5. Energy and the economy

5.1. Economy wide trends in energy intensity over recent years

Notwithstanding the strictures about using past relationships to describe the future, which we made in Chapter 2, an understanding of the current and recent past relationships between economic activity and energy use by different sectors of the economy is an important starting point for thinking about what might occur in the future. We have drawn on a study which the Commonwealth Government commissioned from the IEA (Schipper *et al*., 2001) that examines the relationships between energy use and economic activity in Australia from 1974 to 1995, and on a more recent study by ABARE (Tedesco and Thorpe, 2003). We have supplemented these studies with our own analysis.

Table 5.1 shows trends in aggregate energy intensity, i.e. energy use per unit of value added, for the period 1993-94 to 2000-01. The analysis is performed at the ANZSIC Division level (for Manufacturing at the 2 digit sub-Division level)

Table 5.1: Sectoral trends in Australian energy intensity, 1993-94 to 2000-01

	ANZSIC economic sector	Energy intensity 2001 (TJ/$M value added)	Average annual intensity change 1994 to 2001 (%)
Div B	Mining	7.92	1.2%
	Manufacturing		
21	Food, beverages, tobacco	11.45	-1.5%
23	Wood and paper products	13.89	0.1%
25	Petroleum and chemicals incl. oil refining	27.17	-1.6%
26	Non-metallic mineral products	22.42	-1.8%
27	Metal products	46.86	0.7%
22, 24, 28, 29	All other manufacturing	1.58	-1.1%
Div C	All manufacturing	16.24	-1.1%
Div E	Construction	1.46	0.2%
37, Divs F, G, H, J,K, L, M, N, O, P, Q	Commercial/Services	0.64	-0.3%
Div A	Agriculture/Forestry/Fishing	3.31	-1.8%
	Ownership of dwellings	6.66	-1.8%
	Total of above sectors, i.e. economy excluding electricity generation and transport	3.91	-1.9%
	Whole economy (primary energy)	7.53	-1.2%

The ABARE study provides a more sophisticated analysis of energy intensity trends, using the so-called factorisation approach, which provides insights into the underlying processes which explain the trends. This analysis separates a change in aggregate energy intensity over a given period into two components:

- the structural effect, meaning changes attributable to changes in the relative shares in total production of less and more energy intensive economic sectors, and
- the real intensity effect, meaning changes occurring within component sectors.

The most recent ABARE analysis of trends in Australian energy intensity (Tedesco and Thorpe, 2003) used a similar sectoral disaggregation of economy as for this study, as defined above. The results reported for the period 1994-95 to 2000-01 are as follows:

Aggregate intensity effect	-1.7% p.a.
Structural effect	-1.8% p.a.
Real intensity effect	+0.2% p.a.

What this means is that, over the period analysed, aggregate energy intensity decreased at a significant rate, but that changes in the relative shares of total economic output between sectors at this level more than account for the observed change in aggregate energy intensity. In other words, there was shift within the economy towards a greater emphasis on sectors which are inherently less energy intensive, such as services, and away, in relative terms, from more energy intensive sectors, such as chemicals and metal processing. Changes within each sector, including "pure" technical efficiency of energy use, actually contributed to increasing energy consumption. However, this does not necessarily mean that within each sector the efficiency of energy use actually decreased. It could equally be explained by a reallocation within individual sectors, at the level the analysis was performed, resulting in shifts from less energy intensive to more energy intensive component sub-sectors. Alternatively, or in addition, if prices (and resulting value added) per unit of output decline, then real intensity increases (as discussed later).

Our analysis found that for the same period as ABARE used, i.e. 1994-95 to 2000-01, the energy intensity change for the whole economy, i.e. aggregate energy intensity of the Australian economy, was -1.4% p.a.. The difference between this figure and ABARE's estimate of -1.7% p.a. appears to be attributable to the fact that ABARE uses a composite measure of overall production which differs from GDP, whereas this study simply used GDP.

The ABARE study goes on to analyse trends in final energy consumption, meaning consumption by sectors excluding the major energy conversion industries (mainly electricity generation, oil refining and gas supply). The results show a significantly larger decrease in aggregate energy intensity, with both the structural effect (changes between sectors) and the real intensity effect (changes within sectors) contributing to the decrease. Thus the overall result for total energy consumption of an increase in real energy intensity can be explained by a major shift in fuel mix towards electricity, which is very technically efficient at the point of use, but not particularly technically efficient (in terms of the first Law of Thermodynamics) at the point of generation and through the transmission and distribution system. The electricity sector itself showed a large positive change in energy intensity, i.e. energy consumption per dollar of output value increased at a large rate. This reflects increased use of old, less efficient coal plant at the expense of hydro and more efficient gas plant, such as Melbourne's Newport power station.

These results from the ABARE study are entirely consistent with the data shown in Table 5.1 above. This shows that the energy intensity of all stationary combustion final consumption sectors, representing final demand for energy services, decreased by 1.9% p.a. over the study period, while the energy intensity of the economy as a whole decreased by only 1.2% p.a.. Given that economic output as a whole over the period grew at 4.0% p.a., this result means that final demand for energy services grew at little more than half the rate of overall economic growth. It is also noteworthy that total energy use per head of population grew at an average annual rate of 1.5% over the period analysed.

For the purpose of understanding the processes which may determine future demand for energy services, further examination of the individual sectors shown in Table 5.1 is required, in an attempt to determine whether the sectoral intensity changes that occurred can be explained by structural changes at the sub-sectoral level, by real changes in the technical efficiency of energy use, by a combination of these effects, or by other factors.

5.2. Analysis of individual sectors

Mining: In this sector energy consumption grew faster than value added, and as a result the energy intensity of the sector increased by 1.2% p.a.. The output of the mining sector is various minerals, mineral ores and concentrates, which are sold as commodities, partly into domestic markets but mainly into export markets, at prices mainly set in global markets. One explanation for the observed trend in energy intensity could be a relative deterioration in commodity prices. To test this hypothesis, average export commodity prices in 1994 and 2001 (measured as total value of exports divided by total volume) were examined for Australia's seven most valuable export commodities, excluding crude oil. These commodities are coking coal, steaming coal, iron ore, gold, LNG, zinc concentrates and diamonds. Crude oil was excluded from the analysis because prices contain a very large component of tax and are therefore not a good proxy for value of production and, furthermore, crude oil production is not an energy intensive process and therefore makes only a minor contribution to energy consumption by this sector. The weighted (by 1994 production export value) average real change in unit prices for these seven commodities was found to be –0.1% p.a.. What this means is that the large increase in sector value added (4.3% p.a.) was more than achieved by an increase in the volume of output, with price changes making a small negative contribution. For the production of mineral commodities, an increase in production volume will require an increase in energy consumption, other things being equal. The progressive move over time towards lower grade resources, as the highest grade, lowest course resources are exploited first, will also tend to increase energy consumption per unit of output. Such trends are not sustainable over the long term. It is probable that this trend can also be partly explained by an increase, relative to the rest of the sector, in the output of natural gas and LNG production, which are very energy intensive activities. However, value added data on these industries is not separately available, so it is difficult to be certain. For this study we assume that there will be some continuation of the trend of increasing energy intensity for mining, other than natural gas and LNG production, which we model separately. We model this by assuming that, in the absence of efficiency improvements, energy consumption grows 0.5% p.a. faster than sector value added.

Food beverages and tobacco. This sector includes the sugar milling industry, which uses very large quantities of bagasse (crushed sugar cane residue) as a boiler fuel at very low thermodynamic efficiency. An estimate was made of the energy intensity of sugar milling, assuming that bagasse is the only source of energy. This understates energy consumption, because the industry also uses modest quantities of coal and fuel oil as boiler fuels, and also purchases some electricity. Even so, the energy intensity of this industry was found to be nearly 400 TJ/$M value added, which is much higher than any of the major sectors shown in Table 5.1.

The balance of the food, beverages and tobacco sector, without sugar milling, was much less energy intensive (5.1 TJ/$M value added, which is less than the economy average) but the trend in intensity over time was unchanged at -1.5% p.a.. In this sector, most energy consumption is associated with cooking processes, mostly using low temperature process steam, and, in some cases, subsequent refrigeration. Natural gas, coal and LPG are all used as boiler fuels and the sector also uses significant quantity of electricity for a variety of functions. The total quantity of energy required will be largely related to the quantity of food that is cooked, refrigerated, frozen or dried, and not to the complexity or sophistication of the preparation and cooking processes themselves, within each type of process. Noting that exports account for a relatively small proportion of the output of this sector, it was hypothesised that energy consumption may be more closely related to total population than to the value added in the sector. This was found to be the case; energy use per head of population declined by a modest 0.1% p.a., whereas energy intensity declined by 1.5% p.a.. What this result suggests is that in this sector the increase in value added is attributable to more valuable products, and more than offsets any increase in energy intensive processing which may also be occurring. The shift in the beer market away from mass brands and towards premium brands may be an example of this process, where there is a decrease in energy efficiency, through use of smaller plants, but it is more than offset by the higher margin on the premium brands.

It is possible that the future of this sector may see strong growth in high value exports, partly replacing some unprocessed resource exports, and thus weakening the link between population and activity, but we have not explicitly allowed for this in our projection. Accordingly, output for this sector is assumed to grow at the same average rate as GDP, i.e. 3.1% p.a.. By contrast, our energy projections are based on an average population growth rate of only 0.68% p.a.. Having regard to these considerations, we assume that energy intensity will continue to decline at an average rate of 1.5% p.a.. We also analyse the sugar industry separately. Having regard to the difficult outlook for this industry, we assume that physical output, and hence the availability of bagasse as fuel, will grow by 0.5% p.a. over the study period.

Wood and paper products. Value added in this industry sector divides roughly equally between sawmilling and timber product manufacturing on the one hand and paper and paper product manufacturing on the other. The latter is an energy intensive process, using large quantities of thermal energy, mainly as steam, in the processes that are required to separate the cellulose fibres, of which paper consists, from the other constituents of wood. Some of the boiler fuel required is sourced from the waste biomass streams containing these other constituents (termed black liquor) and some from wood processing residues. Natural gas and coal are also important boiler fuels in this sector. The sector hosts several cogeneration plants and has the potential to support a number of others, including some very large installations. Energy intensity of this sector has remained virtually unchanged over the analysis period. During the period some older, and presumably less technically efficient paper mills have closed and some new ones have opened. Sub-sectoral value added data are not available for the whole analysis period, but over the three years to 2001 the available data show that the more energy intensive paper manufacturing sub-sectors grew much faster than timber product manufacturing. This suggests that there has been a real increase in the technical efficiency of energy use in the sector overall. Increased use of recycled paper may be contributing to this reduction in intensity. We have not undertaken the additional data collection and analysis needed to further explore these issues.

Chemicals. When oil refining is excluded from this sector, the remaining industries fall into two distinct groups, so far as their energy use is concerned. Basic chemical manufacturing includes the production of fertilisers, bulk plastic materials, industrial gases and other bulk chemicals. It is highly energy intensive (and also uses large additional quantities of fossil fuels as feedstocks, i.e. raw materials. Energy is used in a variety of ways, including process steam, higher temperature reactor vessels and gas turbine powered compressors. Natural gas and petroleum products (in some cases "waste" products from process reactions) are the major energy sources, with some use of coal as a boiler fuel. There is some use of electricity in electrolytic production processes, as well as the usual consumption in a wide variety of electric motor applications. The Basic chemicals sector hosts several cogeneration installations, including one very large plant, and has the potential to support more.

All remaining chemical manufacturing includes the production, largely from raw materials produced in the Basic chemicals sub-sector, of such products as paints, detergents, explosives, pharmaceuticals and cosmetics, none of which is particularly energy intensive. This latter group of activities account for three quarters of the value added, but less than one quarter of the energy use, and thus has an energy intensity which is less than one tenth that of the Basic chemicals sub-sector.

Overall, the industry supplies largely a domestic market, with relatively little of its output being exported. For nearly thirty years there has been talk of the potential for establishing a large scale, export oriented basic chemicals industry, using Australia's natural gas as raw material. The first such project is finally being built – a worldscale plant to produce ammonia for export, located on the Burrup Peninsula in WA, near the North West Shelf LNG plant. Our projection assumes that in broad terms the historic experience will continue, as natural gas resources are used preferentially to supply growing domestic and export (as LNG) energy market demands, and very few new export chemical plants. This means that growth of the chemicals industry will be aligned with the growth in the Australian economy.

The output of the sector grew only slowly over the analysis period. Energy consumption grew somewhat faster, with the result that energy intensity also increased at about 1% p.a.. Sub-sectoral value added data is available only from 1997-98. Analysis of the three year period to 2001 is interesting but not conclusive. Energy intensity of the Basic chemicals sub-sector decreased appreciably, while that of the remaining sub-sectors was unchanged. However, the Basic chemicals sub-sector increased its share of total value added with the result that overall energy intensity increased. This is a very clear example of how sub-sectoral structural shifts can be entirely responsible for what looks like a real intensity change at a higher level of aggregation. However, this is a trend that cannot continue over the long term in the absence of major export markets for basic chemical products. In fact, the opposite trend towards more value added products, as in other sectors of manufacturing, is considered to be more likely. Accordingly, we project a long term structural decline in intensity of 1% p.a..

Non-metallic mineral products. This is an energy intensive sector of manufacturing which mainly uses high temperature thermal energy in kilns and furnaces. It includes the production of glass and glass products, cement and lime, plaster and plaster products, concrete and concrete products, ceramics of all kinds (bricks, tiles, pipes, tableware) and other similar products. The cement industry includes some kilns fired with coal and some with natural gas. Natural gas is the dominant fuel in the rest of the sector. With no significant use of steam, this industry sector has negligible capacity to support conventional cogeneration, though use of so-called bottoming cycle installations (see Chapter 8) would be technically possible. Most major sub-sectors are broadly similar in terms of energy intensity, the main exceptions being production of concrete and plaster products. Over the period of analysis, energy intensity has fallen by an average of 1.8%p.a.. It is likely that this reflects a mix of shifting to more value added products and increases in technical energy efficiency, with the latter mainly occurring through the shutting down of older, less technically efficient plant. We assume that this trend will continue.

Basic metal products. Most of the energy used in this sector is accounted for by the production of steel, alumina and aluminium. Aluminium in particular is the most energy intensive major sub-sector within this sector, in terms of both MJ/$ value added and MJ/tonne produced. Steam, high temperature thermal and electrolytic processes are all used extensively, with the choice of process determined by the chemical properties of the metal being produced. Most value added and most energy use is accounted for by the production of steel, alumina and aluminium metal. The main fuel used in steel production is coke which, as in other metallurgical processes, is used in blast furnaces where it functions as a chemical reductant of the metal ores. Natural gas is used as a reductant in BHP-Billiton's hot briquetted iron plant, and also as a supplementary fuel in blast furnaces and in re-heating processes. Electricity is used to produce steel from scrap and iron briquettes in electric arc furnaces. World wide, there is a significant trend away from blast furnace production (so-called integrated steelworks) and towards the use of directly reduced iron and electric arc furnaces. The production of alumina requires the use of both steam and high temperature process heat (in calcining kilns). Four of the current six alumina plants in Australia use natural gas for both processes, one uses coal as boiler fuel and gas for calcining, and one uses fuel oil for both purposes. All six support cogeneration installations and there is potential for a considerable increase in capacity. The production of aluminium metal uses an electrolytic process and Australia's six aluminium smelters currently account for over 20% of Australia's end use consumption of electricity.

Production of aluminium metal has grown at nearly 5% p.a. over the analysis period, average export price by over 5% p.a., and the volume and price of alumina nearly as rapidly also. Thus the increase in energy intensity for the sector as a whole can be explained by sub-sectoral shifts within the sector towards the more energy intensive aluminium metal sector and away from other, less energy intensive production of other metals, which include steel and non-ferrous metals such as copper, nickel and zinc. Data are insufficient to estimate with any certainty the underlying trends in technical energy efficiency within the sector. However, the fact that production of all the major non-ferrous metals increased much faster than total energy consumption over the analysis period indicates an underlying trend of increased technical efficiency. We assume that technical efficiency in non-ferrous metals production will increase by 1.0% p.a..

In the case of steel production, both output and energy use fell, but energy use fell faster, by about 0.6%, again consistent with an underlying increase in technical efficiency. However, the closure of the Newcastle steelworks, the oldest and least efficient in Australia, occurred during this period, which would have affected overall energy efficiency. We assume continuing improvement in technical efficiency of iron and steel production of 0.3% p.a..

All other manufacturing. All the remaining sectors of manufacturing industry are what is often termed elaborately transformed manufactures; they include the manufacture of textiles and clothing, machinery and equipment of all kinds, and all types of household goods. None of these activities are particularly energy intensive. Electricity is the most important energy source used. In terms of value added these sectors account for about 40% of all manufacturing, and are growing faster than manufacturing as a whole. Energy intensity has declined at about 1% p.a. since 1994. However, further disaggregation shows that part of this change can be explained by a structural shift away from the Textiles, clothing and footwear sector, which is more energy intensive than the other sectors, and has been becoming more so, while its already small relative size in terms of value added (only about 10% of this whole group of sectors) has decreased. When this effect is corrected, it is found that the energy intensity of the remaining sectors has decreased at an average 0.9% p.a.. We assume that this is a real intensity (efficiency) effect.

Construction. Almost all energy use in this sector occurs in various types of off road mobile equipment, such as earth moving equipment. Petroleum products, particularly diesel fuel, are the main fuel used. The sector is not particularly energy intensive, but intensity has increased slightly over recent years, as the sector has grown more slowly than the economy as a whole. This may be caused by a trend towards more mechanised, larger scale construction methods, or by more productive use of other inputs, leading to relatively lower prices.

Agriculture, Forestry and Fishing. This sector also uses predominantly diesel fuel in off-road mobile equipment such as tractors, harvesters, logging equipment and fishing boats. Electricity is used for water pumping and other stationary farm machinery. Energy intensity varies considerably between activities, with cropping activities that involve ploughing being relatively energy intensive, particularly when yields per hectare are low. Overall energy intensity has fallen at nearly 2% p.a., with energy consumption growing at only about half the rate of output. This trend could be explained both by increased technical efficiency of energy use, e.g. by a shift towards minimum tillage cropping, and by a shift to higher value added outputs. We expect that environmental and other factors will mean that Australian agriculture continues to shift away from broad scale cropping and towards higher value added activities, and therefore project, with output growing at 2.32% p.a. on average, an average fall in intensity of 1.2% p.a..

Commercial and service industries. This is a composite sector comprising all of the so-called service sector industries, which in the ANZSIC classification account for eleven different Divisions (Divisions F, G, H, J, K, L, M, N, O, P, Q). Altogether they account for just over 7% of total final energy use (12% of final stationary energy consumption). On the other hand, these sectors account for over half of total GDP, and thus are clearly not energy intensive. However, their importance in terms of energy policy is greater than these figures would suggest, firstly because they are growing faster than the rest of the economy and secondly because electricity accounts for a large (almost 70%) and growing share of total energy use. In fact, these sectors account for as much electricity consumption (about one quarter) as the basic metal manufacturing sector.

The best public estimate of the types of activities for which energy is used derives from work originally done from a 1990 baseline (EMET Consultants and Solarch Group, 1999), since updated to a 2000 baseline (Pupilli 2002)which is shown in Table 5.2. It can be seen that nearly two thirds of all energy is used for the heating, cooling and ventilation of buildings, with lighting accounting for a further 18%. The use of office equipment accounts for a quite modest share of total consumption; some commentators believe it may be growing more rapidly than other activities, but this is not borne out by the EMET/Pupilli data. Natural gas is the main fuel used for space heating, water heating and cooking, while use of electricity dominates all other activities. There are a number of small-scale cogeneration installations in this sector, particularly at hospitals, which have a steam load, unlike most of the rest of the sector. There is great potential for far more extensive use of small scale cogeneration, as discussed in Chapter 8, but it is not financially attractive at current electricity and gas prices, and with presently available technology. However, technology trends, institutional change and increasing summer peak electricity charges could well drive change.

Table 5.2: Energy use by activity in the commercial and services sector

Activity	Share of total energy use
Air handling	15%
Space cooling	18%
Space heating	32%
Pumping	3%
Water heating, cooking etc.	6%
Lighting	18%
Other	8%

Energy intensity fell slightly (-0.3% p.a.) over the analysis period, but total energy use grew rapidly. Our baseline projection assumes that this trend in energy intensity was attributable to technical efficiency, and will continue. A “no change” structural effect trend has been assumed.

We have modelled a continuing trend towards greater use of electricity and relatively less use of other fuels, which can be attributed to increasing use of a continually widening diversity of electrical and electronic office equipment. This has been done by assuming a differential structural change effect, with structural change causing the energy intensity of “all other” energy use to increase by 0.9% p.a. and the energy intensity of all other categories of energy use to fall by 0.2% p.a., giving an overall “no change” structural effect.

Residential sector. In terms of energy use, the residential sector is defined to comprise all energy using activities which people undertake in their homes and gardens. It does not include private use of motor vehicles, boats, aircraft or public transport. The residential sector, defined in these terms, does not form part of the system of national accounts, as private citizens are defined as consumers, rather than as producers contributing to national economic production. However, GDP does contain a sector termed Ownership of dwellings, which includes an estimate of imputed rent for owner-occupiers.

A model which allocated residential energy use between the major types of energy using activity was developed by Energy Efficient Strategies *et al*. (1999) for a 1997 baseline, and is shown in Table 5.3. The main energy sources used in the residential sector are electricity and natural gas. As with the commercial/services sector, the use of electricity is increasing faster than overall use of energy, i.e. the sector is becoming more electricity intensive. Electricity is used for all four major activities and is the most important source of energy for all but space heating and cooling.

Natural gas is the main energy source for space heating, and second to electricity for water heating and cooking. ABARE estimates that the residential sector uses a very large quantity of biomass fuel (fuel wood) for space heating. Many analysts consider that the ABARE estimate is overstated. Energy Efficient Strategies *et al*. (1999) estimate fuel wood consumption to be about half the ABARE figure, setting it at 44 PJ for 1999, compared with 81 PJ by ABARE. We use the latter estimate as the basis for the figures in Table 5.3, and throughout this study. On the other hand, ABARE data includes an estimate of the energy supplied by solar water heaters, which is put at 4.3 PJ in 2001. Adding this quantity of energy to the total would increase the share of water heating to 28%.

Table 5.3: Energy use by activity in the residential sector

Activity	Share of total energy use
Electric appliances etc.	29%
Water heating	27%
Cooking	4%
Space heating and cooling	39%

If the estimate of economic output attributed to ownership of dwellings is taken as a measure of economic activity associated with the residential sector, then the energy intensity of the sector appears to fall over the analysis period by an average of 1.8% p.a.. This could be interpreted as evidence that the sector is becoming more technically efficient, as might be expected given the achievements in appliance energy efficiency and the strengthening of requirements for improved thermal energy performance of new houses (see Chapter 6). Offsetting these trends has been increased adoption of residential air conditioning (cooling) and of inefficient low voltage halogen lighting.

Another way of looking at residential energy consumption is to relate it to total household final consumption expenditure, which, over the long term, can be expected to grow at the same rate as GDP. Over the seven year analysis period, GDP grew at an average rate of 4.0% p.a., while residential energy consumption grew at an average rate of 2.1% p.a., representing an average fall in energy intensity of 1.8% p.a.. This difference can be interpreted as either an actual increase in technical energy efficiency, as described above, or as a structural change in which some of the increase in household consumption is due to expenditures which do not increase energy consumption in the home, e.g. overseas holidays. Probably both are occurring. A further factor to consider is the decline in average household size, which in recent decades has tended to increase energy use per head of population, but in the future must eventually slow down and cease.

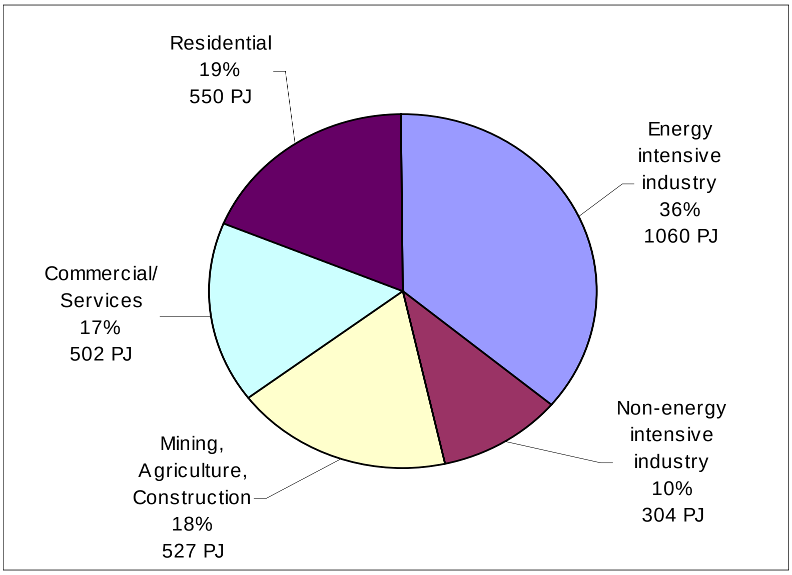
We expect this general trend to continue. Hence, while projecting future economic growth of 2.2% p.a., household energy consumption is projected to grow at 1.1% p.a. on average, representing a decline in energy intensity of 1.1% p.a., of which we attribute 0.5% to technical efficiency and 0.6% to structural change. Additionally, as for the Commercial/ Services sectors, we have modelled increasing ownership and use of a continually increasing diversity of electrical appliances and equipment by assuming a differential structural change effect. The energy intensity of electricity for electrical appliances etc. is assumed to be unchanged by structural change, while structural change causes the intensity of consumption of all other fuels to decline by 0.09% p.a. because of structural change. The combined effect is a structural change decrease of 0.06% p.a. for all energy applications.

5.3. Baseline energy demand

The assumptions about economic growth, structural change and trends in energy efficiency described in the preceding Sections of this Chapter have been used to generate what we call the Baseline final energy demand case in 2040 in the stationary energy sectors, meaning the demand for final energy which can be expected with the projected slight rise in energy costs, but no change in policy settings. Total demand is projected to reach 2,955 PJ in 2040, compared with 1,888 PJ in 2001. Related to population, this equates to an increase from 97 to 118 GJ per head. The increase, compared to the corresponding final demand for energy in 2001, is 57% in absolute terms and 21% in per capita terms. By contrast, economic activity, measured by GDP, is projected to increase more than twice as fast, by 140%. Demand for energy grows much more slowly than economic activity for the two reasons that have been explored throughout this Chapter: structural changes in the economy are progressively shifting economic activity towards less energy intensive activities, and many sectors can be expected to gradually increase their technical energy use efficiency, albeit at a rate much less (in most cases) than the economic optimum.

The distribution between major sectors is shown graphically in Figure 5.1, and more detail is provided in Table 5.4. As previously mentioned, this pattern of demand should be interpreted as the demand for energy which would result from the projected growth in economic activity, sector by sector, with no additional policies or other stimulus to increase the uptake of cost effective energy efficiency technologies.

Figure 5.1: Baseline stationary final energy demand by major sectoral group,



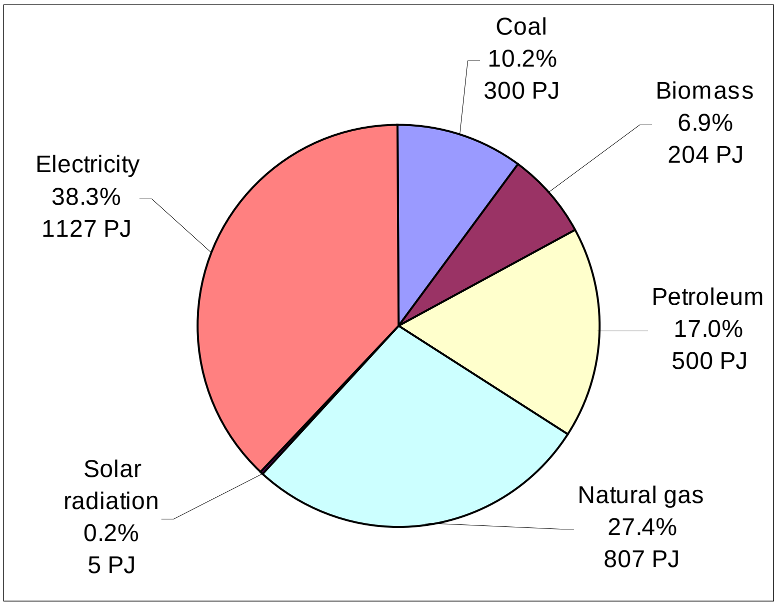
2040

Table 5.4: Baseline (BAU) stationary final demand for energy by sector, 2040 (PJ)

Economic sector	**Energy consumption (PJ)**	
Mining (incl. LNG and coal exports)	416	
Manufacturing	1,253	
Iron and steel		226
Food, beverages, tobacco		203
Basic chemicals		73
Cement, lime, plaster and concrete		63
All other non-metallic mineral products		76
Non-ferrous metals		412
Wood, paper and printing		100
All other manufacturing		100
Construction	117	
Commercial/Services	502	
Agriculture/Forestry/Fishing	104	
Residential	550	
TOTAL final stationary energy consumption	2,943	

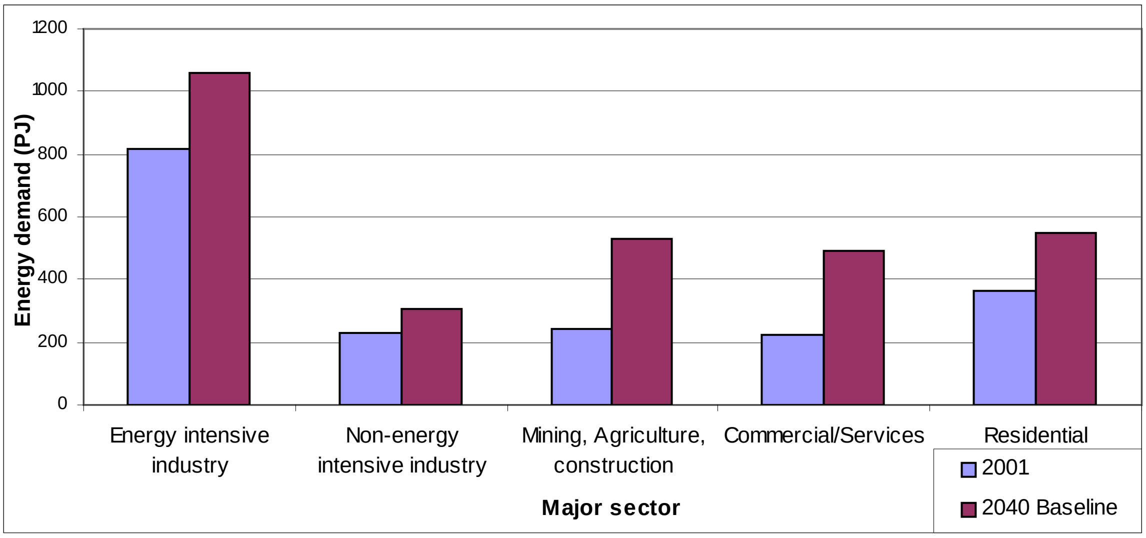
Figure 5.2 shows baseline final energy demand in terms of fuels.

Figure 5.2: Baseline stationary final energy demand by fuel, 2040



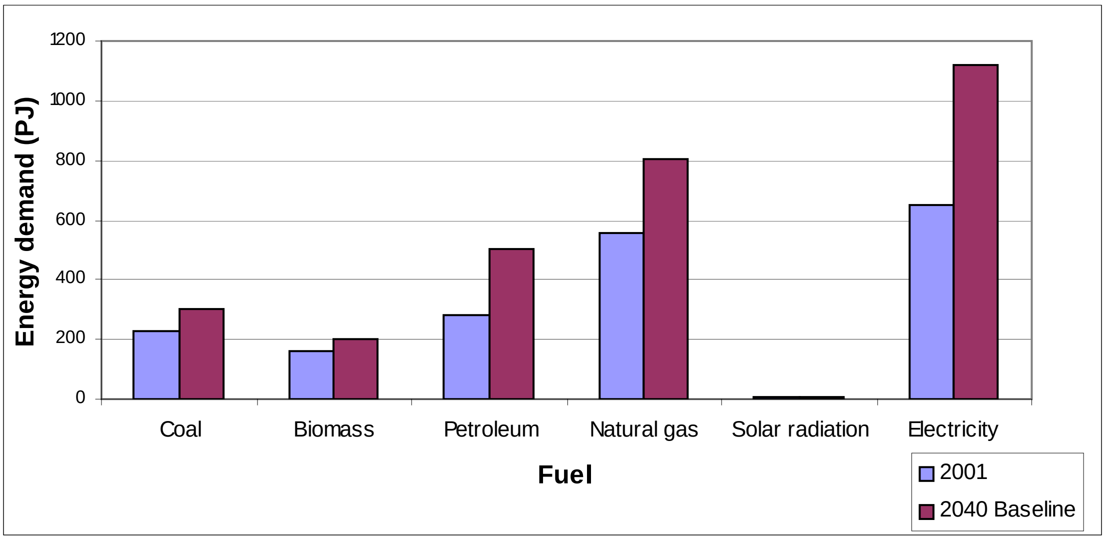
Figures 5.3 and 5.4 compare the projected baseline final demand for stationary energy in 2040 with actual 2001 final demand, by major sectoral group and by fuel.

Figure 5.3: Baseline final stationary energy demand by major sector, 2040



compared with 2001 (PJ)

Figure 5.4: Baseline final stationary energy demand by fuel 2040, compared with 2001 (PJ)



These comparisons show that energy demand from the Mining, Construction and Agriculture sectors and from the Commercial/Services sectors is projected to grow rapidly, more than doubling between 2001 and 2040. Considerably slower growth is projected for the Energy intensive industry and the Residential sectors, reflecting respectively the assumed slower growth for much of the former and the progressive decrease in energy intensity of the latter, as discussed earlier in this Chapter. The data appear to indicate that growth in demand for electricity from Non-energy intensive industry is also relatively slow. However, this is in part attributable to our assumed slow growth of the sugar industry, which forms part of Food, Beverages and Tobacco and uses very large quantities of biomass fuel at currently very low thermal efficiency. More rapid growth is projected for general manufacturing (roughly corresponding to elaborately transformed manufacturing), though total demand and energy intensity remain low.

The fuel mix depicted in Figure 5.4 shows a marked shift towards greater use of electricity, and, to a lesser extent, natural gas and petroleum. This shift is a consequence of the more rapid growth in demand from those sectors, such as Commercial/Services, which already have a high proportion of these fuels in their demand mix. The growth in demand for petroleum products is particularly attributable to the assumed high growth rates in the mining sector.

As described, most of our projections are based on exponential change factors from the 2001 patterns of energy demand by sector and fuel. For comparative purposes, we have constructed a linear interpolation between 2001 and our 2020 projection for the year 2021. At the low rates of change used in our modelling, the difference between linear and exponential interpolation is not great, but, as a generalisation, linear is consistent with slightly faster change in the earlier years and slower in the later years. This interpolation has been compared with ABARE’s projection of Australian energy supply and demand in 2020 (Dickson, Akmal and Thorpe, 2003). In order for the comparisons to be on the same basis, some adjustments had to be made to both sets of projections. The Clean Energy Future figures were adjusted by combining some sectors and by including the use of fossil fuels as chemical feedstocks and carbon anodes for aluminium production in the relevant sectors. The ABARE figures were adjusted by subtracting an estimate of energy used to mine coal for domestic supply from the Mining sector and by adding estimated energy used for LNG production to the same sector.

Table 5.5: Comparison of 2020 Baseline energy demand estimates between interpolation of this study (CEF) and ABARE

Economic sector	**Energy demand (PJ)**	
	CEF	**ABARE**
Mining (incl. LNG and coal exports)	300	484
Manufacturing	1223	1611
Iron and steel	202	329
Food, beverages, tobacco	183	Included with All other manuf.
Chemicals	163	185
Cement, lime, plaster and concrete	52	121
All other non-metallic mineral products	62	Included with All other manuf.
Non-ferrous metals	397	513
Wood, paper and printing	86	99
All other manufacturing	77	364
Construction	82	Included with All other manuf.
Commercial/Services	360	361
Agriculture/Forestry/Fishing	87	99
Residential	472	591
	2,525	3,146

The ABARE figures are significantly higher than the CEF figures. About 30 PJ of the difference is caused by the exclusion of fuel used in cogeneration from this study. However, most of the difference arises from a small number of easily identified differences in assumptions about the future.

- In the Mining sector, ABARE has much higher consumption of natural gas, which is attributable to its assumption of a very high level of LNG exports (growth by a factor of 4.2 from 2001 to 2020).

- In the Iron and Steel sector ABARE has much higher consumption of both coal and natural gas. This implies major expansion of both conventional (integrated) steel production, using coal and coke, and of directly reduced iron, using natural gas, presumably to supply export markets.

- In the Non-Ferrous Metals sector, ABARE has much higher consumption of natural gas and somewhat higher consumption of electricity, implying an assumption of higher growth in production of alumina, and, to a lesser extent, aluminium metal, plus some magnesium smelting (another exceptionally energy intensive process).

- In the Residential sector, ABARE has much higher consumption of both natural gas and electricity. This seems inconsistent with the rapidly spreading introduction of mandatory requirements for improved building envelope thermal performance (albeit much less than could be economically achieved – see Chapter 6), the similar rapid spread of Mandatory Energy Performance Standards for a wide range of residential equipment, and our view that the current “regulatory subsidy" for residential air conditioning simply cannot last. All of these considerations have been factored into our assumptions about the Residential sector.

Apart from these four differences, the ABARE projections are surprisingly close to our interpolated baseline projection for 2020.

In overall terms, the ABARE figures are equivalent to an increase of 48% in total stationary energy consumption and an increase of 40% in associated CO_2 emissions. Emissions increase less than energy consumption because of a decrease in the share of coal in electricity generation, and a corresponding increase in the shares of natural gas, biomass and, to a small degree, wind.

In Chapters 7 and 8 of this report we demonstrate that there is far greater potential than ABARE assumes for shifting the electricity supply mix towards low emission generation sources. In Chapter 6 we examine the extent to which the wider adoption of currently available, cost effective energy efficiency technology could further moderate growth in demand for energy across the economy.