6. Energy efficiency technologies and potential

6.1. Concepts and approaches to assessing the potential

Concepts and their application

Studies which seek to assess the potential for increased energy efficiency commonly make use of a three level definition of potential.

Technical potential represents the minimum consumption of energy for a given output of required energy services, irrespective of cost. In almost all situations, some of the possible improvements in technical energy efficiency will not be cost effective. Thus technical potential by itself is not a direct guide to what is achievable in practice. However, it is often very valuable as a tool for gaining better understanding of energy using processes and the potential for improving them significantly, and it is the ultimate indicator of what might be possible in the future if costs of the relevant energy efficiency technologies fall, which they usually will, and/or the cost of purchased energy rises.

Economic potential represents full adoption of all opportunities for improved energy efficiency that are cost effective, in the sense given above, at a discount rate which is appropriate, given the relatively risk-free nature of the investment. Most of the practical difficulties in applying this concept arise because the main element of the cost of energy efficiency is the capital investment required, while the main element in the offsetting savings is the recurrent cost of avoided energy purchases. Equating the two requires choosing what discount or return on investment rate to use and the break-even point is usually very sensitive to changes in the rate chosen.

If all the relevant economic agents used similar rates in their normal investment decisions, the choice would be simple. In practice, however, energy users almost always use high investment hurdle rates, or short payback periods (typically maximum 5 year payback and mostly 1-3 years), when deciding whether or not to invest in energy efficiency. These much higher rates take account of the high transaction costs, poor information and uncertainties faced by an individual investor in the present imperfect markets for energy services, and constitute one of the major market barriers or imperfections relating to energy efficiency. In contrast, government regulatory agencies use quite low rates, mostly in the range 8-10% real, in determining the prices they allow electricity and gas transmission and distribution businesses to charge. The average rates achieved by electricity generators and gas producers (the competitive parts of the energy supply industries) are not much greater.

Nationally, economic resources will be allocated with maximum efficiency if energy investment decisions use similar return on investment rates. Maximising economic efficiency also requires that costs of purchased energy be defined to include environmental and social externalities, if they have not already been internalised by policy actions, as has been done in this study. Naturally, the choice of a lower discount rate makes a big difference in the range of technologies which are assessed to be cost effective

The wide gap between the high discount rates used in practice by energy users and the much lower rates built into the prices of energy supplied, means that most of the unrealised opportunities for energy efficiency will yield rates of return somewhere between the two. It is only the relatively few marginal projects which will yield a return as low as that embodied in the prices of energy supplied. The average rate of return on increased energy efficiency will be much higher than the marginal rate or, to put it another way, the resource cost to the economy of the additional energy efficiency will be much lower than the resource cost of an equivalent increase in energy supply. This obviously has important consequences when comparing the total economic costs of scenarios that include different mixes of increased energy efficiency and expanded energy supply.

It is most important to recognise that at any particular point in time an energy user is likely to be in a situation where he or she is using a piece of energy using equipment which has not been fully amortised, i.e. still has both economic and technical life remaining, while at the same time being aware that if she or he were choosing new equipment it would be possible to make a cost effective decision to choose a newer, more efficient technology. In such circumstances, premature scrapping of the existing equipment would impose an economic cost, even though the new equipment would subsequently provide cost savings. As we have previously explained, by choosing a 40 year projection, we are able to achieve the full economic potential for energy efficiency, without the cost of any premature replacement of existing equipment. To allow for the turnover of household appliances, a 10 to 15 year period is generally sufficient.

Finally, note that it is the existence of various types of market failure in markets for energy services, usually causing individual decision makers to face high transaction costs when choosing energy efficient technologies, that make economic potential an important concept and a useful analytical tool, but not a description of reality. That is encompassed by the concept of market potential.

The **market potential** is a concept linked to economic modelling approaches to projecting energy futures. It is an estimate of the extent to which economic decision makers in each sector would actually take up the various available energy efficiency technologies. In other words, it is an attempt to represent the behaviour of economic agents within the context of the existing, highly defective markets for energy services. It can be estimated with no change in existing policies, in which case it is equivalent to a Business as Usual projection, or it can be estimated with one or more explicit policy changes that are assumed to influence the behaviour of the relevant economic agents. It is a complex, hard to define and frequently confusing construct, and one of the advantages of the scenario back-casting modelling approach that we are using is that there is no need to be concerned with the market potential for energy efficiency.

The market potential take-up of energy efficient technologies within a given policy environment is what drives autonomous energy efficiency improvement. As described in the previous Chapter, experience over recent years suggests that this varies greatly between economic sectors. In general endogenous energy efficiency improvement is larger in energy intensive sectors, where energy purchases are a larger component of total operating costs. This experience, which means that these sectors take up most energy efficiency opportunities as they arise, has been used, together with projected structural shifts within sectors, to generate the Baseline final energy demand structure summarised in Table 5.4.

Approach

Although it is much easier to assess the economic potential than the market potential of energy efficiency, it is still not easy. To do it thoroughly requires cost and performance data about hundreds of different technical options, together with similarly detailed data about the energy using equipment currently in place across all sectors of the economy. Self-evidently, this would be a very large task, greatly beyond the resources of this study. Moreover, most of the necessary data on stocks of energy using equipment are not available in Australia at the required level of detail.

Consequently, our assessment has been performed at a more generalised level. For the Residential and the Commercial/Services sectors we have drawn on relatively recent Australian studies which did undertake some of the required analysis and modelling. For other sectors, we have used published literature on the performance of a wide variety of energy efficiency technologies, together with the experience and achievements of government programs intended to promote adoption of energy efficiency, notably the former Energy Efficiency Best Practice program. For some particular industries, such as cement and alumina, the industries have themselves commissioned studies which provide considerable information about their current use of energy, and these have been used where available.

Our assessments assume that energy prices will have risen to the levels described in Section 2.2, which will have the effect of making economic a number of technical options which are not economic at current energy prices. We focus on using existing technologies, i.e. hardware, with continuing small improvements, but also assumes that policies, institutions, organisational structures and management practices are changed to ensure that best available, proven and cost effective technology is used when new investment decisions are made.

While falling short of the ideal, the approach we have taken is no less rigorous than previous general assessments of the Australian energy efficiency potential, and clearly more rigorous and detailed than most such assessments. We note that our estimates of the efficiency potential are in general conservative, i.e. smaller than those contained in the recently released discussion paper of the Energy Efficiency and Greenhouse Working Group of the Ministerial Council on Energy (2003), a joint Commonwealth and State/Territory government body.

6.2. Manufacturing

In assessing the potential for increased energy efficiency in manufacturing, we use a combination of specific assessments for selected sectors and generic equipment type assessment for the remaining sectors. In this Section, we discuss first the specific sectoral assessments and then turn to the generic equipment type assessments.

Sectoral assessments

Iron and Steel

In Australia most steel is produced at two integrated steel works, at Port Kembla and Whyalla. The term integrated steel works refers to the production of steel by the chemical reduction of iron ore to pig iron in a blast furnace, using coke (produced from coal in on-site coke ovens) as the reductant and principal source of thermal energy, followed by conversion of pig iron to steel in a steel furnace, which in all modern steel mills is a type called basic oxygen furnace. The steel is then rolled and formed into products.

Smaller quantities of steel are produced from scrap at several so-called mini-mills using electric arc furnaces. Around the world, electric arc furnaces are rapidly becoming the preferred technology for most new steel making investment, because their optimal economic size is much smaller than that of an integrated steel mill and the investment required is correspondingly much less, greatly reducing financial risks. These new mini-mills use both scrap and virgin metal in the form of so-called directly reduced iron (DRI). Although the process has been under development for some decades, commercial production of DRI is relatively new. Production of DRI usually occurs at completely separate locations from the subsequent production of steel, i.e. it is not integrated. Different proprietary DRI processes use different fossil fuels as reductant, not including coke, but natural gas is most commonly used. There is one commercial DRI plant in Australia, BHP-Billiton's plant in Western Australia, using its hot briquetted iron process.

The commissioning of this plant resulted in a significant increase in consumption of natural gas in iron and steel production in Australia. The production of DRI is essentially a way of adding significant value to Australia's current exports of iron ore, and a number of companies are exploring the possibility of building DRI plants to export DRI to mini-mills in Asia and elsewhere round the world.

Some analysts, including ABARE, expect that this will lead to rapid growth in the iron and steel sector in coming years, with concomitant increase in demand for natural gas. For this study, we have not assumed such growth, so that the assumed growth in the iron and steel sector of 42% represents growth in production for mainly domestic markets. We have also assumed no change in the current mix of plant types, with growth in output at the two integrated steel works, but no new integrated steel plant, and some new electric arc furnace capacity, possibly using DRI, but no additional export DRI plants. Hence the consumption of electricity in this sector remains relatively low and the consumption of coke relatively high, with significant consumption also of natural gas for DRI production.

Over the past two decades, the former BHP Steel (now BlueScope Steel and OneSteel) have made significant investments in technologies that increase energy efficiency. There are opportunities for further efficiency improvements, notably by making major investments in near net shape casting, together with increased recovery of energy from waste gases. Much of the potential for improvement in technical efficiency by these means are captured by the efficiency improvement trend included in the baseline improvement of 0.3% p.a.. We assume that greater emphasis on energy efficiency will result in improvements of a further 0.2% p.a..

Chemicals

Most major Australian chemical plants were first built several decades ago, though they have undergone progressive modifications. It is most unlikely that many of them will still be operating in 2040. In general, these plants are below “world scale” in size, meaning that they are smaller than the optimally efficient size. Over the past decades there have been some closures of Australian capacity, e.g. production of vinyl chloride monomer, the precursor of PVC, and some analysts expect that Australia may cease producing many other bulk petrochemicals. However, our projections assume that economic output of the sector as a whole will grow by 140%, and even allowing that there will be a shift towards the non-energy intensive value added parts of the industry, the assumption implies significant growth in production of basic chemicals. This must imply construction of new, more efficient plants.

General options for increasing energy efficiency in chemical production include:

- more efficient boilers and boiler systems,
- process optimisation through improved control systems,
- more effective catalysts, new and improved separation technologies,
- improved waste recovery and associated use of waste products as fuel.

The US Interlaboratory study (Interlaboratory Working Group, 2000) estimated that the technical energy efficiency of that country’s bulk chemicals sector could reduce energy intensity by 14% by 2020. The UK study (Jonathan Fisher *et al*., 1998) estimated that the technical energy efficiency of the British chemical industry could reduce energy consumption by 36% below BAU by 2020.

For this study, we have assumed a relatively modest improvement in the technical efficiency of the industry of 20% to 2040, which implies a 17% reduction in energy intensity.

Cement

The cement industry is a major user of high temperature process heat in kilns, in which limestone undergoes calcination (thermal decomposition to calcium oxide and CO_2). The current Australian cement industry comprises four large, relatively modern plants, accounting for about three quarters of total production, and a number of smaller, older and much less energy efficient plants. When these are shut down there will be an appreciable increase in the overall energy efficiency of the sector. Another important means to reduce energy consumption is greater use of so-called blended cements, in which clinker (the product of cement kilns) is mixed with one or more additives or extenders, such as fly ash or blast furnace slag. The use of blended cements is a particularly attractive efficiency option since the inter-grinding of clinker with other additives not only leads to a reduction in energy use (and carbon emissions) in clinker production, but also results in a concomitant reduction in carbon dioxide emissions in calcinations (which we are not modelling in this study).

There are also significant opportunities for further increases in technical energy efficiency, through changing the design of kilns to achieve greater recovery of waste heat. These include multi-stage pre-heater kilns and pre-calciner kilns (the latter alone is estimated to reduce energy consumption, relative to a modern dry-process kiln, by 12%).

We estimate that the overall potential for energy efficiency improvement, i.e. increase in output per unit of energy consumed, in the cement industry, relative to 2001, is 45%, which would reduce energy intensity by about 31%. Since the baseline trend incorporates an energy intensity reduction of about 18%, enhanced efficiency is estimated to contribute a further 16% (13% of 2001 consumption).

Non-ferrous metals

Although Australia is a major produced of nickel, copper and zinc, all of which require relatively energy intensive processing, the production of alumina and aluminium metal accounts for most of both the value added and the energy use in this sector. Discussion of the efficiency potential therefore focuses largely on these two materials, both of which are highly energy intensive.

In general, energy used in the production of aluminium can be greatly reduced by increased recycling of scrap aluminium. However, this is not of great relevance to the Australian industry, as its major role is as a producer of virgin metal for world markets.

Energy use in the production of alumina is in two main forms: steam to provide heat for the alkaline digestion of bauxite to produce hydrated alumina, and high temperature heat in calcination kilns to produce anhydrous alumina. There are opportunities to improve the efficiency of the boilers and boiler systems, mainly by reducing heat losses. Substantial improvements in kiln efficiency can be achieved by adoption of a new type of kiln, termed gas suspension calciners, which provide increased opportunities for waste heat recovery. A recent study estimated the overall average energy consumption for alumina production in Australia to be about 12,300 MJ/t, compared to world’s best practice of 9,000 MJ/t achieved by the German company AOS (DISR Energy Efficiency Best Practice Program, 2000).

Production of aluminium metal from alumina uses an electrolytic process and electricity accounts for by far the largest proportion of total energy consumption in this process. Electricity intensity of electrolysis at present in Australia is 13-15 MWh/tonne of aluminium, over twice the absolute theoretical limit of 6.34 MWh/t. A realistic eco-technical potential is 10-11 MWh/t, which will require the use of new materials and improved pot design (DISR Energy Efficiency Best Practice Program, 2000). Since all existing pot lines will be replaced by 2040, this is quite feasible by that date. Improved heat recovery also offers potential for further savings.

Our baseline projection assumes a steady improvement of technical efficiency in this sector of 1% p.a., which equates to an energy intensity reduction of 32% by 2040. We assume no additional efficiency improvements will be possible.

Pulp and paper

Energy use in this sector is affected by both structural factors, notably the extent of recycling and the mix of technologies (chemical/mechanical) used to produce virgin pulp, and by the use of a wide variety of specific technical means to increase energy efficiency. Most energy use is in the form of steam, which is used in all chemical pulping processes and also for most types of dryers. There is also significant use of mechanical energy, usually provided by electric motors.

The US and UK studies differ in their assessments of the potential for energy efficiency improvements in the paper industries of their respective countries. The UK study estimates that specific energy consumption could be reduced by 36% beyond BAU, while the US study estimates an improvement of less than 3%. It is not clear why these two studies reach such different conclusions about their respective countries.

Our 2040 baseline includes a trend improvement in the technical energy efficiency of the paper industry of 1% p.a., which equates to a total reduction in energy intensity of 32% by 2040. We assume zero additional efficiency improvement through pursuit of further efficiency options.

Sugar milling

The sugar milling industry constitutes, in terms of value added, a relatively small part of the Food, Beverages and Tobacco sector of manufacturing. We analyse it separately because the industry is extremely energy intensive by virtue of the quantities of bagasse (the fibrous residue from sugar cane crushing) used as boiler fuel. Much lesser quantities of coal and petroleum products are also used as supplementary boiler fuels. Most sugar mills also host small cogeneration installations, which are sized to supply most of the mills' own electricity requirements, but with little surplus for export to the grid.

The boiler plant in most Australian sugar mills is quite old, in part because the poor economics of the sugar industry over recent years has made it difficult to justify new investment. Furthermore, bagasse is essentially a waste product, with no demonstrated alternative uses, making low efficiency combustion a least cost waste disposal option.

We assume that sugar mills will continue to use bagasse as their primary energy source in 2040. However, all mills will be rebuilt (as a few have been over the last few years) to incorporate much larger and more efficient cogeneration plant. As a result, the quantity of bagasse required per tonne of raw sugar produced will be halved, i.e. the efficiency of producing and using process steam is doubled. The remaining bagasse is then available as a fuel for electricity production in the associated cogeneration plant. We make no assumption as to whether bagasse is gasified or simply undergoes direct combustion (as in all current sugar mills).

Generic equipment assessments

As previously noted, we allocate energy use in manufacturing into one of six major equipment or process types, each of which offers distinctive opportunities for energy efficiency improvement. We apply these generic assessments of potential to all the remaining sectors of manufacturing industry.

These remaining sectors, in the classification used for this study, are: Food, Beverages and Tobacco (excluding sugar milling), All Other Manufacturing, and Other Non-metallic Minerals (i.e. excluding Cement). With the exception of the latter sector, which includes the manufacture of glass, bricks and other ceramic products, these industries are much less energy intensive than the major process industry sectors discussed above. They also include the great majority of individual manufacturing establishments, including many relatively small ones. For these reasons, consumption of energy typically attracts a lower attention from management and is a lower priority for capital investment. Accordingly, the potential for energy efficiency improvement beyond the current levels will in general be greater than in the energy intensive process industry sectors.

Boiler systems

The term boiler systems refers to both the boiler itself, where combustion of fuel heats water to produce steam, but also the system of pipes for delivering the steam to where it is required and the great diversity of equipment in which steam is used as a source of heat.

Some studies of energy efficiency potential concern themselves only with the boiler itself, where there are certainly significant opportunities for efficiency improvement, notably by the progressive replacement of older boilers with newer models incorporating more efficient combustion and heat transfer designs and also by the general adoption of condensing (latent heat recovery) boilers, which provide efficiency improvements of up to 15%. However, much greater savings are usually available elsewhere in the system. These include improved insulation of steam pipes, elimination of leaks and other “good housekeeping” measures, and improved control of boiler operation, such as matching steam output to steam demand, rather than operating the boiler continuously at full capacity. Improvements in the design and operation of steam using equipment can result in further major savings in boiler energy demand.

It is understood that the former Energy Efficiency Best Practice program of the Department of Industry, Tourism and Resources identified energy savings of 40% or more in selected case studies.

For this study we assume that the average increase in boiler system efficiency will be 50%, i.e. energy intensity will be reduced by a factor of 0.67. When allowance is made for the efficiency improvement included in the respective baseline trends, the factors by which energy intensity will be additionally reduced are:

Food, Beverages and Tobacco	0.67
All Other Manufacturing	0.91

Kilns, furnaces etc.

In high temperature thermal equipment the main opportunities to improve technical efficiency are improving combustion efficiency, improving heat transfer efficiency from flame to the kiln chamber (depending on the type of kiln or furnace), reducing the amount of energy needed to bring fuel and combustion air up to combustion temperature, and, most importantly, reducing the amount of energy lost in exhaust gases.

As with many relatively mature technology systems, incremental improvements are continually being made in the various components of kiln systems, so that new equipment will generally be more efficient than older existing equipment. This turnover of stock is the major source of the trend for gradually increased technical efficiency across most sectors and types of equipment.

Major efficiency improvements, going beyond trend, are possible through the widespread adoption of the most efficient types of regenerative combustion systems. This is a well established, but still not widely used technology that recovers much of the heat contained in flue gases, with resultant large increases in overall efficiency. There is also a range of advanced burner designs which can provide modest, but useful, efficiency increases.

We assume that such technologies can be in general use in kiln systems by 2040, providing an average increase in the energy efficiency in kilns, furnaces and other high temperature thermal process equipment of 35%, i.e. energy intensity will be reduced by a factor of 0.74. When allowance is made for the efficiency improvement included in the respective baseline trends, the factors by which energy intensity will be additionally reduced are:

Other Non-metallic Mineral Products	0.87
All Other Manufacturing	0.97

Electric motor drive systems

Although individual motors can achieve efficiencies of near or above 90 %, the total system (including motor, shaft coupling, pump and throttle valve, etc.) may achieve an overall efficiency of 50 % or less. Ways to increase the efficiency of electric motor systems include the following.

- adoption of Minimum Energy Performance Standards (this took effect in October 2001 for three phase motors between 0.73 kW and 185 kW in size);
- shift to high efficiency motors;
- better sizing motors to the load they supply so that they run nearer full load most of the time (the efficiency of electric motors is much lower under part load);
- more extensive use of variable speed drives in applications where load varies, such as fans, pumps and conveyors,
- improved lubrication, maintenance and installation practices.

Energy consumption by electric motors is also reduced by improving the performance of equipment powered by electric motors, such as commercial refrigerators, air conditioning systems, air compressors and a wide variety of equipment used in manufacturing.

We assume that the average increase in electric motor drive systems will be 40%, i.e. energy intensity will be reduced by a factor of 0.71. When allowance is made for the efficiency improvement included in the respective baseline trends, the factors by which energy intensity will be additionally reduced are:

Food, Beverages and Tobacco	0.74

Other Non-metallic Mineral Products	0.90
All Other Manufacturing	1.00

Non-electric motors, Other non-electrical equipment, Other electrical equipment

Each of these types of equipment accounts for relatively little energy use in these sectors. For each, energy intensity is assumed to decrease by a factor of either 0.83 or the sectoral trend in technical intensity improvement, whichever is the greater reduction.

6.3. Mining, Construction and Agriculture etc.

In this Section we deal with energy use in Mining of non-energy minerals, Mining of coal for export, LNG production, Construction, and Agriculture, forestry and fishing.

The common feature of all these sectors is that they mainly use energy in various kinds of motors. These include:

- diesel engines:
    - shovels, dump trucks, generators etc. in coal and other mining,
    - earth moving and other equipment in construction,
    - tractors, pumps, other farm machinery, logging equipment, fishing boats in agriculture, forestry and fishing;
- gas turbines:
    - providing power for compressors and most other equipment used in LNG production;
- electric motors:
    - shovels, drag lines, underground mining equipment and mineral processing equipment (crushers, conveyors, pumps etc.) in mining,
    - pumps and miscellaneous farm equipment.

Other uses of energy include boilers, kilns and driers used for mineral processing in the mining sector, and relatively small amounts of energy used for space heating in agriculture.

For the Mining (including coal mining) sector our baseline projection assumes no trend increase in energy efficiency. The following improvements in energy efficiency for the various equipment categories are assumed:

boiler systems	40%
kilns and furnaces	40%
non-electric motors	20%
electric motor drives	35%
all other equipment	20%

These rates of efficiency improvement assume the same sorts of technology changes and adoptions as were described in the previous Section for the Manufacturing sector. However, it is assumed that energy using equipment in the Mining sector is on average larger in scale and more modern than equivalent equipment in the Food and All Other Manufacturing sectors, and that the potential for efficiency improvement is correspondingly less.

For the LNG industry, our baseline assumes a trend improvement in energy efficiency of 1.0% per annum across all types of energy use in the industry, which equates to an improvement in energy efficiency of 47% over the entire period to 2040. We allow no additional efficiency increase in the "efficiency" scenario.

For Construction, the baseline, as for Mining, assumes zero increase in energy efficiency. The efficiency improvement potential by 2040 is assumed to be 20% for non-electric motors, which account for the great bulk of consumption, and other non-electric equipment. An improvement potential of 35% is assumed for the relatively small amount of energy used by electric motor drives.

6.4. Commercial and services sectors

Energy use in the commercial and services sector essentially means energy use in buildings of all kinds. It is almost universally recognised that the potential for increased energy efficiency is very large in this sector. Moreover, electricity accounts for nearly 70% of total final energy use and 90% of greenhouse gas emissions in this sector, and its share is growing, so reductions in energy use will result in large emission reductions.

The EMET/Solarch study (EMET Consultants and Solarch Group, 1990) estimated abatement achievable by 2010, relative to a BAU baseline projected forward from 1990. The study estimates are structured in two tranches: firstly what was termed BAU abatement, defined as all abatement available at zero or negative cost, and secondly what was termed technical improvement potential, defined as all abatement with a positive NPV when an 8% discount rate is used. The more recent study (Pupilli 2002) estimated total energy savings with a payback period of 3 years or less to be 32% of projected energy consumption in 2010. However, an unspecified proportion of this 32% was said to be included in the BAU projection, i.e. actual additional savings with payback of 3 years or better is less than 32% by an unspecified amount. While it is difficult to equate the EMET/Solarch results, all expressed in terms of emissions, with the data used in this study by ABARE and by the more recent Pupilli update, all expressed as energy, it appears that the EMET/Solarch estimate of BAU + economic potential abatement is over 25% of the 2010 baseline. The EMET/Solarch estimates are based mainly of retrofitting and refurbishment, combined with enhanced performance levels for new building. They do not include substantial replacement of old buildings. Hence potential abatement over the longer period to 2040 should be significantly greater.

The discussion paper of the Ministerial Council on Energy (2003) estimates that the cost-effective energy consumption reduction in the commercial sector is over 25% under a so-called low energy efficiency improvement scenario (current technologies with a 4 year payback) and up to 70% under a high energy efficiency improvement scenario (existing and developing potential technologies with an 8 year payback).

The UK study (Jonathan Fisher *et al.*, 1998) estimated that by 2010 BAU energy consumption in the UK service sector would be 9.4% below the level it would have reached had there been no improvement in technical efficiency (termed "frozen efficiency"), which is equivalent to efficiency improvement of 0.7% p.a. from the study's 1996 base year. The technical potential was estimated to be a further 25% lower.

The overall assumption for this sector is that the potential for technical improvements in energy efficiency is for a saving of 40%, relative to the baseline, in all applications. Taking into account the efficiency improvement trend of 0.3% p.a. which is included in the baseline, the total energy demand reduction relative to current efficiency levels is 47%.

6.5. Residential sector

The residential sector affords great opportunities for limiting the growth in fossil fuel derived energy for the three main categories of energy use by:

- increased use of solar energy both actively, for water heating, and passively, through improved building design to reduce active use of energy for space heating,
- more efficient use of energy to achieve required energy service levels for heating and cooling by improved building shell design and construction, to reduce or eliminate the need for active energy using systems, and
- continuing improvements in the efficiency of both electrical and gas appliances and equipment.

Water heating

Our model assumes a large scale shift to solar water heating for the provision of residential hot water. It assumes:

- a modest underlying shift from electricity to gas in non-solar water heating (levelling out a trend which has operated for many years),
- that these shares of electricity and gas will determine the shares of these two fuels for boosting solar systems,
- that solar systems displace 75% of current electrical water heating and 90% of current gas water heating,
- that the average solar fraction Australia-wide is 70%,
- that the performance parameters for the various types of water heater specified in the standards for conventional and solar water heaters (Standards Australia, 1990, 1994) apply, and
- that the average fuel efficiency in the market (fuel to delivered hot water) of electric and gas water heaters are at present 76% and 65% respectively and that these increase at the sectoral trend rate of 0.5% p.a..

The overall effect of these assumptions is that electricity consumption for water heating is decreased by 59% and gas consumption is reduced by 56%, relative to the baseline.

Space heating and cooling

Examination of the data on residential energy use of Energy Efficient Strategies *et al.* (1999) shows that natural gas (used for heating) accounts for most of the energy used for space heating and cooling and that most of this occurs in Victoria. Our modelling therefore focuses on the thermal performance of residential buildings in that State (though it would also apply to Canberra, and the tableland areas of NSW).

The underlying baseline trends for technical efficiency and structural change in the residential sector, described in Section 4.2 above, are assumed to incorporate both increased technical efficiency of space heating equipment and any take up of improved technical performance as increased comfort, rather than reduced energy consumption. Other assumptions are:

- 50% of current electricity use is for heating and 50% for cooling,
- technical efficiency improvements in all types of heating and cooling equipment are 0.5% p.a., as in the sectoral trend, and
- there is an additional improvement of 0.5% p.a. in the technical efficiency of wood heating and a market shift from wood to gas.

Against this background, our model assumes that 50% of the 2040 housing stock in areas with significant heating load will achieve the equivalent of 5 star or above house energy rating, and the other 50% will achieve a 2.5 star rating. These building envelope performance levels equate respectively to heating energy consumption of about 140 and 280 MJ/m^2 in the Melbourne climate. We also assume, based on data contained in Energy Efficient Strategies *et al*. (1999), that the 2001 average performance of Melbourne housing stock is 500 MJ/m^2.

The overall effect of these modelled assumptions is that electricity consumption for space heating and cooling is decreased by 21% and consumption of natural gas and LPG is reduced by 42%, relative to the baseline

Electric appliances, lighting etc.

The Mandatory Energy Performance Standards (MEPS) program has already resulted in worthwhile reductions in energy demand from appliance use. A recent study of the effect of both current MEPS and those foreshadowed, i.e. announced but not yet in force, (National Appliance and Equipment Energy Efficiency Program, 2003) estimated that existing MEPS would reduce demand by about 9% below BAU by 2020 and one new MEPS alone, the “One Watt” standby power requirement, will achieve a further 9% by the same date. Other new MEPS will achieve further reductions.

Such detailed modelling has not been undertaken for other appliance and lighting applications in Australia.

The UK study (Jonathan Fisher *et al*., 1998) summarises the findings of several other British studies which conclude that adoption of the full technical potential for improvements in the efficiency of lighting and appliances could results in reductions in energy demand from these applications of between one third and one half.

The total potential for improvement in the technical efficiency of all types of electrical equipment and appliances is assumed to be for energy consumption savings of 40% beyond the sectoral trend of 0.5% p.a.. This equates to a total reduction of energy consumption, relative to 2001 performance, of 51%. Note that the discussion paper by the Ministerial Council on Energy (2003) estimates the overall potential for energy savings from the Residential sector to be about 35% under the low scenario and 70% under the high scenario. For cooking, a relatively minor use of energy in this sector, we assume a more modest potential reduction in energy demand of 10% beyond the sectoral trend, equivalent to a total reduction of 24% compared with 2001 performance.

6.6. Transport

In order to estimate the possible call on energy resources by transport, and also to estimate the energy which may be required to process fuel for transport, we make some very simple assumptions about the future of the Australian transport system. The assumptions are:

- no change in the current mix of fuels, i.e. almost complete dependence on petroleum products, with the exception of electricity use for part of the rail transport task;
- an overall reduction in the energy intensity of road, rail and air transport of 36% (equivalent to 1.1% p.a.);
- an overall reduction in the energy intensity of water transport of 65% (equivalent to 2.0% p.a.).

These reductions in energy intensity arise through a combination of greater technical efficiency and structural change within the sectors.

As described in Chapter 4, the economic projections are for differential rates of growth for the various transport modes, with rail growing most and road transport least. The overall outcome is that energy consumption by transport is projected to increase by 45%, with a consequent large increase in consumption of petroleum products.

Our stationary energy consumption scenarios incorporate the additional energy consumption in oil refineries to produce this quantity of petroleum products. However, given the scope of this study, we have not considered whether crude oil resources available in 2040 will be sufficient to support this level of petroleum consumption. Neither have we explored fuel and technology options to petroleum. These could include greater use of electricity, or of natural gas or, conceivably, use of coal with CO_2 capture to produce hydrogen.

6.7. Fugitive emissions

The production and supply of energy from fossil fuel sources is associated with emissions of CO_2 and methane from a variety of activities not directly related to the combustion of the fuels to produce useful energy. As a group, these emissions are termed fugitive emissions.

In 2001 fugitive emissions were estimated to be about 32 Mt CO_2-e, which was 9.5% of emissions from fossil fuel combustion. This study is not directly concerned with fugitive emissions. However, because they are an important source of emissions from the energy sector, we consider it important to briefly describe what we consider to be achievable in terms of reducing emissions from this source.

The most important sources of fugitive emissions in 2001 were:

• uncontrolled venting of methane from underground coal mines	12.3 Mt CO_2-e
• escape of methane from open cut coal mines	6.2 Mt CO_2-e
• flaring of combustible waste gases at oil refineries, petroleum production facilities and gas processing plants	3.9 Mt CO_2-e
• venting of CO_2 removed from raw natural gas at gas processing plants	3.7 Mt CO_2-e
• leakage of methane from natural gas transmission and distribution systems	3.6 Mt CO_2-e

The means to reduce substantially the emissions from most of these sources are available, technically proven and to some degree already in use.

- Some underground coal mines already capture fugitive methane and use it to generate electricity, while others capture and flare the methane, which does not completely eliminate greenhouse gas emissions, but reduces them by about 87%, by converting methane to CO_2. Most other mines could similarly oxidise waste methane at an abatement cost of a few dollars per tonne of CO_2-e abated.

- Oil and gas companies have for some years been progressively reducing emissions from flaring by undertaking incremental process modifications. We expect that this trend will continue, and would be accelerated if the costs of greenhouse gas emissions were internalised or if oil and gas prices increase.

- Venting of CO_2 from gas processing can be almost completely eliminated by reinjecting the extracted CO_2 into suitable geological formations, which are normally readily available nearby, e.g. depleted petroleum reservoir formations. Such geological sequestration is already occurring on a fully commercial scale at one large gas field in the Norwegian sector of the North Sea. It is likely to become a condition of development approval for new natural gas projects, particularly those with high concentrations of CO_2 in the raw gas, and will in any case be undertaken when there is a price on greenhouse emissions.

- Most methane leakage from natural gas distribution comes from old and/or poorly maintained pipes. Leakage from high pressure transmission pipelines is very low, as it is from new low pressure distribution networks. Several Australian gas companies have made significant (commercially justified) investments to reduce gas leakage from older pipe networks and further reductions are achievable with a very modest price on greenhouse emissions or, in some cases, simply a change in regulatory incentives.

Of the current major sources of fugitive emissions, only those from open cut coal mines are relatively intractable. Consequently, we expect that in our clean energy scenario fugitive emissions will be much lower than they are today, notwithstanding the continued high level of coal mining for export markets, the level of natural gas production and processing for both domestic and export markets, and the high level of natural gas use in domestic markets.

6.8. The Medium Efficiency demand case

The effect of the foregoing assumptions about energy efficiency is to reduce energy demand in 2040 from the baseline value of 2,955 PJ to 2,352 PJ, a reduction of 20%. We have termed this demand projection the Medium Efficiency final energy demand case, because it includes a significant increase in energy efficiency, compared with the Baseline case, but nevertheless contains a number of conservative assumptions about the take-up of energy efficiency. For example, as already pointed out, the improvement in energy efficiency overall is less than that estimated in the report from the Ministerial Council on Energy (2003).

The distribution between major sectors is shown graphically in Figure 6.1, and more detail is provided in Table 6.1. Figure 6.2 shows the mix of fuel type in this Medium Efficiency demand scenario for 2040.

Figure 6.1: Medium Efficiency stationary final energy demand by major sectoral group, 2040

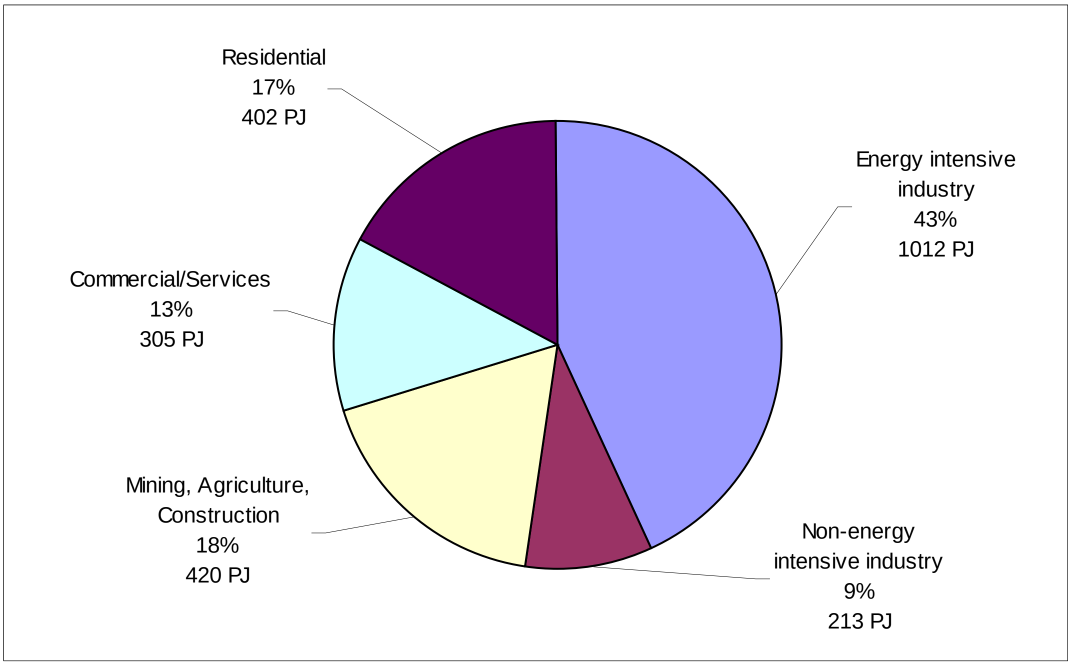
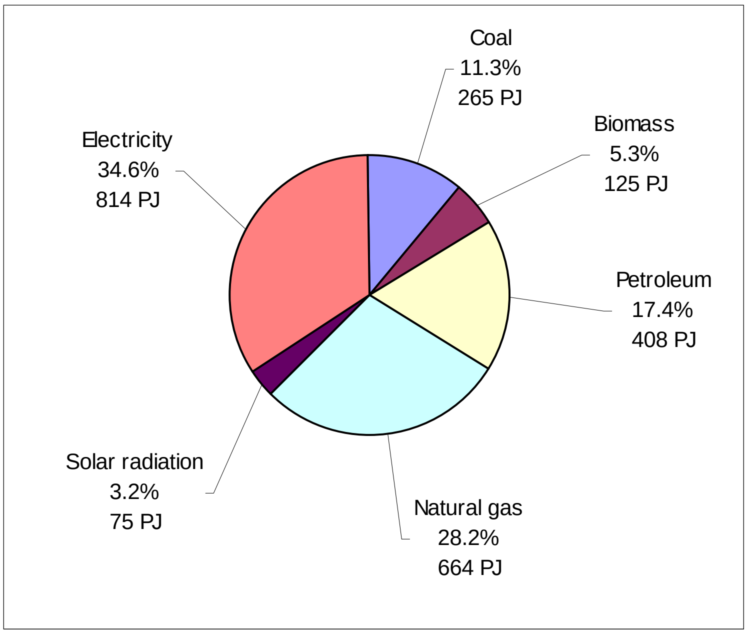


Table 6.1: Medium Efficiency stationary final demand for energy by sector, 2040

Economic sector	Energy consumption (PJ)
Mining (incl. LNG and coal exports)	350
Manufacturing	1,115
Iron and steel	209
Food, beverages, tobacco	117
Basic chemicals	61
Cement, lime, plaster and concrete	53
All other non-metallic mineral products	68
Non-ferrous metals	412
Wood, paper and printing	100
All other manufacturing	95
Construction	97
Commercial/Services	305
Agriculture/Forestry/Fishing	83
Residential	402
TOTAL final stationary energy consumption	2,352

Figure 6.2: Medium Efficiency stationary final energy demand by fuel, 2040



The effect of enhanced efficiency, relative to the baseline demand in 2040, is shown by sectoral group and by fuel in Figures 6.3 and 6.4 respectively. In the sectoral analysis, it can be seen that the enhanced efficiency has relatively little effect on demand from the energy intensive industries, because these are assumed to be taking up most efficiency opportunities as they arise, with consequent significant efficiency improvements in the baseline case, whereas increased efficiency has a big effect on the Commercial/ Services and Residential sectors, since these are where markets for energy services are least effective. The analysis by fuel shows that, as would be expected, the larger gains in energy efficiency in the Commercial/ Services and Residential sectors have most effect on demand for electricity, since that is the most important fuel for those sectors.

The energy intensive sectors have grown, in terms of value added, more slowly than the economy as a whole, so that in 2040 they account for just over 1.7% of GDP. However, their share of total final energy consumption has fallen only slightly, to 38, because, as explained, these sectors have less opportunity for really large gains in energy efficiency than the less energy intensive sectors.

The increased use of solar thermal energy is the result of the switch to solar water heating in the Residential sector, which in our modelling is analysed jointly with increased efficiency in this sector. In Chapter 9 we describe the effect of further fuel switching towards both solar thermal and natural gas, which forms part of the last stage of our analysis – decarbonising energy supply.

Figure 6.3: Medium Efficiency and Baseline final stationary energy demand by major sector, 2040

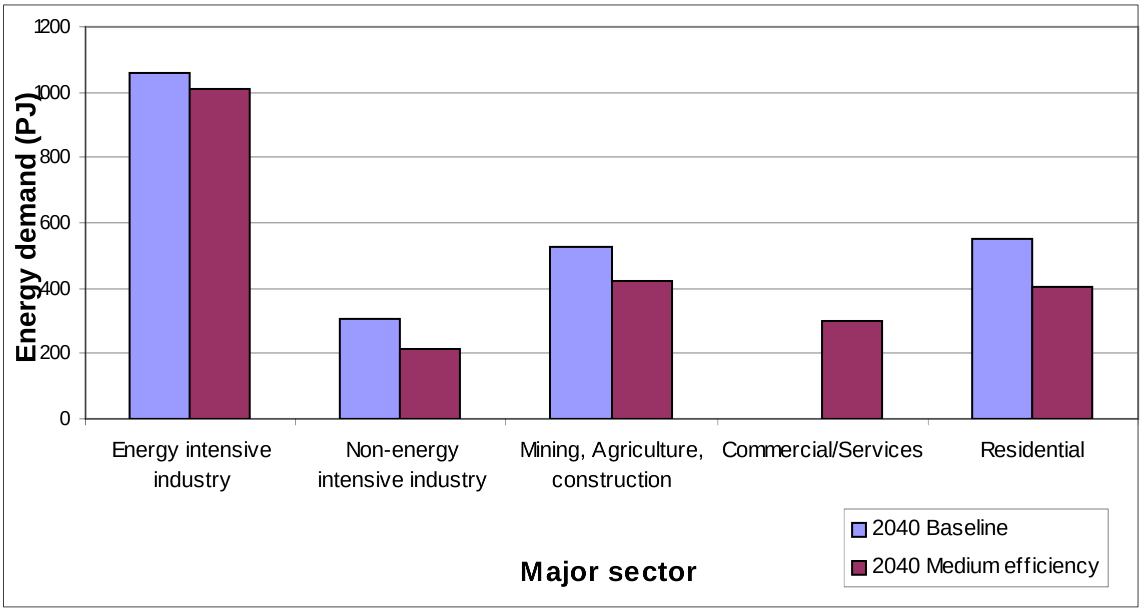
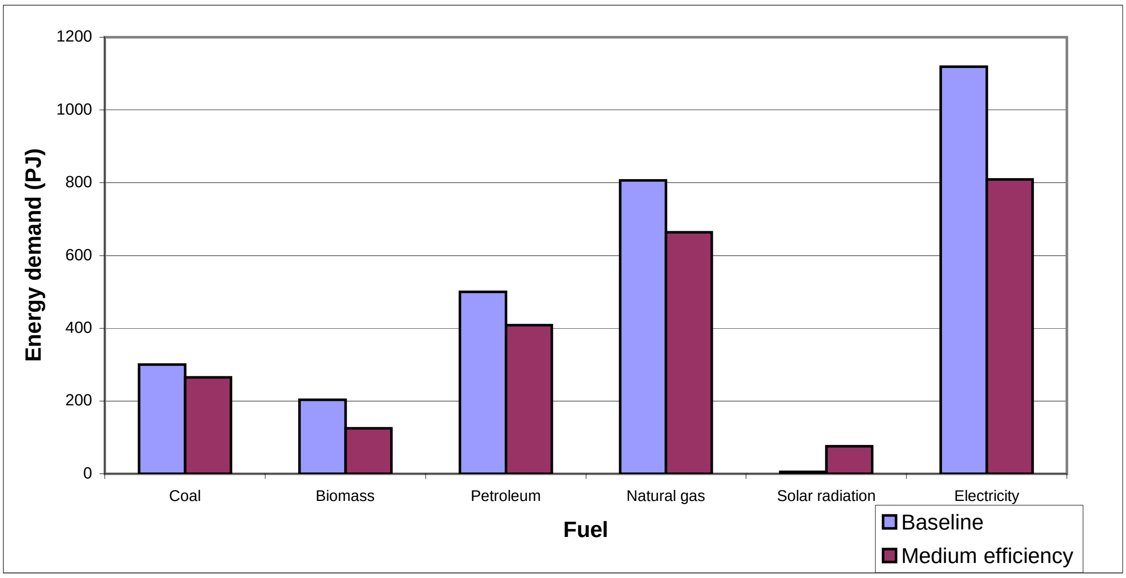


Figure 6.4: Medium Efficiency and Baseline final stationary energy demand by fuel, 2040 (PJ)



Figures 6.5 and 6.6 show the comparisons between the Medium Efficiency demand in 2040, and demand in 2001. The overall effect is to increase stationary final energy demand from 1,888 PJ in 2001 to 2,363 PJ in 2040, an increase of 25%. This compares with growth of 57% for the baseline case Energy demand per capita actually falls slightly, from 97 GJ in 2001 to 94 GJ in 2040.

It will be noted that demand for biomass is actually less than in 2001. This is caused by the great increase in efficiency of bagasse use in the sugar milling industry, which frees up a significant biomass fuel resource for additional generation of electricity. The greater technical efficiency in the sugar industry is also the reason that total demand for energy in the non-energy intensive manufacturing sectors is actually less than in 2001. Energy demand in the Residential sector is also less than in 2001, reflecting the great potential for increased energy efficiency in this sector.

Economic modelling for the Ministerial Council on Energy (2003) shows that a 50% penetration of a low energy-efficiency scenario over a 12 year period would deliver the following substantial economic benefits:

- real GDP would be $1.8 billion higher (+0.2%);
- employment would increase by about 9000 (+0.1%);
- stationary final energy consumption would be reduced by 9% (-213 PJ);
- greenhouse gas emissions from stationary energy would be reduced by 9%.

Accessing these benefits would require an investment in energy efficiency over the 12 years of approximately $12.4 billion (NPV terms) generating lifetime energy savings of approximately $26.9 billion (NPV terms). Overall these measures would achieve a 26% internal rate of return on investment.

The Ministerial Council's strong energy efficiency scenario, which envisages 100% penetration of end-use energy efficiency measures with a four year payback period or less, would achieve double the above greenhouse benefits (18% reduction). This is very similar to our own results for 2040, namely a 20% reduction in energy demand. Given that we are assuming a time period of nearly 40 years to achieve our assumed energy efficiency target we believe that this represents a reasonably conservative and readily achievable estimate.

Figure 6.5: Medium Efficiency final stationary energy demand by major sector, 2040 compared with 2001 (PJ)

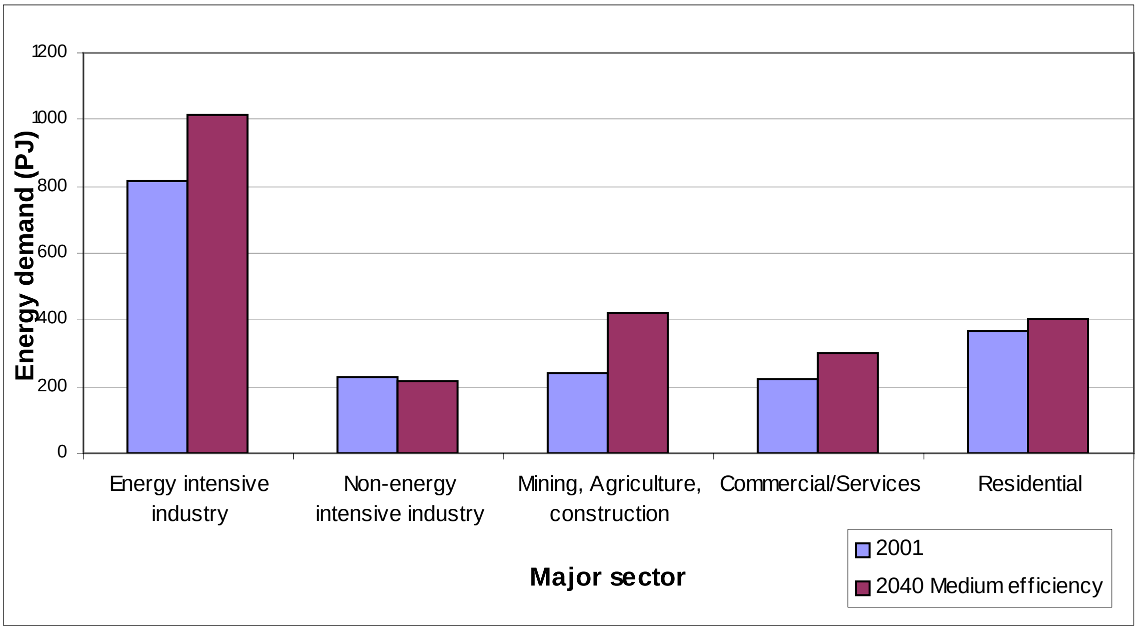


Figure 6.6: Medium efficiency final stationary energy demand by fuel 2040, compared with 2001 (PJ)