it is possible to design houses that require little or no heating or cooling energy while providing high standards of comfort in most parts of Australia. However, a more achievable target for mainstream housing will be a 50% reduction in heating and cooling energy requirements.

The key features of an energy-efficient home are:

- management of glazing, including limiting the area of glass, shading glass from summer sun, using effective window coverings to cut winter heat loss, and positioning modest areas of glass to capture winter sun. Advanced glazing systems, which are declining in cost, facilitate much higher energy efficiency
- insulation of ceilings in all locations, walls in most locations, and floors where they are suspended and the climate requires significant heating or cooling
- management of air infiltration and ventilation, so that the amount of air entering buildings is not excessive, but it is possible for occupants to flush out built-up heat easily
- avoiding thermal bridges such as metal framing without thermal breaks, edges of concrete slabs exposed to outdoor air, gaps in insulation, etc. These often seem trivial to a builder or designer, but they can seriously undermine performance

It is often considered desirable to include significant amounts of mass in buildings, such as in a concrete slab-on-ground. This has the effect of stabilising the building's temperature, slowing its response to outdoor temperature variations. In temperate climates, this approach can provide a relatively comfortable home without the need for frequent intervention such as heating, cooling or ventilation. However, lightweight buildings can be designed to achieve similar levels of energy efficiency, although they are more likely to require intervention to maintain comfortable temperatures: if they are well-insulated, the amounts of energy required are quite small, so energy efficiency objectives can still be achieved.

For the 45% of Australian homes that have no insulation, installation of ceiling and wall insulation; installation of external shading of windows exposed to sun, and basic draughtproofing should be capable of at least halving heating and cooling energy consumption. In colder climates, advanced glazing systems may also be required.

In areas with moderate climates, it may be difficult to justify some of the above measures if only the benefits for households are considered. However, since heating and cooling are major contributors to summer and winter peak demand problems for electricity suppliers, there is a case for them to contribute to this alternative to expanding supply capacity. It may be necessary to apply levies to electricity suppliers to fund such programs, because individual electricity retailers may not consider that they can be confident they will be the beneficiaries.

For new homes and major renovations, House Energy Rating schemes, mandatory requirements, and/or financial incentives can be used to ensure that good standards of thermal performance are met. Emerging energy rating schemes can be easily used to ensure new houses meet appropriate performance targets at minimum cost, as designers can evaluate a range of options before selecting a preferred solution.

For existing homes, upgrading performance may not be so easy. Ceiling insulation, external shading and draughtproofing can be applied to most houses, although education and incentives may be required to achieve significant rates of adoption. Retrofitting wall insulation is difficult and relatively expensive at present, and only one product (hydrophobically treated rockwool) is commercially available. In colder climates, and where walls are exposed to sun for long periods, wall insulation is very important, so there is a need to fund RD&D and commercialisation of products, and to assist them with market development.

A range of home retrofitting strategies have been used in various parts of the world, including schemes run by local community groups, local councils, and commercial organisations, or combinations of them. The Energy Saving Trusts in the United Kingdom and New Zealand provide useful examples, while experience has also been gained by SEDA in NSW, and through the Victorian Home Energy Advisory Service, which operated from 1983 to 1993.

It will also be desirable to encourage people to build ‘leading edge’ houses, and to work with industry to improve the performance and reduce the prices of energy-efficiency measures such as advanced glazing systems and improved insulation systems. This can be done via a range of incentives, competitions, information and promotion. Establishment of CRCs or other frameworks, and targeted funding for groups such as CSIRO could also accelerate progress.

The trend towards higher density housing seems likely to contribute to reduction of greenhouse gas emissions. Sharing of walls and, in some cases, ceilings and floors, reduces the surface area exposed to the environment, thus reducing heat flows. But sharing of walls also tends to lead to a reduction in glass areas, which further reduces energy flows. When dwellings with shared walls are oriented north-south, they also tend to have few east and west windows, and those that exist are usually fairly well shaded. However, these factors mean that terrace-type housing is far more sensitive to orientation than traditional detached dwellings (Pears, 1996). This places greater importance on the role of the developer and urban designer, who lay out new developments.

Selection and installation heating and/or cooling technology

Heating equipment spans a broad range of complexity and cost, from a $30 fan heater to a $15,000 central heating system. Table 15 summarises the range of options for heating and includes comments on their greenhouse emissions and scope for emission reduction. Installation of heating equipment in an energy-efficient house will greatly reduce the quantity of greenhouse gas emissions generated.

A strong shift towards central heating over the past decade has seen significant growth in heating energy consumption, even in relatively moderate climates. However, much of this energy growth is caused by the much poorer efficiencies of most central heating systems compared with space heaters, and the interaction of central heating systems with thermally-poor buildings. Also, the better-insulated and more energy-efficient a building envelope is, the smaller the difference in energy consumption between space heating and central heating. In Victoria, where growth in central heating has been very rapid, average gas consumption per household has remained almost constant, due to the compensating effects of insulation regulations, better-sealed buildings and improving appliance efficiency.

Table 15. Summary of heating options and their greenhouse gas emissions. Potential savings are shown in italics.

APPLIANCE	ANNUAL	HOURLY	COMMENTS
Heating	(Tonnes pa)	(kg/hour)	
elect o/p slab central htg	5 to 15 t	n/a	Highest emitter - inefficient, difficult to control, but warm feet! *Insulate slab, smart controls, energy-efficient envelope - preferably switch to an alternative*
elect o/p storage space heater	2 to 5 t each	n/a	Second highest emitter - high standby heat loss, so inefficient, difficult to control in moderate weather. *Smart controls, energy-efficient envelope, switch to alternative*
electric rev cycle a/c ducted heating	1 to 5 t	up to 12 kg/hr	Similar emissions to equivalent gas central heater, large (up to 35% losses from ducts). *High COP compressor, see gas ducted heating*
gas ducted cent htg	2 to 6 t	5 kg/hr for typical unit at max output	Many still have wasteful pilot lights, large (up to 35% losses from ducts), often suck too much fresh air into house. *High efficiency burners, electronic ignition, better-insulated ducts with no airleaks, zoning, air deflectors on outlets, draughtproof house, fit vents to internal doors for return air, intelligent controls*
gas hydronic cent htg	2 to 6 t	7 kg/hr for typical unit at max output	Older units have inefficient boilers, large pilot lights. Large losses from under-insulated pipes and through walls next to heating panels. Zonable. *High efficiency boilers, electronic ignition, upgrade pipe insulation, insulate walls next to panels, intelligent controls*
gas space heater, flued	0.5 to 5 t	2 kg/hr typical max output	Older units have pilot lights, wide range (up to 50%) of efficiencies. *High efficiency burners, fans, electronic ignition, use outdoor air for combustion*
gas space heater, unflued	0.2 to 2 t	1 kg/hr typical max output	Older units may have pilot lights. Require ventilation via open window or equiv for safety - heat loss from ventilation comparable to savings from avoiding flue losses. *High eff flued heaters preferable, otherwise controlled ventilation system may help*
electric rev cycle a/c	similar to gas		If mounted high on wall, heating performance less acceptable due to temperature stratification. Performance deteriorates under 5C. *Higher COP, variable speed compressor, intelligent controls, geothermal heat source or gas pre-heat in cold weather.*
electric resistive heater	3 to 4 times gas for same heat	2.4 kW is 2.4 kg/hr at max output	Widely used in mild climates, and for auxiliary heating in rooms with no permanent heating. *Where spot heating replaces space or central heating, can reduce ghgs, radiant panels, smart thermostats cut usage - preferably replace with low emission option and upgrade building*
Wood	(approx 5-10% of natural gas)		Emissions from landclearing, air pollution are major issues. Most too big for energy-eff houses. *Optimise combustion, sizing, improve controls, consider fundamental re-design*
Active solar	zero		Not generally considered to be cost-effective in most areas. However, improving technology could make it viable, especially for those who are at home during the daytime

Major inefficiencies occur when a large capacity heating system is installed in a draughty, uninsulated house. There is a case to require that installation of, for example, central heating in an existing house should be accompanied by upgrading of insulation, draughtproofing and other appropriate measures.

Purchase of heating equipment is an extremely complex process, which varies markedly from location to location. On one hand, many householders in mild climates treat winter heating as a minor issue, and are simply not prepared to spend money preparing for cold weather, or to buy an efficient heater. In colder areas, people may spend many thousands of dollars, and a high quality heating system is often seen as an asset when a house is being sold. However, a common factor is that ongoing running costs are given relatively minor consideration in most cases. It seems that most people either see heating costs as a minor issue, or as an unavoidable cost associated with maintaining comfort. Of course, where a system is installed by a builder, the objective is to achieve appropriate market positioning at minimum up-front cost. After heating bills begin to arrive, there is often more interest in them, but it is often too late to overcome fundamental design problems.

Major options for cooling are listed and commented upon in Table 16.

Table 16. Options for home cooling

OPTION	EMISSIONS	COMMENTS
Fans	0.02 to 0.1 kg CO_2/hour	Reduce effective temperature by up to 3C. Can be used with airconditioners to improve comfort
Windows	zero (unless left open when running heating or cooling equipment)	If appropriately placed, can remove heat when outdoor temperature is lower than indoors
Evaporative cooler	0.04 to 0.4 kg CO_2/hour	Reduce air temperature by around 80% of the difference between dry bulb and wet bulb temps, so do not work well in humid conditions, when wet bulb temp is above 25C. Actual emissions are around half those of refrigerative a/c, due to tendency to run for longer periods, cool larger areas. If automatic damper not fitted to ducts, may dramatically increase heating costs, as warm air escapes via evap unit
Refrigerative a/c	approx 0.5 kg CO_2/ kW of cooling capacity	Most greenhouse-intensive cooling option. Ducted systems may be very inefficient due to heat gain from hot roofspace through poorly insulated ducts High capital cost/kW, so cost of shading, insulation etc can be offset against cost saving from reduction in required capacity - but few salespeople consider this

The thermal performance characteristics of a house have a major impact on cooling energy use. For example, one square metre of unshaded glass can allow up to a kilowatt of heat to enter a house, so shading and management of glass is critical. And each airchange per hour adds 2 kilowatts to the cooling load in a centrally-cooled home on a hot day.

Evaporative coolers are improving, and increasingly provide a practical alternative to refrigerative cooling in many parts of Australia. Unfortunately, models sized appropriately for energy-efficient houses do not seem to exist, so there is a need for further development activity. Ongoing demonstrations and promotion will be needed to promote this option, as many believe evaporative cooling is insufficient.

As can be seen from Table 13, the operating costs of airconditioners in much of Australia are relatively low, because they are not needed for long periods. This makes it difficult to justify investment in insulation, shading and other measures that reduce the need for cooling under typical usage conditions. However, where cooling is used for longer periods, cost-effectiveness improves.

Airconditioners are a very expensive load for electricity suppliers to satisfy, because they contribute to summer peak loads, which occur at a time when system capacity must be de-rated because of the effects of high temperatures on powerlines, transformers and generation plant. On this basis, there is a case for the electricity industry to contribute to the cost of limiting airconditioning loads. But, as with heating loads, individual electricity suppliers may not benefit from such actions, so there may be a need to apply industry-wide levies to fund airconditioning reduction programs.

Scope for emission reductions from space heating

In theory, switching from electric resistance heating to wood, gas or electric reverse cycle heating should significantly reduce greenhouse gas emissions, as emissions per unit of heat delivered are reduced by a factor of three or more. While this is certainly true when off-peak electric heating is replaced, it may not hold when day-rate electric heating is replaced, particularly in areas with mild climates. As can be seen from Table 13, households that use these other heating options consume much more energy than would be expected, so emissions may not be significantly reduced or could even increase. Presumably, this is because gas and electric reverse cycle heating systems have greater capacity, and are designed to heat larger areas, while electric resistance heating is often used for spot heating, or in smaller areas. Also, day-rate electric heating is known to be expensive to run, while the other options have much lower running costs, so much more can be used before energy bills start to look expensive.

The increasing adoption of airconditioning provides some scope for replacing resistive electric heating with reverse cycle airconditioning equipment at very little additional cost: this offers significant emission reduction potential. However, most wall and window-mounted models are installed high on walls, so they do not deliver warm air where it is most needed. More attention must be paid to providing satisfactory comfort in heating mode.

A development in reverse cycle heating technology is the 'geothermal' heat pump. This circulates a fluid through underground pipes, then uses this fluid as the heat source for space heating. This type of system has advantages in regions with cold overnight temperatures, where conventional equipment may freeze as moisture from the air cools in its heat exchanger. Also, the warmer heat source allows a higher Coefficient of Performance (ie more heat out per unit of electricity used) to be achieved, and increases the overall heat output in extreme conditions. However, these systems are still expensive. Further, the extra pumping energy required to circulate fluid through underground pipes can cancel out a significant proportion of the savings in milder climate zones. If a US target of US$600 extra for the underground pipes (Turiel et al, 1995) can be achieved, these products would be much more attractive. Geothermal heat pumps offer energy suppliers significant benefits, as they limit peak electricity demand under extreme weather conditions: so there is a case for them to assist with purchase of this equipment. Overseas, gas-fired booster heaters are now being fitted to heat pumps to achieve a similar improvement to that provided by geothermal heat sources. It would also be feasible to use solar heated water as a heat source.

In technical terms, the efficiency of heating equipment has improved significantly over recent years, but there is still scope for substantial improvement. As noted above, central heating systems have scope for large efficiency improvements through improved duct and pipe insulation, zoning and improved controls: these can often deliver 50% savings. Gas appliances typically have combustion efficiencies in the range of 70 to 85%, but up to 95% efficiency is feasible if condensing burners (flue gases from which reach such low temperatures that the water vapour in them condenses, providing energy for pre-heating of inlet air). Overseas, gas-fired heat pumps (which use gas-fired engines to drive compressors) have been developed, and these are being trialled in Australia. Our moderate climates and low energy prices probably mean that they will struggle to achieve cost-effectiveness.

Wood heaters have improved in efficiency over recent years, with new Australian Standards for efficiency being introduced in 1993. However, these Standards are generally not mandatory, and many households are still installing relatively inefficient equipment. Also, oversized heaters are commonly installed: these run at poor efficiency when delivering small amounts of heat. Although data are very poor, it seems that wood-heated houses use very large quantities of energy for heating: this suggests that either their wood heaters are operating inefficiently, or the buildings are thermally very poor - or both. If the 16.4% of Australian households who, according to ABS, use wood for heating consume all the wood estimated by ABARE (Bush et al 1997) to be used in the residential sector, each one uses around 75 GJ per year: this compares with 30 GJ per year for a gas space-heated house in Melbourne.

Smaller, more efficient wood heaters are needed, designed to match the heating requirements of modern, energy-efficient houses: this may require a shift from traditional design to models that gasify wood, or grind it to small size, then feed it to a controlled combustion process. Indeed, it may be preferable to shift from individual wood heaters in urban areas, to gasifying biomass and distributing it to gas heaters!

It will also be important to address sustainability issues regarding supply of fuelwood, as noted earlier in this report.

It is important that any actions regarding heating and cooling equipment be set in a context of a drive for high standards of building thermal efficiency. This will minimise both capital and operating costs, as well as controlling rates of greenhouse gas emissions. Possibly installation of central heating equipment could be linked to a requirement or an incentive for the building to be upgraded to a 3-star or 4-star energy rating.

A clear message from data presented here is that off-peak electric central and space heating systems using fossil fuel-generated electricity should be discouraged in new homes, and replaced where possible in existing homes. Where such systems are highly valued, very high standards of building thermal performance should be required, including insulation of heated concrete slabs (at least around their edges).

Since there is extensive evidence of very poor installation practices related to central heating and cooling systems, it will be important to develop appropriate codes of practice, and to ensure they are implemented. This will add to installation costs, so public education programs that show most of the cost of a heating and cooling system is in its operation, and demonstrate that the measures built-into codes of practice will reduce that cost. For example, a $3,000 ducted heating system in Melbourne will cost around $10,000 to run over its 15 year life. An extra $1,000 spent on better-insulated and sealed ducting, return air vents in internal doors, and sealing of gaps around the house will save $3,000 or more over the life of the system. Installation packages could also include retrofit wall (and ceiling, if needed) insulation. Advertising programs that ask people to compare their bills with those from a well-designed house with properly installed heating and cooling could focus people's attention on how much money they are wasting, then show them how they could change that.

Scope for emission reductions from space cooling

In the USA, two-stage and indirect evaporative coolers are being developed for use in a wider range of climatic conditions. CSIRO has developed an indirect evaporative system for use in Australia. However, indirect systems consume more energy to run fans, so unless very efficient fans are fitted, consumption can rise to levels close to those of conventional refrigerative airconditioners in humid regions.

Refrigerative airconditioners are also improving in performance, and variable speed compressors, more efficient compressors, sophisticated controls, improved fans, etc are all contributing to efficiency improvement. A recent US study has indicated that it should be cost-effective to improve the COP of window-mounted airconditioners to around 2.8, from the typical value of 2.0 achieved today (Rosenquist, undated). Geothermal units (see above) use loops of pipe in the ground to provide a low temperature sink for cooling, and this can further improve efficiency.

Gas-fired airconditioners are again attracting attention. These may use absorption systems (like the 'kero fridge'), gas-driven compressors (where there is a use for the waste heat from the engine), or dessicants (where the gas is used to dry out a dessicant which then de-humidifies air moving through an evaporative cooling system). At present, these are most cost-effective for large systems, however, ongoing refinement and economies of scale may make them competitive in the residential market.

User behaviour

Users influence heating and cooling energy to a great extent, in ways such as:

- selection of thermostat setting: a one degree change can change heating costs by 10%
- leaving windows open while heating or cooling: each airchange per hour increase adds up to 7 MJ to the heating load or 2 kilowatts to the cooling load
- running heating or cooling unnecessarily
- leaving curtains open when heating

There are indications that many householders do not understand how to set thermostats, so they may tend to overheat and overcool as they adjust the controls in search of comfort.

Some of these modes of behaviour reflect fundamental issues, such as the belief that large amounts of fresh air should enter the house to maintain good indoor air quality, or the desire to stop mould growing on clothes and walls in humid climates. There is a need to work through these issues, then inform and educate people about practical ways of resolving the perceived conflicts between energy efficiency and other factors.

Maintenance

Household heating and cooling equipment usually receives little or no maintenance until it breaks down, because the cost of maintenance calls is seen as much larger than the benefit of improved operation - and there is some basis for this. Yet cleaning of filters, maintenance of fans and burners, checking the state of ducting, etc are important if equipment performance is to be maintained. It may well be that the introduction of diagnostic self-testing by increasingly intelligent equipment provides a solution here, as such systems could notify the householder (or even the energy supplier, via emerging communication systems) of the need for maintenance.

Tools for energy-efficient design

The development of user-friendly, widely-available computer-based rating systems and analytical tools is an important advance in the practical implementation of building energy efficiency improvement. In the past, reliance on ‘rules of thumb’, experience and crude analysis has led to a situation where:

- stereotypes have been used to define energy efficient house design. These have limited public acceptance, and have created unnecessary conflicts between building product manufacturers, and different groups of designers and builders
- some specific features have been addressed while other, possibly more important, factors have been ignored: for example in many cases, solar access has been considered more important than insulation, when the opposite is generally the case; timber-framed single-glazed windows have been replaced by double-glazed metal-framed windows with only marginally improved performance, because of thermal bridging through the frames
- there has been a tendency to see energy-efficiency as an ‘all or nothing’ issue: if the stereotype solution could not be achieved, it was often assumed little could be done to improve energy efficiency
- impacts of new construction on adjoining buildings have been either ignored, or overstated. For example, use of traditional shadow analysis overstates the impact of a building on houses to the south, so regulators have been reluctant to include solar access issues in residential planning codes because of perceived restrictions it would place on urban consolidation

The House Energy Rating tools now becoming available are a major step forward, because they encourage a shift from the stereotyped, ‘all or nothing’ position to one that recognises any house can be improved significantly. But this is just a beginning. Further developments are required, along the following lines:

- greater emphasis on diagnostic feedback to designers, not just rating of performance
- integration of energy analysis into standard design tools
- development of simplified guidelines consistent with outcomes from rating tools, for use by builders and tradespeople who are not 'computerised'
- consideration of rating in hot, humid climates where some argue comfort, instead of energy, should be used as the rating criterion
- extension of design tools to include lighting, and selection and installation of heating and cooling equipment
- development of analysis tools that facilitate assessment of the impact on winter solar access of existing homes by construction of new dwellings nearby, and provide feedback on trade-off options that can maintain the energy performance of the affected dwelling, as well as assisting with maintenance of amenity.

Progress in urban consolidation, which is important for transport emission reduction, will be increasingly dependent on community attitudes. Unless proponents of new developments can demonstrate that their proposals will not adversely affect existing homes, or that compensating action will be taken, conflict and opposition will continue to grow. As urban density increases, there is also an increasing probability that a new development will impact on the energy efficiency of not just one neighbouring dwelling, but several. And anomalies in development guidelines that encourage or require new dwellings to have solar access, but do not protect that solar access from overshadowing by future development on adjoining sites will have to be addressed.

The good news is that it is possible to develop tools that can deal with these problems. But a lot of work is required to develop them into practical, user-friendly forms, then to promote their use.

Where to for heating and cooling?

If the clear trends towards whole home comfort and all-year comfort are accepted as being entrenched, it seems that greenhouse strategies in regard to home heating should be based on the aim of minimising greenhouse gas emissions while maintaining most of a home comfortable most of the time over the whole life of the house - and comfort is most valued under extreme weather conditions. This leads to a problem of economic optimisation. The developer, builder and first occupant of a house see only a small proportion of the total cost of providing life-cycle comfort, so they will tend to under-invest unless they are offered incentives or required to meet high standards. On average, this will be justified, but in individual cases, it may not be. Further, as noted earlier, significant financial savings are gained by electricity suppliers when heating and cooling loads are reduced.

A combination of energy-efficient building design, high efficiency equipment, high standard installation, and appropriate user management would mean that most Australians could live in very comfortable homes while generating less greenhouse gas than is generated by heating and cooling activity today. Best practice buildings could generate much less greenhouse gas while maintaining comfort. But this will not happen until all participants in this market look beyond initial cost, to life-cycle costs, and all costs are included in analysis.

An important aspect of achieving emission reductions from heating and cooling is the effectiveness with which the benefits of improvements are promoted. A recent US study (May et al, undated) shows that the heating industry preferred the government to invest in effective consumer education, to create demand. The study also found that advertisements needed to be very specific. Their most successful advertisement showed a picture of two identical houses, one with a heating and cooling bill of $720, and the other with a bill of $500. The question "Guess who saved on heating and cooling costs this year?" was asked, then the benefits of using the US EPA *Energy Star* rating to choose equipment were explained. Financing arrangements were also highlighted as a critical factor in the study.

Chapter 9: Priorities and Principles for a Household Greenhouse Emission Reduction Strategy

Introduction

Strategies pursued to date with the aim of reducing energy consumption and greenhouse gas emissions within the household sector have addressed a number of key areas. However, this report shows more comprehensive and sophisticated approaches are needed if these aims are to be achieved. Past efforts to pursue the aims of energy efficiency and greenhouse emission reduction have been impeded by market barriers and distortions, as well as by actions of interest groups who believed they might be adversely affected by change.

There is enormous potential for household greenhouse gas emission reduction programs and policies to cut costs as well as emissions, as Australian households spend over $25 billion each year on building and renovating homes, buying new appliances, and paying for energy. It will be critical to build on this potential, but it must be recognised that these financial benefits are, at present, dispersed among a number of beneficiaries who are often not involved in critical decisions, or who have other priorities.

In this chapter, an outline is presented of actions required to create a suitable context, broad policy frameworks, and specific programs.

Creating the context for emission reduction

The following actions are necessary to create a positive attitude within the community to household greenhouse response measures, and to provide a basis for identifying, developing, implementing and evaluating them.

<u>1. Continue to develop a comprehensive knowledge base to support program development</u>
Ongoing surveys, monitoring of energy use, market research, technical RD&D and pilot programs are all needed if effective programs and measures are to be developed, fine-tuned and monitored. In particular, such analysis can help to identify areas of possible future growth in emissions (eg release of digital TV), so that constructive pre-emptive action can be taken to avoid that growth.

<u>2. Support development of infrastructure</u>
The infrastructure needed to support greenhouse emission reduction strategies includes the products which can be used to satisfy energy service requirements of households while reducing emissions, tradespeople trained in installation and maintenance of low emission technologies, salespeople conversant with emission reduction features of products, and tools that make selection and optimisation of low emission solutions easy. Very little of this infrastructure exists, so it must be built-up through RD&D programs, TAFE and tertiary courses, short courses and other training materials, backed up by certification requirements, appropriate industry standards and market development programs.

<u>3. Provide effective information and advisory services and materials</u>
Decisionmakers in the household sector are poorly informed on emission reduction options. They need high quality, practical and specific information to assist them in their purchase and design decisions. Also, no matter how efficient technologies become, their users will always have a significant influence over the amount of energy they use, so householders need to understand the implications of their behaviour. Further, the values associated with reducing waste, environmental responsibility, etc are important elements in maintaining pressure on market participants to remain focused on greenhouse emission reduction and in maintaining community support for actions in support of Australia's international obligations.

Information must be presented in ways that are relevant to people, and with an adequate level of support. Since many emission reduction decisions involve doing things differently from how they were done in the past, it will often be necessary to provide personal advice and support.

There is a clear need for provision of information on the energy use of a wide range of appliances and equipment, including lighting, which, at present, are not included in energy labelling or MEPS programs.

4. Set up state level (and possibly regional) emission indicators
It is often said that if you are not measuring something, you can't manage it. If this philosophy is to be applied to the household sector, it makes sense to establish indicators such as greenhouse gas emissions from household energy use per capita at the state (and possibly regional) level. This provides a basis to monitor performance of each state and other agencies involved. Over time, relevant agencies can be held accountable for their performance, especially where this may have involved investment of Commonwealth resources.

There is also a case to provide households with feedback on their levels of emissions relative to their state and the national averages, along with access to mechanisms to assist them to achieve emission reductions.

Policy frameworks

Several key policy issues must be considered, and appropriate frameworks put in place if household greenhouse gas emission strategies are to achieve their full potential.

1. Energy supply industry policy
At present, most of the signals to the emerging energy market encourage increases in greenhouse gas emissions and fail to reward emission-reducing actions. Further, when households become contestable customers over the next few years, there is a real possibility that changes in tariff structures and marketing strategies of the energy supply industry will work against energy efficiency and fuel switching, while encouraging increased energy consumption. These issues must be addressed as a matter of urgency, so that the powerful marketing strategies if the energy supply industry are harnessed for emission reduction, instead of working against it.

Legislation is needed that will ensure household energy tariff structures have low fixed supply charges and do not offer reduced charges for large consumers.

Clear guidelines are needed for management of high supply cost consumers. Where subsidies exist, these must be costed, and compensating programs implemented which promote energy efficiency, fuel switching, use of renewable energy and other measures which reduce the level of subsidy. This requires development of a consensus costing methodology which identifies benefits and costs to all parties, including households, energy suppliers, product and equipment suppliers, and the community. While it may not be possible to reach consensus on some aspects of such a methodology (such as costing of environmental and social externalities), even a simplified methodology will improve the quality of decision-making.

Where it can be shown that individual energy suppliers are not prepared to fund 'least cost' solutions because they may not be able to capture the benefits, application of levies to energy supply, to be used to fund qualifying programs, should be considered. For example, super-efficient refrigerators save electricity suppliers capital investment in supply infrastructure: a levy could be used to fund development and marketing incentives for such products. This is similar to the approach used in a number of industries to fund joint marketing, RD&D, health and safety and other programs which are recognised as beneficial, but which would not be funded by individual market participants.

2. Appliance and equipment industry policy
A long term policy approach to the appliance and equipment manufacturing, distribution and installation industries must be developed. This must consider the costs and benefits to all market participants of measures that reduce greenhouse gas emissions. While it must recognise the difficulties faced by manufacturers and others involved in the supply of appliances and equipment, it must ensure that balanced consideration is given to the value of the emission reductions achievable: where appropriate, industry participants should be provided with assistance and incentives, rather than threatened with penalties. Funding required could be raised via levies on appliance and equipment sales, or consolidated revenue.

Where heating and cooling equipment is installed in existing (or new buildings), there is a case to require or encourage upgrading of the building to a satisfactory standard, such as a 3-star or 4-star energy rating, so that the new equipment will not unnecessarily increase greenhouse gas emissions. This will require a significant change within the heating and cooling equipment market, which tends to take the building as a fixed factor.

4. Urban planning policy
Urban planning policies are potentially powerful influences on greenhouse gas emissions. At present, they are either neutral, or work against emission reduction. Specific issues that could be considered include reasonable protection of solar access, access to open space for occupants of medium-density housing, provision of facilities for solar (or low emission) clothes drying, and strategies for minimising the cost of installing gas supply infrastructure in new and existing developments and dwellings.

Specific programs

1. Act to minimise ‘energy leaks’
‘Energy leaks’ include heat losses from storage hot water services, power used by electrical equipment on standby, and gas used by pilot lights. This energy performs little or no useful function. Where homes have relatively low occupancy or appliances are used relatively infrequently, present rates of ‘energy leakage’ can be a substantial proportion of total energy use by an appliance. It is technically feasible and economically viable to cut ‘energy leakage’ to very low levels. However, this is unlikely to be achieved without mandatory standards, as this issue is not highly visible, and the cost of applying energy labelling would, in most cases, be comparable with or greater than the cost of dealing with the problem. Standards should be applied across all household electrical appliances, and could also include requirements for minimum Power Factor. Gas pilot lights should be banned. Tough heat loss standards for storage of heat should be introduced as quickly as possible, recognising that some commitments have been made to the water heater industry with regard to timing.

As a priority, requirements should be introduced for all new classes of equipment, such as digital televisions and converter modules, as it is essential to achieve ‘best practice’ performance for the first cycle of products entering a new market: otherwise, it will take decades to remove this inefficient equipment from the marketplace.

2. Aim to influence decisions with significant lifecycle implications
Many decisions made in the household sector have long-term implications. Where this is the case, it is important that due consideration is given to the greenhouse implications of those decisions. Purchase, design, construction and installation processes associated with buildings and products are all likely to have significant lifecycle impacts over a long period. Every effort should be made to ensure that they help reduce greenhouse gas emissions instead of increasing them.

In order to minimise lifecycle emissions, it is not sufficient to just focus on the purchase decision. The design of equipment and buildings is an important focus. For example, the decisions made during design of a domestic appliance influence the lifecycle emissions of hundreds of thousands of individual products manufactured to that design. The design phase is often the most cost-effective point of intervention.

There is also a need to establish infrastructure for the resale and disposal of appliances and equipment, so that it does not remain in homes, wasting energy.

3. Target greenhouse-intensive equipment

A variety of items of greenhouse intensive equipment have been identified in this study (due to either long periods of operation, or high emissions during each cycle of operation), including:

- hot water services, especially resistive electric storage units
- heating and cooling systems, especially resistive electric equipment
- swimming pool filter pumps and associated equipment (responsible for almost 2.5% of household energy-related emissions even though they are owned by only 12% of households)
- refrigeration equipment
- incandescent and quartz-halogen lights
- clothes dryers
- electric cookers
- heated water beds
- dishwashers
- buildings

In all the above cases, there is scope for substantial improvement in energy-efficiency or reduction in greenhouse gas emissions through technological innovation, as discussed in relevant sections of this report. This should be facilitated via RD&D or other measures, and must be supported by measures that facilitate adoption in the marketplace. It will be necessary to phase out (or permanently link use to *Greenpower* tariffs) resistive electric heating elements for water and space heating, other than where very small amounts of energy are used.

For existing buildings, there is a need for development and market support for products such as retrofit wall insulation systems and retrofit hot water service insulation blankets. These types of products are essential if retrofit programs are to be successfully implemented.

4. Work with market intermediaries to target key types of emissions

Market intermediaries are very powerful forces in the household sector. Unfortunately, there are few circumstances in which present market frameworks provide incentives for them to focus on greenhouse emission reduction. Thus, market structures and processes need to be transformed so that they provide signals to key market intermediaries to encourage them to pursue greenhouse emission reducing options.

Community networks are a potentially powerful and cost-effective mechanism for implementation of some programs which might otherwise not be cost-effective, such as retrofitting of insulation and other measures to existing homes. Local government and community-based organisations such as charities can be assisted to implement such programs.

Key targets for action include:

- households and loads that are costly to supply with energy (with energy supply industry and/or local government)
- households experiencing high energy bills (with energy supply industry and/or local government)
- regions where energy supply costs are high or usage of particular technologies is unusually high or low (with energy suppliers and/or local government)
- specific energy-intensive technologies with specialist market intermediaries (eg swimming pool pumps, lighting, kitchen appliances, working with pool supply shops, lighting designers and kitchen designers)

- home construction and renovation, not just because of heating and cooling, but also because this process is often associated with many appliance purchases (working with designers, developers, builders and/or local government)
- people planning for retirement
- buyers, landlords and managers of investment properties

5. Implement a fuelwood strategy
Collection and distribution of fuelwood is a significant greenhouse and environmental issue that requires an integrated and comprehensive strategy. But there is also a need to develop efficient wood heating systems of smaller capacity, suited to energy-efficient houses.

6. Develop and implement strategies addressing other major household-related greenhouse gas emissions
In the introduction to this report, a brief review of a number of household-related greenhouse gas emissions was presented. A number of these emission sources are potentially significant, and could be reduced by appropriate strategies. Options for dealing with these should be explored and, where appropriate, strategies implemented.

Setting priorities

All of the actions described in this chapter can be legitimately described as important steps towards reduction of household energy-related greenhouse gas emissions. Each has the potential to cost-effectively contribute to this objective. Even something as seemingly trivial as ensuring heated waterbeds are properly insulated has the potential to cost-effectively cut emissions by more than a hundred thousand tonnes of CO_2 per year!

Attempts to implement each action will confront different barriers, be they political, technical or financial. That is why they have, in most cases, not been pursued to optimum levels to date. Further, a given agency will see its role as addressing only certain aspects of the range of proposals put forward.

The key actions are those that change the signals to market participants, so that they actively support emission reduction instead of (often unknowingly) increasing emissions: this exerts leverage in responding to the issue. And actions that avoid purchase or installation of an item of equipment that will generate higher emissions than necessary over its life will underpin long-term success. Aiming for gradual improvement and implementing piecemeal elements of a strategy will not achieve the outcome needed by Australia and the world.

Appendix 1: CFCs and CFC replacements in household equipment

Introduction

In 1986, home airconditioning equipment consumed 3% of Australian CFC consumption, while home refrigerators were responsible for 1%. However, plastic foams were responsible for an additional 20% of CFC consumption, and home refrigerators are major consumers of foam, with up to five times as much CFC being used for blowing the foam insulation as is used in the refrigeration system. Thus, household airconditioners were responsible for up to 9% of Australian CFC consumption in 1986. The CFCs used in household equipment were also more active than those used for most other activities, so their share of impact on global warming was probably higher (see Greene, 1990).

In 1988, CFCs were responsible for 65 Mt CO_2 equivalent of greenhouse gas emissions, so Australian households' share of these emissions seems likely to have exceeded 7 Mt CO_2 equivalent at that time. Since then, airconditioner and refrigeration manufacturers have shifted away from ozone depleting CFCs in compliance with the Montreal Protocol. But many of the replacements used are still quite powerful greenhouse gases, with Global Warming Potentials of up to 20% of that of the original CFCs.

From the perspective of household greenhouse response strategies, this raises some important opportunities for greenhouse emission reduction:

- existing refrigerators and airconditioners contain substantial amounts of CFCs and HCFCs, which could be recovered. This would bring substantial once-off greenhouse and ozone-depletion benefits
- increasing production of new refrigerators and airconditioners, and growth in use of heat pumps for space heating and hot water means that lifecycle emissions from their use of HFCs (which are not controlled under the Montreal Protocol) will be increasing contributors to Australia's greenhouse gas emissions unless steps are taken to address this issue

This appendix takes a preliminary look at the implications and opportunities associated with CFCs. HCFCs and HFCs in household equipment. It does not claim to be a definitive analysis, but it at least provides a preliminary assessment.

CFCs and CFC replacements in refrigerators

Before the early 1990s, CFCs were used in both compressors and for blowing of insulating foam in cabinets: in fact, around five times as much CFCs were used for foam blowing than for refrigerant, giving a total of up to a kilogram per appliance. While CFCs from the foam do leach out over time, a substantial proportion of them remains over the life of the appliance. If it is assumed that 5 million existing refrigerators and freezers contain CFCs, their capture and controlled destruction could reduce future greenhouse emissions by up to 40 million tonnes of CO_2 equivalent. Capture of these CFCs would also contribute to reduction of ozone depletion.

Most new refrigerators and freezers now use HFCs and/or HCFCs for refrigerants and foam blowing. If it is assumed that 500,000 refrigerators are retired each year, and that each leads to release of a kilogram of HFCs, annual emissions would be around 650,000 tonnes of CO_2 equivalent, comparable to the emissions from energy use by over 3 million high energy-efficiency refrigerators.

Some manufacturers are shifting to foam-blowing with hydrocarbons or carbon dioxide, and adoption of non-foam insulation systems is expected to occur. So there is scope to almost eliminate HFC emissions from insulation. Some manufacturers of refrigerators are shifting to non-HFC refrigerants such as hydrocarbons, but there has been heated debate about the relative merits of options.

Airconditioners and heat pumps

In 1997, there were around 2.7 million airconditioners or heat pumps in Australian homes. If it assumed each one holds 250 grams of HCFC or HFC, the global warming potential of gases in these appliances (assuming 0.5 tonnes per appliance) is 1.35 Mt CO_2 equivalent.

If, in future, an upper limit of 700,000 airconditioners (cooling and/or reverse cycle) and water heating heat pumps were disposed of - equivalent to an appliance stock of around 10 million units, annual emissions associated with use of HFCs for these appliances would be around a third of a million tonnes CO_2 equivalent. This is around half of the long-term impact of refrigerators, but is based on very high market penetration of these technologies.

Hot water storage tanks

Electric HWS units mostly use blown foam insulation. In the past, these have used CFCs, but have now switched to lower ozone-depletion alternatives. Stocks of existing electric HWS units probably contain CFCs with greenhouse impact equivalent to several million tonnes CO_2 equivalent, and with significant ozone-depleting potential.

In future, if the water heater industry shifts to HFCs for foam blowing, in compliance with the Montreal Protocol, annual emissions associated with use of HFCs for these appliances could also be around a third of a million tonnes CO_2 equivalent (if emissions of 0.5 tonnes per appliance are assumed).

Possible actions

Further analysis of the greenhouse implications of CFCs, HCFCs and HFCs is required beyond that carried out here. Rough assumptions regarding the quantities of these substances present in appliances have been made: these may significantly understate the actual quantities, and hence understate future greenhouse impacts.

Clearly, management of CFCs in existing refrigerators airconditioners and hot water tanks, and HFCs in future appliances, is a significant global warming issue. Properly managed recovery programs which remove old, inefficient appliances from the marketplace could also facilitate managed recovery of CFCs and HFCs from the recovered appliances, so that these emissions could be avoided. Encouraging a shift to non-HFC refrigerants and foam blowing agents would help solve the long-term problem.

There is scope to work closely with people working on the Ozone strategy, as much of the data they have collected may be relevant. Further, many of the frameworks they have put in place could be extended and utilised for greenhouse emission reduction.

References

Allwood P, Pham T and Guthrie K *Matching water heaters to the load* **Transactions of International Symposium on Energy Environment and Economics,** University of Melbourne Nov 1995

Anon (1998) *How our five new electricity retailers are faring* in **The Age** Energy '98 advertising feature p.3, 31 March, Melbourne

Australian Bureau of Statistics (1981) *National Energy Survey: household appliances, facilities and insulation Australia Nov 1980* Cat No 8218.0, Canberra

Australian Bureau of Statistics (1983) *National Energy Survey: household appliances, facilities and insulation Australia June 1983* Cat No 8212.0, Canberra

Australian Bureau of Statistics (1987) *National Energy Survey: household appliances, facilities and insulation Australia 1985-86* Cat No 8212.0, Canberra

Australian Bureau of Statistics (1992) *Social Indicators Australia 1992* Cat No 4101.0

Australian Bureau of Statistics (1992) *Australia's Environment 1992* Cat No 4140.0

Australian Bureau of Statistics (1994) *Projections of the Populations of Australia States and Territories 1993 to 2041* Cat No 3222.0, Canberra

Australian Bureau of Statistics (1994) *Household Expenditure Survey Detailed Expenditure Items* Cat No 6535.0, Canberra

Australian Bureau of Statistics (1994) *Household Expenditure Survey Summary of results* Cat No 6530.0, Canberra

Australian Bureau of Statistics (1994) *Projections of the Populations of Australia States and Territories 1993 to 2041* Cat No 3222.0, Canberra

Australian Bureau of Statistics (1994) *Environmental issues, people's views and practices* Canberra

Australian Bureau of Statistics (1996) *Australian Social trends* Cat No 4102.0, Canberra

Australian Bureau of Statistics (1996, 1997, 1998) *Australian Yearbook*, Canberra

Australian Consumers Association (1996) *Laundry Detergents: update* **Choice** April, Sydney

Australian Consumers Association (1997) *Washing Machines - from the high end of the market* **Choice** April, Sydney

Department of Primary Industries and Energy (1994) *An Alternative Approach to Renewable Energy* in **Australian Energy News** Issue 2, Dec 1996, Canberra

Australian Gas Association (1994) *Gas Industry Statistics 1994* AGA Canberra

Bush S, Harris J and Ho Trieu L, *Australian Energy Consumption and Production: historical trends and projections to 2009-10* ABARE Research Report 97.2, Canberra

Commonwealth of Australia (1997) *Climate Change: Australia's Second National Report under the UN Framework Convention on Climate Change* Nov, Canberra

Electricity Supply Association of Australia (1995) *Electricity Australia 1995,* Sydney

Energy Efficient Strategies (1999) *Study of Greenhouse Gas Emissions from the Australian Residential Building Sector to 2010* with Energy Partners, George Wilkenfeld & Associates, Graham Treloar and Mark Ellis. Final Report 21 Feb 1999, Australian Greenhouse Office

Energy Victoria, EPA Victoria, Dept of Infrastructure and Energy Research & Development Corp (1996) *Urban Villages Project: Encouraging Sustainable Urban Form Summary Report* Melbourne

Energy Victoria (1997) unpublished statistical analysis by marketing section, Melbourne

E-Source (1997) *E-Source Technology Atlas Series* E-Source Inc, Boulder Colorado, USA

Expert Group on Renewable Energy Technologies (1996) *The Development and Use of Renewable Energy Technologies* Report to the Minister for Primary Industries and Energy, Department of Primary Industries and Energy, Canberra

Fiebig D and Woodland A (1991) *Residential energy consumption in New South Wales: an economic analysis of the 1985-86 ABS household energy survey* Report for the NSW Dept of Minerals and Energy and electricity Commission of NSW, Sydney NSW

Gas and Fuel Corporation of Victoria (1990) *High Efficiency Gas Appliance Penetration and Gas Savings in Victoria* Gas Demand Management Discussion Paper No 5, Economic Policy and Research Department, Melbourne

Gilchrist G (1994) *The Big Switch: clean energy for the twenty-first century* Allen & Unwin, St Leonards

Government of Western Australia (1990) *Energy Conservation Strategy for Western Australia: a discussion booklet* Energy Policy and Planning Bureau, Perth

Government Prices Oversight Commission (1996) *Hydro-Electric Commission Retail Prices Investigation Final Report 1996*, Hobart

Greene D (1990) *Reducing greenhouse gases: options for Australia* ANZEC Report No 26 with G Gavin and National Institute for Economic and Industry Research, AGPS, Canberra

Greene D (1992) *Life Cycle Analysis: a view of the environmental impact of consumer products using clothes washing machines as an example* Australian Consumers Association, Sydney

Greening L, Sanstad A, McMahon J, Wenzel T, Pickle S (undated) *Retrospective Analysis of National Energy Efficiency Standards for refrigerators* Reprint from Lawrence Berkeley National Laboratory, California

Kieboom J, Frazer K and PAWA (1998) personal communication and excerpt from PAWA Annual Report, Darwin

Levine M, Koomey J, McMahon J, Sanstad A and Hirst E(undated) *Energy Efficiency Policy and Market Failures* reprint from Lawrence Berkeley National Laboratory, California

Lumb J, Pears A and Buckley K (1996) *Key Areas for the Review of the National Greenhouse Response Strategy* Report to ICESD Greenhouse Working Group, Melbourne

May C, Brown R, Banwell P, Foery K, Offutt S and Wilson A (undated) *Increasing the use of energy efficient HVAC equipment in homes through voluntary prevention programs* US EPA Washington DC and Lawrence Berkeley National Laboratory, California USA

Meier A (1998) personal communication, Lawrence Berkeley National Laboratories, California

Nadel S and Pye M (1996) *Appliance and Equipment Efficiency Standards: Impacts by State* American Council for an Energy-Efficient Economy, Washington DC

Newman P, Kenworthy J and Vintila P (1992) *Housing, transport and urban form* Background Paper 15, National Housing Strategy, Dept of Health, Housing and Community Services, Canberra

Pacific Power and electricity distributors of NSW and ACT (1993) *The Residential End-use Study*, Sydney

Pears A (1994a) *Getting out of Hot Water* in **Energy Use and Greenhouse Gas Emissions Scenarios: Three sectoral studies** No 11 in a series of greenhouse studies published by the Department of the Environment, Sport and Territories, Canberra

Pears A (1994b) *Access to daylight and sunlight: impact of Viccode 2 and how it might be ameliorated* unpublished submission to VicCode 2 Review Panel, Victoria

Pears A (1996) *Non-transport energy issues for urban villages* in **Urban Villages Project - Transport and non-transport energy assessment: background papers** Energy Victoria, EPA Victoria, Dept of Infrastructure and ERDC, Melbourne

Pears A (1997) *Global warming: closing the gap between economic modelling and technology-based analysis of emissions trends and cost of response measures* Proc 'Creating a Green Future' Conference, Australia and New Zealand Society for Ecological Economics, Nov, Melbourne

Rheem Australia (1992) *Hot Water Manual* Water Heater Division, Sydney

Rogers G (1997) *Environmental financing strategies for sustainable urban and regional development* presented at **Pathways to Sustainability conference,** Newcastle City Council, NSW

Rosenquist G (undated) *Opportunities for improving the energy-efficiency of window-type room airconditioners* Lawrence Berkeley National Laboratory, California USA

Schipper et al (1997) *International Indicators.....* International Energy Agency, Paris

State Electricity Commission of Victoria (1984) *Energy Use in Victorian Homes: results of an energy survey of households in Victoria* with Dept of Minerals and Energy, Melbourne

State Electricity Commission of Victoria (1991) *Annual Report 1990-1991* Melbourne

State Energy Commission of Western Australia (1991) *Domestic energy use in Western Australia* Demand Management Paper No.1, Perth

Sustainable Energy Development Authority (1997) *New South Wales Energy Smart Homes Model Policy* Sydney

Sustainable Solutions (1993) *Green Home Guidelines (Victorian Conditions)Revised Edition* Australian Conservation Foundation, Fitzroy

US Environmental Protection Agency (1993) *Multiple pathways to super-efficient refrigerators* Office of Atmospheric and Indoor Air Programs, Washington DC

Victorian National Parks Association (1997) *Winter of discontent: firewood cutting threatens forests* press release 20 July, East Melbourne

Wilkenfeld G (1991) *Residential Appliances in Australia: an assessment of market and technology developments with particular reference to energy-efficiency* Report prepared for the State Electricity Commission of Victoria Demand Management Unit, Melbourne

Wilkenfeld G (1993) *Benefits and Costs of Implementing Minimum Energy Performance Standards for Household Electrical Appliances in Australia* Report prepared with assistance of Lawrence Berkeley Laboratory for the State Electricity Commission of Victoria Demand Management Unit, Melbourne

Wilkenfeld G et al (1996) *Australia's National Greenhouse Gas Inventory 1988 and 1990: Cross-sectoral Analysis of Emissions* with Woodlots and Wetlands, Dames and Moore and Dr G Faichney. Report to the Department of the Environment, Sport and Territories, Canberra

ROLE OF ABS REGIONAL DATA IN DEVELOPMENT OF AUSTRALIAN GREENHOUSE OFFICE RESIDENTIAL SECTOR STRATEGY

A supplementary paper for the Australian Greenhouse Office

Alan Pears
Sustainable Solutions Pty Ltd
2/78 William Street
Brighton Vic 3186

July 1998

Introduction

In the major report *Strategic Study of Household Energy and Greenhouse Issues*, prepared by Sustainable Solutions for the Australian Greenhouse Office, it was shown that there is considerable variation from household to household in greenhouse gas emissions, depending on factors such as types of appliances, fuels used, climatic conditions, household size, etc. This variation provides an opportunity to improve the cost-effectiveness of programs, by using targeting to focus on greenhouse-intensive households, activities and appliances.

The Australian Greenhouse Office has purchased appliance ownership data on a regional basis across Australia, and made it available to Sustainable Solutions for preliminary review. This brief report suggests a number of ways in which this data may be used to assist in development of cost-effective programs. The data may also assist in estimation of the possible impact of programs in different regions.

The data

In 1994, ABS collected data on ownership and purchase of a range of household appliances across 33 regions in Australia, as part of its household *Environmental Issues* survey. Similar data have been collected in a number of other surveys, but the sample size of the most recent survey was too small to allow valid disaggregation into regions.

The regions used for the breakdown are the *Labour Force Regions* and are used as a basis for disaggregation of data collected in a range of surveys.

The data purchased include:

- main heating by fuel type
- hot water service by fuel type
- airconditioners by type and number
- numbers of refrigerators and freezers
- numbers of dishwashers, clothes dryers, washing machines and airconditioners
- numbers of appliances (by major type) purchased or replaced in the previous 12 months

These data can be analysed in a number of ways, and could be combined with data from other surveys to further improve targeting of programs. This paper provides examples of some methods of doing this. It does not claim to provide a comprehensive insight into the potential for use of these data.

Hot water

The greenhouse intensity of electric water heating is much higher than that of natural gas. Further, solar and electric heat pump HWS units can also deliver hot water at much reduced greenhouse intensity.

Particularly in cold areas, additional insulation of electric HWS tanks could deliver significant emission savings.

In areas where there is extensive natural gas infrastructure, switching from electricity to gas could be an effective emission reduction measure while, in other areas, electric heat pumps or solar-electric HWS may be the most practicable low greenhouse intensity options, although high efficiency LPG HWS could be a viable option under some circumstances. Areas with sunny climates and no frosts, with little access to natural gas are prime targets for solar HWS.

Examples of findings from review of the ABS data include:

- Sydney region homes have 25% of all electric HWS units in Australia while comprising only 20.7% of households. Even though natural gas is reasonably widely available throughout Sydney, only 23.4% use gas hot water. Similarly, Brisbane, with 8% of Australian households, has 10.1% of all Australian electric HWS units, and only 14.1% of Brisbane households use gas hot water. The ACT, with 1.6% of Australian households, has 2.0% of all Australian electric HWS units and only 20.1% of ACT households use gas hot water
- even though 70% of Melbourne region homes use gas hot water, 8.1% of all Australian electric HWS units are installed in that region.
- While 57% of Northern Territory households use solar hot water, only 7 to 9% of Queensland households north of Mackay-Mt Isa have solar hot water.
- In the lower half of Queensland, only 2.5 to 5% of households use solar hot water, compared with over 20% throughout Western Australia.

Space heating

The lowest greenhouse intensity heating source is wood from sustainable sources, however, there are concerns that much fuelwood use is not sustainable. There is a case to focus efforts to grow fuelwood plantations in areas where ownership of wood heaters is high, such as north and NW NSW and central Victoria. Consideration should also be given to the possible financial and environmental impacts on households, energy suppliers and society if wood use shifts to electricity or gas.

The lowest greenhouse intensity fossil fuel heating is provided by natural gas, LPG or electric reverse cycle airconditioners. Resistive electric heating is the highest greenhouse intensity option, although its high operating cost often means less is used than other energy sources.

It would be desirable to integrate the ABS data on numbers and types of electric reverse cycle airconditioners with that on main heating energy sources, so that the proportion of households using resistive electric heating in each region could be determined.

In 1986, ABS also carried out detailed surveys in which the minutes of use of heating, cooling and other major appliances were recorded (ABS 1988). If these data can be broken down to a regional level, it may be possible to more accurately estimate heating and cooling energy use at a regional level.

It would also be possible to cross-tabulate data from ABS surveys (including the 1994 survey from which selected data have been purchased) on insulation and type of heating/cooling, to identify scope for emission savings from increasing adoption of insulation.

Regional climate data and data on expenditure on fuel and power could also be used in conjunction with data on ownership of heaters to identify areas where high levels of energy use and/or greenhouse gas emissions occur, and to identify target groups.

Examples of findings from review of the ABS data include:

- 38.4% of all Australian electrically-heated homes are in the Sydney region, and 55% of homes in that region use electric heating. Published data from the ABS 1994 survey suggest that only around half of Sydney homes have ceiling insulation (40.8% said their home was insulated, 17% said they didn't know)
- 38.8% of northern and north-west NSW use wood as their main heating fuel. While this may reflect good access to sources of wood, it also means these households are prepared to invest substantial capital in heating equipment
- 37.8% of ACT households use electric heating. Only around 10% of ACT households have reverse cycle airconditioners: this implies over a quarter of ACT households use resistive electric heating in a fairly severe climate.
- 80% of Melbourne homes use gas heating. However, there is a strong trend towards central heating within this group, with anecdotal information suggesting that over 60% of new homes have central heating

In assessing options for emission reduction from space heating, it should be recognised that a shift from one technology to another may significantly alter the amount of energy used. For example, shifting from resistive electric heating to electric reverse cycle heating involves a shift from small area heating to heating of rooms. The heating market is a very complex one, with many people being prepared to invest substantial capital in exchange for improved comfort or lower running costs. For example, many Melbourne households invest up to $10,000 in hydronic heating systems because they dislike ducted air heating (which costs only around $3,000). In areas where wood is available, many people spend well over $2,000 to install a wood heater, even when the climate is relatively moderate.

Airconditioners

Ownership of airconditioners is extremely variable across Australia, and does not necessarily follow patterns of climatic severity. For example, 36% of Melbourne households have airconditioners, while only 30% of Sydney homes and 14% of Brisbane homes have them. Over three-quarters of Northern Territory households have at least one airconditioner. Other ABS data (ABS 1988) suggest that many of the airconditioners in Northern territory are used for long periods for much of the year - 11.4 hours/day in spring, 10.6 h/d in summer, and 13.3 h/d in autumn). The ABS 1994 survey also shows that only 43% of NT homes have ceiling insulation, which suggests that a lot of their airconditioners may be working quite hard to maintain comfort.

Around 8% of the airconditioners in Australia are ducted reverse cycle or refrigerative airconditioners: these typically have low efficiency, due to heat leakage through the ducting. Almost a third of these systems are located in the Sydney region.

Refrigerators and freezers

Almost a quarter of Australian households have more than one refrigerator and 45% have a separate freezer.

There is significant variation in refrigerator ownership. Over 30% of Brisbane households have a second refrigerator, 32.5% in Northern Territory, 34.2% in 'Balance of WA', and over 35% in NNW Queensland and SE NSW. This variable seems to be related partly to climate, and there is a higher likelihood that non-capital city households will have more refrigeration equipment.

Ownership of separate freezers varies widely on a regional basis, too. Almost two-thirds of Western Australian households outside Perth have a freezer, as do 70% of Gippsland households. There is a bias towards country households having freezers, which may reflect their tendency to buy in bulk, but it could also reflect other factors, including a cultural predisposition, lack of capital to buy modern two-door refrigerator-freezers, etc.

Conclusion

This brief review of regional ABS data has confirmed that there is significant regional variation in ownership of appliances and equipment. There is scope to integrate these data with other data, such as expenditure on fuel and power, ownership of insulation, appliance usage, climate data, and access to natural gas. This would provide a more sophisticated picture of potential target groups for energy efficiency, renewable energy and greenhouse emission reduction strategies.

References

Australian Bureau of Statistics (1988) *National Energy Survey - weekly reticulated energy and appliance usage patterns by season and households, Australia 1985-86* Cat No 8218.0, Canberra

Australian Bureau of Statistics (1994) *Environmental issues, people's views and practices* Canberra

Australian Bureau of Statistics (1998) unpublished statistics on a regional basis from ABS (1994)