IMAGINING AUSTRALIA'S ENERGY SERVICES FUTURE

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Abstract
The ways Australians use energy have changed significantly over the past thirty years, for example the low energy intensity services sector has grown its share of the economy. Over the next two hundred years they will change far more, as factors such as climate change, an ageing population and changing cultures and technologies impact. Many consider that energy use is driven by economic and population growth. While these are important, the nature of change in energy service requirements and the efficiency with which energy services are delivered are even more important. This paper discusses past and future trends in Australia's energy service requirements, and assesses the implications for energy supply.

Changes in global and local energy service requirements mean that demand for Australian energy and resource exports may decline significantly in absolute terms, and the viability of conventional energy grids, even in cities, will be questionable. The actual outcome will be sensitive to decisions, both conscious and unconscious, made by individuals, business and governments.

Key words
Energy efficiency, energy demand, energy trends, residential energy, commercial energy, industrial energy, transport energy, energy services

1 Introduction

We don't use energy for its own sake. We use it as an input to the delivery of services that we value or believe we need. As shown in Figure 1, our energy use occurs within a cultural and technological context. While it is fashionable to describe energy as an essential service, the reality is that it is one of a number of essential inputs to the delivery of services. And what we define as a service is, in many cases, a cultural construct.

Figure 1. Energy's role in delivery of services

So when we imagine Australia's energy future, we need to reflect upon the activities and services that will be needed or desired. These, combined with the technologies available, will determine the requirements for energy.

2 What will we use energy for?

Traditionally, energy has been used as an input to the delivery of:

- Food and water
- Materials and the goods manufactured from them
- Shelter, including construction materials, light, food storage and preparation, maintenance of comfortable conditions, facilities for cleaning people and clothing
- Services, including maintenance of health, education, entertainment and recreation
- Access/mobility
- Generation of income for individuals, businesses and, through exports, for the whole economy

Particularly over the past sixty years, we have seen expectations of the level of services as well as the range of services increase dramatically. Rapid technological development and declining costs of provision of services relative to income have underpinned trends towards larger homes, central heating and cooling, more and larger refrigerators, near universal car ownership, and so on. Australian national policies have encouraged expansion of production and exports of minerals and energy, as well as energy intensive materials such as aluminium. Population growth, combined with a decline in household size, has also been a driver of energy growth.

Within the Australian economy, the low energy intensity services sector has expanded relative to other activities, now comprising almost three-quarters of total economic activity, as shown in Figure 2. This sector is now also the dominant employer of Australians. This structural change has offset, to some extent, the energy growth from resource processing.

Figure 2. Trends in shares of Australia's GDP [1]

In 200 years, our requirements may be very different, and there is great uncertainty. For example, while many now expect Australia's population to stabilise at around 25 million within the next 50 years [2], the following 150 years could bring dramatic change. Climate change could drive climate refugees towards Australia, and parts of northern and central Australia could also become uninhabitable, due to extreme heat or frequent cyclones. The capacity of Australian agriculture to support population while sustainable ecosystems are established will change, but it is not clear in which direction. Trends in energy service requirements will be linked to these population trends.

Trends in energy service requirements will also be linked to the mix of types and the level of economic activity, as well as the actual level of energy intensity of each type of activity. While it is easy to say that, all things being equal, energy requirements increase with an increase in GDP, the future is potentially very different. First, ongoing restructuring from high energy intensity to low energy intensity activities (eg from metal production to services, as can be seen in Figure 2) means less energy is required for each unit of economic activity. Second, trends such as dematerialisation, shifts towards reuse and recycling of materials, switching to less energy intensive materials, 'virtual' replacements for previously physical activities (eg telecommunications replacing travel), and so on mean that the energy intensity of any given task can potentially fall. Lastly, it may be that a trend towards 'enoughness' instead of insatiable growth in demand may dominate. Or it may not.

With what is likely to be an older population, as well as the possibility of refugees, energy service requirements for health care and aged care are also likely to grow.

Some parts of Australia could be chronically short of water. Desalination, pumping and water treatment are therefore likely to grow in significance as energy-consuming activities. The nature and extent of agricultural activity, and its associated energy service requirements, will also be affected by climate change in Australia and other countries.

With climate change will come an increase in the need to cool buildings to maintain comfort and health.

Over the past few decades we have seen strong growth in international air travel to and from Australia, both for tourism and business. Freight volumes, dominated by raw materials, have also grown. If wealth continues to grow and international specialisation in manufacturing and resource production continues, the level of international travel and freight activity can also be expected to grow.

The future for exports of fossil fuels and raw materials is less certain. If response to climate change involves a shift towards energy efficiency and renewable energy, world demand for fossil fuel exports from Australia will decline. But if the mainstream energy solution is to capture carbon dioxide emissions from fossil fuels and store it underground (known as geosequestration), and/or growth in conventional nuclear energy production, then Australian energy exports could continue to be substantial.

The future for materials is also unclear. Energy use for mining and processing of materials is a major part of Australian energy use at present. Dematerialisation, increased recycling and re-use, and shifts towards renewably-sourced materials could reduce demand for virgin materials sourced from places such as Australia. Competition from resource exports from developing countries is also likely to apply pressure to Australian exports. On the other hand, ongoing wasteful use of materials and lack of support for material recovery and recycling could lead to continuing growth in demand for virgin materials.

These possible futures for energy service requirements will not automatically flow on to increase demand for energy itself. There is scope for dramatic improvement in the efficiency with which energy is used, sufficient to offset most or all of the growth in demand for energy services, or even lead to an overall reduction in the amount of energy required.

Energy supply technologies are also likely to evolve away from large centralised technologies towards diversified local and regional solutions matched to the much more energy efficient end-use technologies that are emerging. Capture of economies of scale through replication of modular technologies, and improving intelligence of control systems, combined with increasing perceptions of financial risks for large centralised energy projects, are likely to be key drivers of this trend.

The remainder of this paper reviews the detail of these future possibilities. It looks at recent trends, then future possibilities. A fundamental issue is that past trends must be seen in their context: our energy future will be very different from the past, because the technologies, environmental pressures and cultural perspectives will be different.

3 Residential Energy Use and Supply

Energy is a relatively minor component of Australian household budgets. On average, non-transport energy comprises 2.6 percent of expenditure, while transport fuel is 3.8 percent [3]. Indeed, Australian households spend more on buying energy-consuming appliances than they do on the energy they use [3].

Australian residential energy use by activity is shown in Figure 3. Space conditioning (mainly heating) dominates energy use, with 45% of total energy. This is followed by water heating, at 25%. Electrical appliances and lighting comprise 27% of energy use, with cooking comprising 4%. Electricity provides 45% of total residential energy, and generates 83% of greenhouse gas emissions from residential energy use, due to the predominance of high greenhouse intensity coal-fired electricity generation [4]. Over a quarter of this electricity is believed to be used for heating water, and half for appliances – but data quality is poor, so there is substantial uncertainty due to lack of comprehensive field data.

More than 70% of present Australian residential energy use provides low grade heat for space and water heating and cooking. Looking into the future, this energy requirement can be expected to dramatically decline, despite population growth, decline in household size and increasing dwelling area.

Australia's present housing stock is thermally poor, with less than two thirds of homes having ceiling insulation and less than a fifth having wall insulation [5]. Before 2003, only Victoria and the Australian Capital Territory (about a quarter of Australia's population) had residential building energy regulations. National regulations were introduced in 2003, and are being strengthened from 2006 [6]. These standards are relatively weak in comparison with parts of Europe and the USA such as the Netherlands, Germany and California. Developments in advanced glazing systems, heat recovery ventilation, heat storage materials and improved insulating materials, combined with increased utilisation of passive solar design and other forms of renewable energy mean that space heating service requirements in Australia's generally mild climates should be minimal in the future. Present heating technologies are extremely inefficient, with relatively crudely designed wood heaters, non-condensing gas heaters, and poorly insulated ducting being standard practice. Where heating is required in future, much more efficient appliances will be available.

Figure 3 Australian residential sector energy and electricity use, 1999

One trend towards growth in space heating energy use is the recent enthusiasm for outdoor heating! As Australians embrace indoor-outdoor living, many have installed radiant gas heaters on outdoor decks. These typically consume around 40 Megajoules per hour, more than is used to centrally heat most homes. Alternative solutions are feasible, but have not been developed to a commercial form. This trend is an example of the kinds of new energy services people may desire, and it also reflects the significance of cultural norms and technologies in shaping future energy use patterns.

Water heating is another area where future conventional energy requirements can be expected to decline sharply. The drive towards improving water efficiency of showerheads, taps, clothes washers and dishwashers, as well as use of lower clothes and dishwashing temperatures due to improvements in detergents, will reduce demand for hot water. There is potential to halve hot water usage per person through these efficiency measures. Around a third of the energy used for water heating today is lost from storage tanks and fittings [4]: improved insulation and appliance design, optimisation of water pipe design and improved management of water usage should halve this waste. Solar and electric heat pump water heaters will further improve, and should replace up to 80% of the remaining energy requirement with renewable energy.

Developments in cooking energy use are more difficult to predict. Recent decades have seen a decline in household cooking energy use, as use of pre-prepared food and take-away food has increased. Australians also dine out much more often now. Ownership of microwave ovens is now almost universal, and they have replaced much use of conventional cooking equipment. It seems likely that trends towards centralised food preparation, balanced by 'recreational cooking' in homes, will further reduce cooking energy use. Innovative cooking technologies such as steam cooking also offer potential for faster, more efficient cooking. As the population ages and people seek greater convenience, services such as 'meals on wheels', the delivery of prepared meals to elderly and housebound people, may also expand.

There are complex energy trade-offs in provision of food to consumers. For example, centralised cooking can cut cooking and refrigeration energy use but increase transport energy use as people travel to restaurants or collect take-away food, or providers transport food to users. The actual net energy outcome is sensitive to the efficiencies of all the elements in the system.

The remaining 30% of household energy use (and half of residential sector energy-related greenhouse gas emissions) is electricity, mainly for appliances, with some usage for lighting and space cooling. Household electricity consumption for these activities has been growing rapidly due to trends such as:

- Widespread installation of inefficient low voltage halogen lighting (partly due to widespread belief that low voltage means low energy – when it is the Watts that matter, not the voltage) with higher lighting levels and in larger homes, as well as an increase in outdoor lighting for aesthetic and security purposes
- Dramatic increase in energy use for home entertainment systems, including larger televisions, more televisions per household, and increased use of stereos
- Increasing ownership and usage of appliances such as airconditioners, dishwashers, clothes dryers and home computers
- Increasing standby energy use by appliances and equipment ranging from home security systems, smoke alarms and remote control doors to DVD players and whitegoods with electronic features. Estimates of standby energy use vary from 8-12% of household electricity usage [4,7].

Given present trends, it is likely that the number of items of electrical and electronic equipment in homes will continue to increase, and expectations of quality of service will increase. Home theatre, virtual reality systems, whole home airconditioning, intelligent home systems, etc can be expected to become almost universal. So the requirements for energy services will increase substantially. However, equipment efficiency can also be expected to improve, potentially faster than growth in energy service requirements, so that total electricity usage for appliances and equipment could decline. Even now, there is wide variation in energy efficiency of equipment and scope for efficiency improvement through careful consumer choice, as illustrated by Figure 4. This variation in performance has led the Australian government to consider introduction of energy labelling for televisions.

Potential developments include:

- Dramatic improvements in lighting energy efficiency: for example, Navigant [8] estimate that lighting efficiency could improve by a factor of ten by 2025 as new developments in solid state lighting occur.
- Emerging television technologies such as Organic Light Emitting Diodes will offer large screen TV using about as much energy as today's 34 centimetre portable televisions, and less than half as much as typical existing family TVs [9]. Virtual reality systems could project images into people's eyes using very little energy.
- Potential for virtual elimination of standby energy use through improved design combined with small solar cells and batteries
- Improving efficiency of computers, with laptops now consuming less than 20 watts, compared with conventional computers that use over 100 watts [10]

- Potential for ongoing efficiency improvements in whitegoods, such as clothes dryers that use domestic hot water (sourced mostly from solar) as a heat source or high efficiency heat pump technology combined with heat recovery. While today's Australian refrigerators are 70% more efficient than those of the mid 1980s [11], best available technology such as a new Turkish Arcelik unit [12] uses less than half as much energy, and further efficiency improvements are certainly feasible.
- Airconditioning energy requirements will be contained by improving building thermal performance and cooling technology efficiency, despite climate change and increasing expectations regarding comfort
- Developments in intelligent systems for homes seem likely to provide the capacity to manage energy use of equipment, identify faults, and educate users. Flexible systems that can be easily retrofitted to homes and equipment are emerging [13].

Figure 4 Operating power consumption of different television types

Overall, if the above trends and efficiency improvements are considered, it could be expected that household energy use per capita could decline by two-thirds. If Australia's population stabilises at around 25 million, total household energy use per person would decline by around 55 percent, but electricity use would decline by just under 50 percent. This would be equivalent to usage of around 1 000 kilowatt-hours per person per year of electricity and 3-5 Gigajoules of other forms of energy per person per year, ignoring on-site utilisation of solar energy for space and water heating. This allowance of 1 000 kWh per person is quite high compared with the level of usage of some efficient households today, however this allows for high usage of home entertainment equipment, use of some electric cooking, and growth in other services such as refrigeration. There is certainly potential for household electricity usage to be much lower than this estimate. Total household expenditure on energy would be likely to decline, as any increase in energy costs due to use of renewable energy would be offset by the reduction in the quantity of energy required. Further efficiency improvements and lifestyle changes offer potential for additional reductions in future energy requirements – for example development of cooling technologies that utilise solar heat could cut electricity requirements by up to 100 kWh per year per person in this scenario.

This energy for households could be supplied in quite different ways from today. For example, a typical household of, say, 2.3 people, would require a photovoltaic panel of around 1.5 to 2.5kW capacity to provide its electricity, which would cover less than 25 square metres of roof area and cost less than the kitchen appliances in a typical home. The annual heat requirement could be provided by around half a tonne of wood or 100 litres of biodiesel. Green waste generated within a typical Australian city could be converted into biogas, biodiesel or hydrogen to provide heat and back-up electricity for all household energy requirements. While there could still be some benefits from interconnection of clusters of homes, for example to share a back-up generator, the economics of large scale energy supply grids, which today comprise around half of the total cost of household electricity for residential areas, could come under serious question. Modular local storage of compressed gas, biodiesel or hydrogen may therefore become fairly normal. High density housing is likely to incorporate cogeneration (using fuel cells) as well as renewable energy systems.

4 Commercial Sector

The commercial sector provides services throughout the economy. Its greenhouse intensity is low, around a tenth that of industrial activity while, in 2000, it employed 82 percent of the Australian workforce, and comprised 74% of GDP [1] and 22.5% of export value [14]. Non-transport energy is a very small component of input costs for the commercial sector, about 0.5 percent of all input costs.

Figure 5 shows the strong growth in commercial sector energy use, and the increase in electricity's share of energy for the sector over the past three decades. It also highlights the dominance of the retail/wholesale sector in relation to both growth and absolute significance. The communications sector has grown dramatically, but remains a very small user of energy: since this is a major area of future growth, its low energy use bodes well for future energy trends. The enormous growth in energy use of the retail/wholesale sector reflects growth of energy intensive retail facilities such as hot bread and fast food outlets and restaurants, as well as growth in energy intensive activities such as refrigeration and airconditioning, and increasing light levels.

Figure 5. Commercial sector energy and electricity use, 1973-74 and 1998-99

Figure 6 shows estimates of energy and electricity use by activity within the commercial sector [4]. It can be seen that almost 80% of energy used in the Australian commercial sector is used to provide a comfortable environment and light. This reflects the high priority applied to these activities in this sector, the appalling inefficiency with which these services are delivered, and the relatively low energy cost of providing services. Refrigeration comprises the next major activity and, again, there is ample evidence of extreme inefficiency in this area. It is of interest that the energy used for office equipment, which is a major contributor to productivity in this sector, is quite small, estimated at just 3.5% of the sector's energy use.

There have been no energy efficiency regulations targeting commercial buildings in Australia, although the Australian Building Codes Board has announced that building energy performance standards will be introduced in 2006, with the intention of improving energy efficiency by 20% [15]. Since 1999, the Australian Building Greenhouse Rating Scheme (ABGR) has been applied to office buildings throughout Australia, with 14% of total office floor area covered by ratings by late 2004 [16]. This scheme applies to both tenancies and base building services, so it is presumably having some impact in the office sub-sector. ABGR is being incorporated into more comprehensive Australian building environmental rating schemes as the greenhouse/energy module: this minimises duplication.

Figure 6. Energy and electricity use in the commercial sector by activity, 1999.

The Australian Greenhouse Office [17] is progressively introducing a number of mandatory Minimum Energy Performance Standards for airconditioning equipment, fluorescent lamps, ballasts and other equipment. The Australian scheme stringency is set on the basis of an international review of existing Standards, with the Australian requirement being set at the most stringent level already in place in a major country. On one hand, this applies pressure to suppliers of equipment in Australia to meet the toughest international standards but, because of the time delay in implementation, it also means that Australia will always be several years behind the leading regulatory edge. In general, Standards set levels of performance well below best practice. At present there are no energy rating or labelling schemes for most commercial equipment and, indeed, it is generally very difficult to gain access to product-specific comparative information on energy performance.

The author has been involved in projects addressing energy efficiency in fast food restaurants, hot bread shops, supermarkets and office buildings. In all cases, energy savings of 15 to 70% have been relatively easily achieved. Much larger savings potential exists, but the lack of high efficiency equipment in the marketplace, combined with concerns about impacts of changes in equipment characteristics on sales from marketing staff, have hampered capture of the full potential. For example, around 60% of the energy used by Australian supermarkets is for refrigeration, but much of the refrigeration equipment is comprised of open vertical cabinets. One US study [18] showed that by installing glass doors, energy consumption could be reduced by 70%. Hot bread ovens have been found to be very inefficient, with one Australian example estimated by the author to lose nine times as much heat as it should if it were properly insulated and fitted with a heat recovery system. The 60L Green Building in Melbourne, a purpose-designed environmental building with which the author has been involved, consumes 77 kilowatt-hours per square metre per year compared with an average for Melbourne of around 275 kWh. Sub-metering data indicates potential to further reduce 60L's energy consumption by 25 percent or more.

The potential for energy efficiency improvement in the activities shown in Figure 6 includes:

- In the short to medium term, 60 percent savings in heating, ventilation and cooling requirements of commercial buildings seems quite feasible by applying existing, cost-effective technologies. In the longer term, insulating glazing systems such as silica aerogels, daylighting systems, smarter control and fault detection systems, more efficient and flexible motors, fans and pumps and other technologies should allow 80 percent savings to be achieved.
- Increasing flexibility in working from home, online shopping and electronic communications technologies offer the potential to reduce the floor area required for a given commercial activity, thus reducing the energy overheads
- Already lighting energy efficiency improvements of 60 to 85 percent can be achieved with existing technologies. Further improvements in lighting efficiency, daylighting and controls will increase the

savings potential, although it may be difficult to discourage sales people from using very bright lights in the belief that they will increase sales. Recent studies indicate that sales are actually increased where stores have daylighting, so experience may provide arguments to counter the 'more light is better' culture.

- Much of the energy used for water heating in the commercial sector is wasted as water is pumped through poorly insulated ring main systems in buildings, or is lost from long pipes, poorly insulated storage tanks and boilers, and water-wasteful taps and fittings. Large quantities of hot water are also commonly wasted, and water efficiency measures will reduce this factor. Waste heat (for example, from airconditioning systems), solar energy and electric heat pumps, as well as heat from cogeneration systems (on-site electricity generators that provide both electricity and useful heat) will be able to provide a significant proportion of the hot water required.
- Energy use by office equipment grew strongly through the 1980s and 1990s as computers, printers and other electronic equipment spread throughout the commercial sector. However, recent trends indicate that efficiency improvements are beginning to outstrip growth. Power management systems on office equipment are dramatically cutting unnecessary operation of equipment, while most equipment is becoming much more efficient. For example, a typical LCD (liquid crystal display) monitor halves power usage from 60 watts to around 30 watts [10] and adjusting the brightness to the minimum (but still satisfactory) level halves the LCD's power usage. New types of displays, such as Organic Light Emitting Diodes, are expected to further reduce energy consumption. However, we may see more people using multiple screens in future, although this could be balanced by development of micro systems that project images into eyes or onto spectacle lenses using very little energy.
- Typical computer centres are very wasteful, not just because they are full of equipment that is often poorly power managed, but because the airconditioning systems used are often extremely inefficient (and expensive to maintain). For example, one computer centre assessed by the author used over 40% of an office tenancy's total electricity use. Modern computer equipment is much less sensitive to temperature variations, with some equipment being designed to operate atop mobile phone towers, and it is also becoming much more efficient. Careful layout of computer centres to ensure adequate airflow, combined with power management and improving efficiency, means that the need for airconditioning can be reduced and, in some cases, avoided [10]. Of course, in the longer term, the need for data centres may be almost eliminated as decentralised systems dominate.
- As noted above, commercial sector refrigeration equipment is typically very inefficient. Improved insulation, high efficiency compressors, multi-stage compressors, high efficiency fans and fan motors, larger condensers and evaporators and optimisation of management can deliver large savings. However, energy waste from open refrigeration units may need to be dealt with by regulation, so that there is a level playing field: otherwise marketing staff are likely to resist measures they believe will disadvantage their stores relative to competitors.
- Other energy use includes cooking, lifts and escalators, and a myriad of miscellaneous equipment such as coffee makers, health care equipment, and so on. In every case, there is potential for large savings through improved design and management. For example, an analysis by the author indicated that, at best, typical chip fryers were 25 percent efficient, with large standby losses. A coffee maker analysed by the author in a fast food restaurant was found to be less than 10 percent efficient.

Overall, there seems to be potential to reduce energy consumption per unit of activity in the commercial sector by at least 75 percent. However, if economic growth continues, it will also be necessary to drive ongoing fundamental change in the way services are provided, for example by greater use of the Internet and other communications technologies, further reduction in the time spent in hospital for surgical procedures, and so on.

5 Industry (including Mining and Agriculture)

In 1999, Australian agriculture generated 3.3 percent of GDP, while mining generated 4.6 percent and manufacturing generated 13.3 percent. Rural activity employed 821 000 workers, while mining employed 78 000 and manufacturing employed 1.1 million. In 1999-2000, rural activities generated 21.2 percent of export revenue while the resources sector (including metal processing) was responsible for 34.8 percent and other manufacturing 21.5 percent [14]. So, while these sectors are not large employers or contributors to the local economy in comparison to the services sector, they play a major role in managing Australia's Balance of Payments, by offsetting imports of manufactured goods and services. On average, non-transport energy is a small input cost factor for Australian industry, averaging less than 2 percent of input costs. For a small number of energy intensive industries, energy comprises 10 to 30 percent of input costs.

Over the past three decades, the major areas of growth in Australian industrial energy use have been mining, non-ferrous metal production (mainly aluminium) and food processing. Energy use in the steel industry, and in the glass, bricks and cement industries have declined. Around half of the energy used for mining is actually used for extracting and liquefying natural gas for export.

Figure 7. Industrial energy and electricity use, Australia 1973-74 and 1998-99

In considering future trends in Australia's industrial energy use, the future of materials is central. More than two-thirds of industrial energy is used for extraction or basic processing of materials, most of which are exported.

In 200 years, it seems unlikely that Australia will still have significant natural gas resources to export, so the gas liquification component of energy use is likely to decline markedly. Depending on progress regarding geosequestration or other mechanisms to capture carbon dioxide emissions from coal use, coal exports may continue, or may be phased out due to competition from other energy sources.

The long-term future of metal production from virgin material is also open to question. If global population has stabilised, then recycling, dematerialisation, ongoing improvements in alloys, and switching to non-metals (such as carbon composites, plastics, etc – which could be produced from renewable feedstocks or recycled material) could significantly reduce Australian energy use for mining and processing these materials. Perhaps the future potential can be best summarised by the following quote from US visionary R Buckminster Fuller [19], who noted:

"We have reached the point where no more mining need be done. In my tracking of resource curves, I discovered that the average of all metals recirculates every twenty-two and a half years. …. Each time they come around again, we have gained so much more know-how and can do so much more with so much less in the way of physical resources per function that ultimately we need not mine any more."

Figure 8. Australian industrial energy and electricity use by activity, 1999

Already, there is potential for best practice paper and pulp mills to improve efficiency and utilise energy from wastes and renewables to provide all of their energy requirements, and even become net electricity exporters [20].

Within 200 years, 'green' chemistry may have replaced much conventional chemical processing energy, while nanomachines and other technologies may replace much conventional manufacturing activity. These changes will dramatically reduce industrial energy requirements. To the extent that they replace global scale industrial facilities that rely on international shipping, these technologies could have major impacts on global transport and on the location and nature of industrial facilities.

Overall, indications are that industrial energy use will decline as emphasis shifts from processing of virgin raw materials towards higher value, less energy intensive activities.

6 Transport

Australia's present transport energy use is dominated by road transport which, in turn, is dominated by cars. Cars are used for personal mobility and business purposes, mostly within urban settlements.

Already, it is clear that cars could use much less fuel than today's Australian average of more than 11 litres per 100 kilometres. Weight reduction and advanced engine technologies offer potential to reduce fuel consumption to less than 3 litres per 100 kilometres.

However, improving the fuel efficiency of cars will not solve urban congestion, address the social problems faced by the poor, elderly and young who cannot drive, nor recover the time spent by unpaid chauffeurs such as parents. With developments in high efficiency electric motors, energy storage and fuel cells, small low speed vehicles such as electric buggies and electric bicycles are increasingly appearing as local transport modes. Intelligent, fuel-efficient vehicles will become commonplace. Safety concerns regarding the emerging mix of vehicle types and speeds will be addressed by systems such as air bags, radar, collision avoidance technologies, high strength materials and speed limited lanes. Advanced, intelligent public transport vehicles will also play an important role in urban transport. Inter-city and interstate transport services will be most efficiently delivered by very high speed trains of some kind, running on above ground tracks so that the environmental impact and crash risks are minimised.

Urban consolidation will reduce distances people need to travel.

Development of services such as on-line shopping and virtual reality technologies will also reduce the need for travel for many purposes. For example doctors will be able to remotely diagnose and even treat illness, much education will occur on-line, and so on.

Light commercial vehicles consume nearly as much fuel as do trucks, even though they travel much shorter distances (see Figure 9). The rapid growth of this sector reflects the development of a 'just in time' mentality, whereby almost empty vans rush around cities delivering small items. It also reflects decentralisation and declining organisation of business activity, and an increase in home deliveries and provision of on-site services. Some of this business travel actually reduces personal travel, for example home delivery of take-away food can use less fuel than when individuals visit stores. But much light commercial vehicle activity could be reduced through improved coordination and alternative forms of provision of services. In the long term, intelligent fuel-efficient small vehicles could be used for both local freight and passenger activities.

Figure 9 Recent trends and projections of Business As Usual transport energy-related greenhouse gas emissions.

Over the past few decades, trucks have replaced rail for many freight tasks. However, this trend is beginning to reverse as rail systems are upgraded and the fundamental economics of rail are recognised. Australia's rail infrastructure is still of a poor standard, but its potential is beginning to be recognised. Much of Australia's overall freight task is for bulk materials, as shown in Figure 10. Dematerialisation, increased use of locally sourced renewable and recycled materials, and declining exports of bulk materials will all lead towards a decline in the total freight task.

Figure 10. Australian domestic freight task, 1999.

Transport will, of course, be well into the post oil era in 200 years. While it is fashionable to suggest that hydrogen will be the fuel of the future, it is also possible that methanol from biomass, biodiesel from vegetable oils and ethanol from sugar beet, trees or sugar cane could play important roles. It is likely that different mixes of fuels will be used in different regions. As in the non-transport sector, conventional thinking on transport fuel sees a need for bulk volumes of fuel. Once very high efficiency transport service solutions dominate, the economics of more diversified regional and local transport energy solutions may be superior to centralised options.

International travel to and from Australia is likely to be an area of major growth over the next two centuries. Increasing wealth, globalisation and vehicle speed will make it increasingly normal to travel long distances for both recreation and business. Larger planes with more fuel-efficient engines and improved aerodynamics will reduce energy use per passenger-kilometre but, based on the potential for growth in demand, this will not be sufficient to limit overall energy growth. Further, development of supersonic planes to satisfy markets for faster travel could add to the increase in energy consumption.

Virtual travel using advanced telecommunications and computer technologies may replace much business international travel, as the time savings and avoided jet lag have substantial value to a business. Some tourists may also opt for virtual travel. Also, there is potential to encourage tourists to take trips of longer duration, so that the benefit of each international trip is increased. On the other hand, tourism operators also like to encourage spontaneous weekend and even day trips.

Innovative travel solutions such as airships and surface skimming planes, which ride on the boundary layer of air close to the surface of the sea, could reduce energy consumption. Such vehicles may also be more suited to using renewable fuels, which are generally more bulky than present fuels.

Renewable fuels will also be used for air travel. Given the potential fuel efficiency improvements in air travel, even a doubling in the cost per litre of fuel due to use of renewable energy would be balanced by the fuel efficiency improvements, so that overall travel cost would not change much. Indeed, given the importance of fuel volume and the long lives of modern planes, it may well prove worthwhile for airlines to pay extra to process renewable fuels such as biogas or alcohols into synthetic aviation fuel, despite the energy and financial costs involved.

7. Energy Supply

Many energy analysts paint pictures of widespread use of nuclear power and ongoing dependence on large scale fossil fuel use. Underpinning these visions of our energy supply future is the belief that future energy requirements will continue to grow indefinitely, and that the efficiency of delivery of services for which energy is required as an input will improve only marginally. For example, if we project present transport fuel use into the future, biofuels will not be able to play more than a minor role because of resource limits. But if dramatic fuel efficiency improvements occur, and demand for conventional transport moderates as society and technology evolve, so that many of the services now provided by transport are provided in other ways, biofuels offer the potential to provide sufficient fuel for all Australia's road transport requirements.

Similarly, those who see a nuclear or coal-fired future assume that future households and businesses will continue to require as much electricity as today's homes, offices and factories per person or per unit of economic activity. Tomorrow's technologies (and indeed, many that are already available) will allow the amount of energy required to provide services to be dramatically reduced. As discussed in the *residential* section of this paper, these changes will lead to serious questioning of the economics of conventional large scale centralised energy supply systems: we just won't need them. Modular interactive energy systems will be cheaper and more reliable for most purposes.

At the same time, choices Australians make about their lifestyles and the energy options they use will have enduring impacts on both the amount and types of energy they use to satisfy their energy service requirements. A society that lives in enormous houses, commutes long distances and continues to consume large quantities of non-renewable materials and resources will not be consistent with the relatively benign energy future scenario this paper maps out – although application of technology would still make a remarkable difference to its long term viability.

8. Water

As noted earlier in this paper, with climate change it is likely that many parts of Australia will become drier. It is likely that within 200 years, water efficiency will need to improve in all sectors, and that reprocessing and desalination of water will be more common.

For households, desalination or water treatment is likely to be a relatively modest energy requirement. Present technologies can desalinate water using around 5 kilowatt-hours per litre. An average Australian uses around 275 litres per day around the home, and this would require 1.4 kilowatt-hours per person per day (500 kWh per year) to produce. With improved water efficiency and use of waste water for gardens, etc, as well as improvements in desalination efficiency, both the quantity of water and the energy requirement would be much reduced.

Household water comprises only a small proportion of Australian water usage, with most being used for agriculture. So if more widespread desalination or water processing is required for agriculture and industry, the energy cost could be very substantial. And since farmers pay very low prices for water now, they would see large cost increases, which would drive them towards extreme water efficiency and require decisions to be made regarding the types of agriculture pursued in Australia.

9. Recreation and Lifestyles

A typical speedboat is a heavy user of fuel, with fuel consumption typically from 1 to 5 kilometres per litre. In comparison, a sailboat uses almost no fuel. Many people think little of driving 500 kilometres to go skiing for a weekend. As sport becomes increasingly national, large numbers of enthusiasts travel around Australia following their teams. The energy use of international air travel has been discussed earlier. Watching DVDs with headphones and 3-D glasses or gardening are, in comparison, low energy activities. So the choices people make about their recreational activities will have potentially large impacts on energy use. But how people might spend their time in 200 years is difficult to predict. However, if the real costs and impacts of different recreational activities are signalled to their participants, there is potential to direct activity towards sustainable paths.

10. Conclusion

The reality is that Australians have a range of demand side and supply side energy options, all of which can help to satisfy our future energy service requirements, and are or can be made cost-effective. The choices we make regarding energy will either consciously or unconsciously involve assumptions relating to our culture and personal priorities. External factors such as climate change, the resource constraints of our old and weathered continent, and our relationships with the rest of the world will also shape our energy future. There is no reason why the Australia of two hundred years from now cannot provide for its energy service requirements sustainably. But there is no guarantee that this will be the case.

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Figure 1. Energy's role in delivery of services [21]

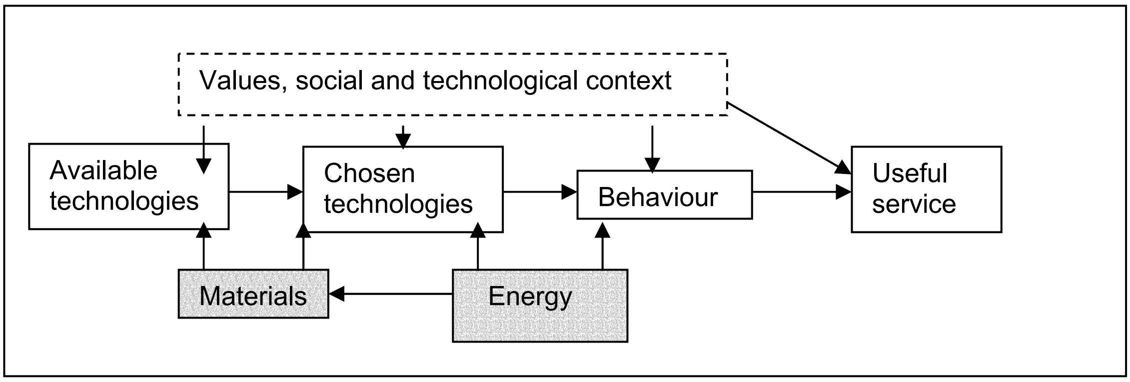

Figure 2. Trends in shares of Australia's GDP [1]

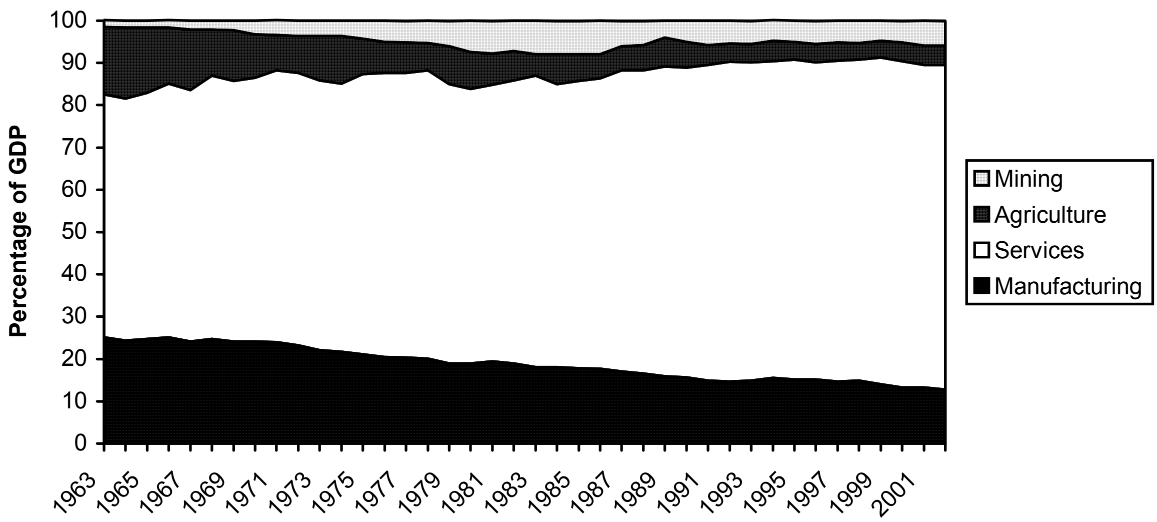

Figure 3. Australian residential sector energy and electricity use by activity 1999. Total energy use 381 PJ, electricity use 170.6 PJ [4]. This compares with 1973-74 residential energy use of 231.4 PJ and electricity use of 71.1 PJ [22].

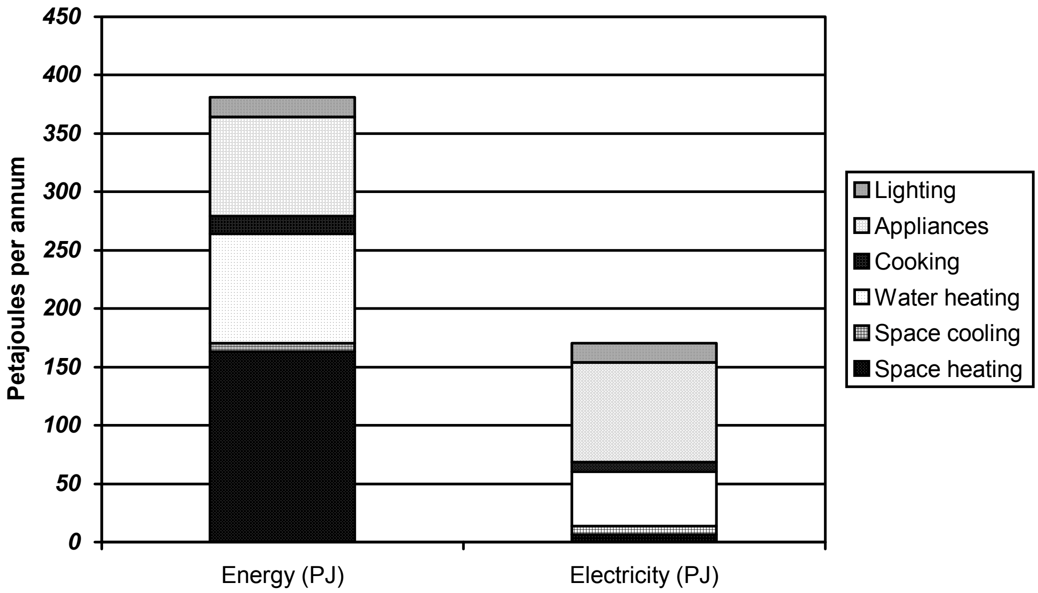

Figure 4. Operating Power Consumption Performance for Different Television Types [9]

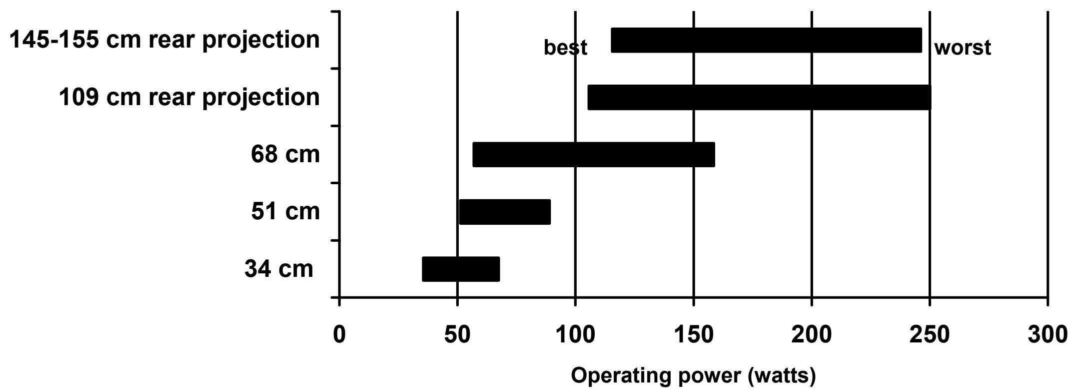

Figure 5. Australian commercial sector energy and electricity use by sub-sector, 1973-74 and 1998-99. [22], [23]

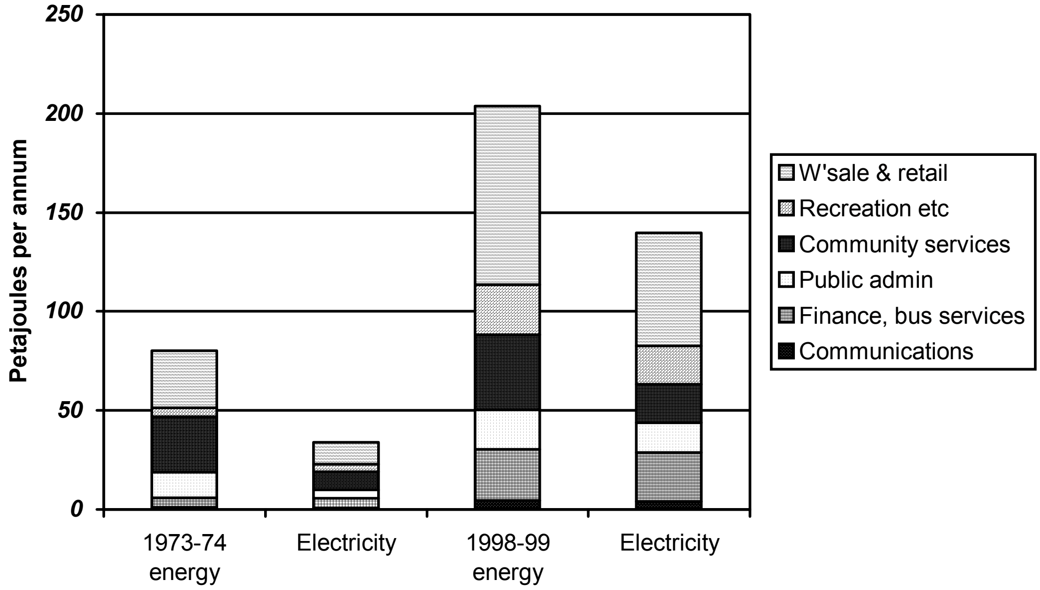

Figure 6. Australian commercial sector energy and electricity use by activity, Australia 1998-99 [4]

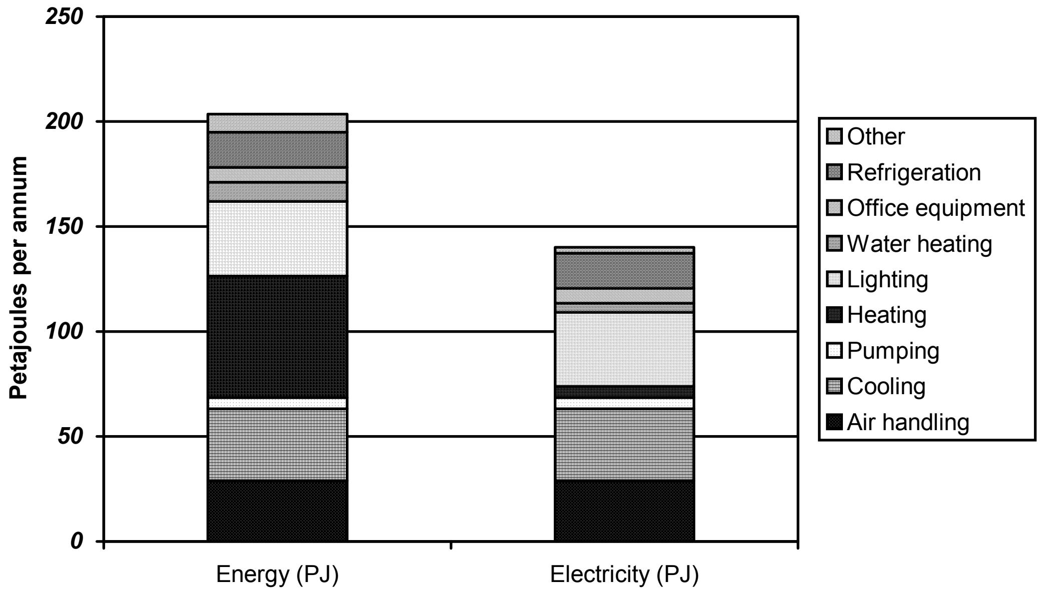

Figure 7. Australian industrial energy and electricity use by sub-sector, 1973-74 and 1998-99 [22].

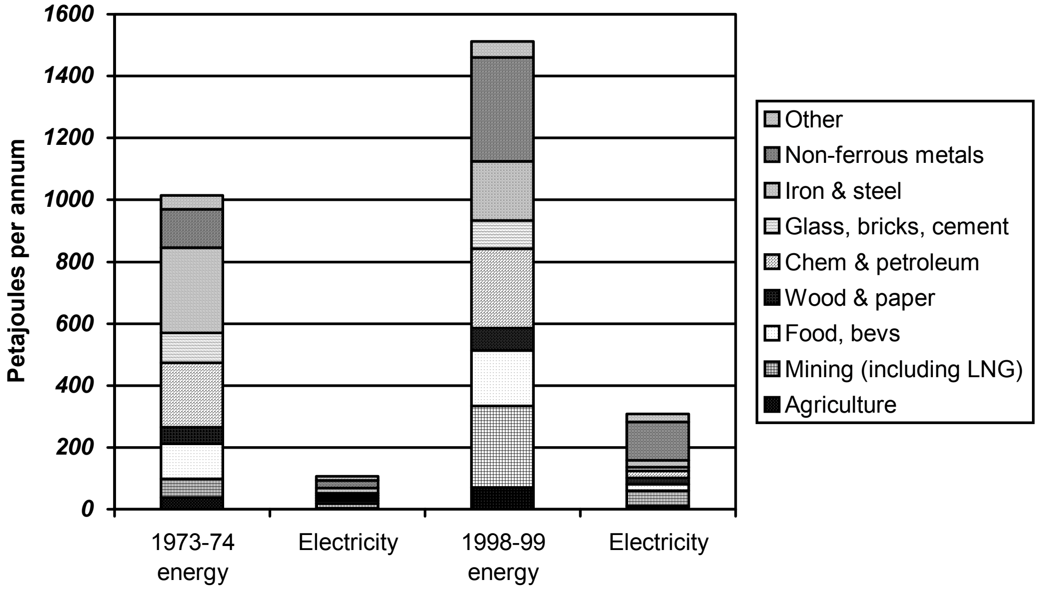

Figure 8. Australian industrial energy and electricity use by activity 1999, excluding some mining and petroleum processing [4]

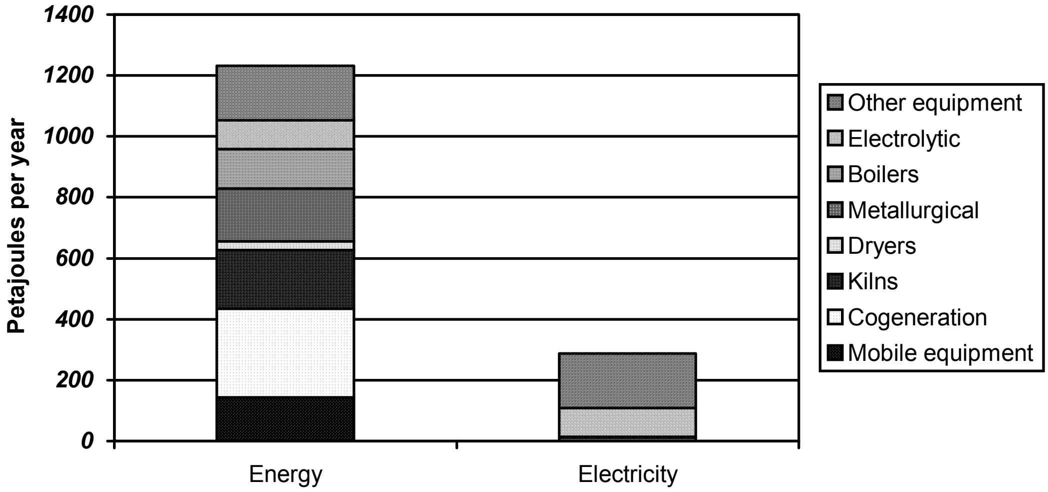

Figure 9. Recent trends and Business As Usual projections for transport energy-related greenhouse gas emissions, Australia [24]

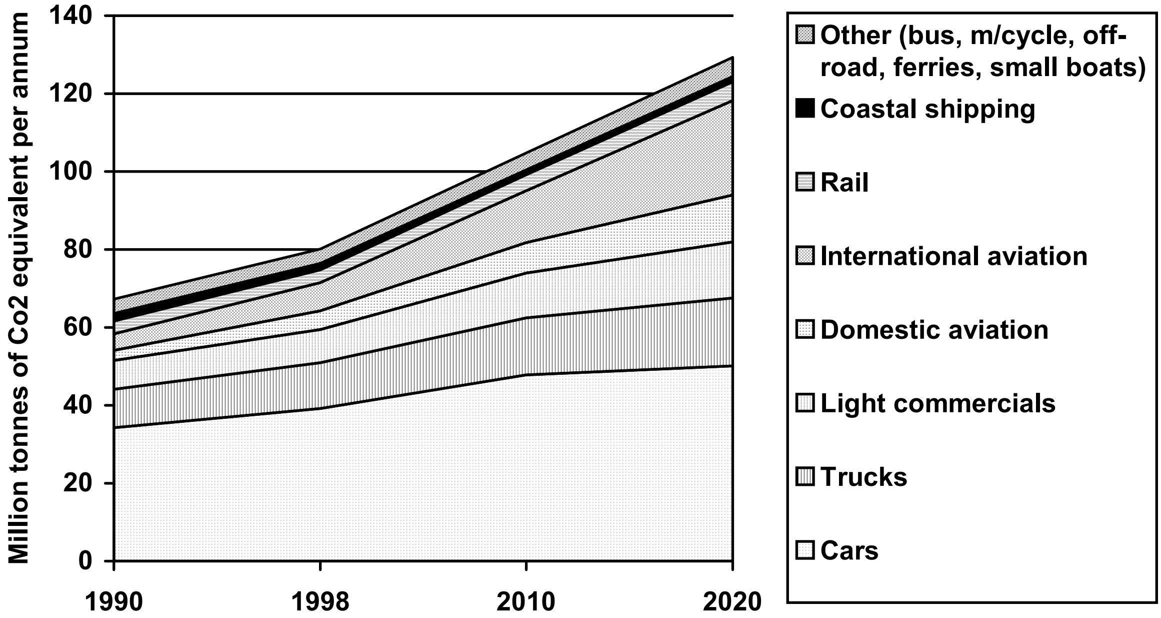

Figure 10. Australian domestic freight task 1999 [4]