



Australian
Business Council
for Sustainable
Energy

Ms Delwyn Rance
Inquiry into Energy Efficiency
Productivity Commission
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Collins Street East
Melbourne 8003

Email: energy@pc.gov.au

22 November 2004

Dear Ms Rance

Please find attached the BCSE's written submission to this Inquiry. This builds on material provided to members of the Inquiry team in our previous meeting.

A key part of the BCSE submission is the attached report prepared by the Allen Consulting Group titled "The Energy Efficiency Gap – Market Failures and Policy Options.

The BCSE and its members welcomes the opportunity to expand on this submission and further participate in the Commission's Inquiry.

Yours sincerely

Original signed by

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Productivity Commission
SUBMISSION COVER SHEET
(not for publication)

Inquiry into Energy Efficiency

Please complete and submit this form with your submission to:

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- contains confidential material and the whole submission is provided 'IN CONFIDENCE'

Australian Business Council for Sustainable Energy

Submission to the Productivity Commission Inquiry into Energy Efficiency

November 2004



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About the BCSE

The Australian Business Council for Sustainable Energy (BCSE) is the leading independent member-based industry association representing the sustainable energy industry in Australia. The BCSE was formed in September 2002 through the merger of the Australian EcoGeneration Association (AEA) and the Sustainable Energy Industry Association (SEIA). Predecessors of these organisations date back to as far as 1976.

The BCSE has more than 270 organisations as members, ranging from installers and designers of renewable energy systems to large project developers and equipment manufacturers and including both energy retailers and energy service providers.

The sustainable energy industry has been growing at about 25 per cent per annum over the last few years. Direct sales for the industry are estimated to be in excess of \$4 billion. The sustainable energy industry directly employs an estimated 17,000 full-time people. The sustainable energy industry is expected to continue to grow strongly and is poised to be a major contributor to Australia meeting its greenhouse reduction targets.

Heightened community concern over changes to our climate and Australia's growing greenhouse gas emissions continues to create pressure for additional policy responses at the national and state level. There are currently a range of policy measures that are actively supporting the growth of the sustainable energy industry these include the Mandated Renewable Energy Target (currently limited to 9500 GWh, but with scope to expand through state government initiatives), Commonwealth government programs such as the \$75m Solar Cities and \$100m Renewable Energy Development Initiatives. There are an increasing number of state measures such as Queensland's 13 per cent gas strategy and the NSW Benchmarks Scheme. The Victorian government is currently also considering its approach to market based measures. In addition Victoria and NSW have implemented mandatory energy efficiency and greenhouse schemes for residential housing.

About this submission

The BCSE, along with the Insulation Council of Australia and New Zealand (ICANZ) and the Australasian Energy Performance Contractors Association (AEPCA) have commissioned a report by the Allen Consulting Group - "The Energy Efficiency Gap – Market Failures and Policy Options". The Allens report provides an overall economics-based review of the key aspects of relevance to this Inquiry, such as the existence and nature of the energy efficiency gap, policy options, and related issues. This report forms a substantive part of the BCSE's submission and is attached.

We have not sought to restate the key issues from the Allens report in this part of our submission but rather we have sought to expand on a number of other issues that were raised in the Commission's September 2004 Issues Paper. We have also outlined what we believe the key policy measures are to enable the potential that energy efficiency provides to be captured.

Introduction

This Inquiry is a critically important step towards the incorporation of energy efficiency into mainstream Government policy. The BCSE is critically concerned however that the scope of the Inquiry is too narrow. As the Commission's Issues Paper states on page 10, it is considering only a subset of energy efficiency potential. Its focus on measures that are cost effective for producers or consumers means that it is not considering measures that have net societal benefits that cannot be captured by individuals or businesses.

It is important that the Productivity Commission emphasizes this in its report, so that the Inquiry's conclusions can be put into context. This means where the Inquiry concludes there is a case for Government intervention, the justification for action is strong, as it has passed tough criteria. However, where the Inquiry does not find a case for intervention, this is not a strong argument against Government intervention, as other benefits that are not captured by individuals have not been considered. It simply means that further analysis is required before the action can be rejected.

In its Review of National Competition Policy (NCP)¹ the Productivity Commission made a number of recommendations that are particularly relevant to its Inquiry on Energy Efficiency. The following two recommendations are particularly important:

- Develop ways to manage environmental externalities more effectively; and
- Develop a more effective process for achieving a national approach to greenhouse gas abatement

Importantly the Commission put into context the need for continued reform given the important environmental challenges that Australia faces;

There will also be pressure both domestically and internationally to improve environmental outcomes and encourage more sustainable resource use. And, as in other countries, reducing output of greenhouse gases is likely to involve substantial adjustments in the pattern and nature of economic activity, with the likely ratification of the Kyoto Protocol reinforcing those adjustment pressures even in countries which are not signatories. (Page 147)

Further competition-related and other economic reforms will be an important part of the policy mix:

However, Australia faces a number of significant economic, social and environmental challenges that will put pressure on living standards in coming years. While a variety of strategies will be required to address these challenges, further competition-related and other economic reform will be an important part of the policy armoury. (Page 146)

Greenhouse gas emissions is the most critical externality that has failed to get properly dealt with in Energy Market reform to date. This point was acknowledged by the Commission in its NCP Discussion Draft:

More broadly, it is important to recognise that any inherent 'over-reliance' on electricity generation with high CO2 emissions is a reflection of the failure to price for externalities, rather than from the introduction of greater competition. That is, as Hamilton and Denniss (2001) argue, prices for electricity from whatever fuel source do not fully reflect the social costs of provision. (Page 112)

¹ Discussion Draft released on 27 October 2004, refer to Media Release included as Appendix 1

The Commission then went on to articulate the importance of externality pricing in infrastructure provision;

As discussed in chapter 8, the Commission sees externality pricing as an important element in the future infrastructure reform agenda — though there are limits on what price-related solutions can achieve. (Page 112)

With regard to its recommendations on water reform, the Commission acknowledged the success of market based instruments to date but recognised the importance of the application of a suite of policies, that draws on pricing, regulatory and other mechanisms;

Importantly, prices that provide for full cost recovery of infrastructure services and that include a component for the externality costs associated with the delivery of water will not be sufficient to guarantee efficient allocation of a limited water resource. To achieve efficient outcomes, prices would also need to reflect externalities associated with the use of water in different applications. These are likely to vary considerably, thus making such pricing very difficult.

Accordingly, as in the energy sector, full externality pricing is at best a longer term goal. In the mean time, governments are increasingly drawing on a broad range of market-based instruments to deliver more efficient allocations of water between different users. For example, in New South Wales, the Hunter River Salinity Trading Scheme involves capping environmentally damaging activities and using trading to deliver the most efficient mix of production activities within the cap (Department of the Environment and Heritage, sub. 97, p. 5).

Indeed, given the information requirements and administrative logistics associated with environmental pricing, it cannot be assumed that price measures are inherently superior to other market-based instruments, or even to regulatory controls governing levels and patterns of water use. It needs to be recognised that even market-based instruments typically have a range of regulatory conditions attached, especially where unfettered trade could prejudice environmental goals.

Effective management of environmental externalities is likely to require the application of an integrated suite of policies, that draws on pricing, regulatory and other mechanisms. In this context, administrative water allocation may often be one of the more efficient policy instruments available to governments. However, the mix of instruments is likely to evolve over time as knowledge about externalities increases and case history on the effectiveness of particular approaches expands. Effective monitoring of the implementation and the effects of the water reform program will therefore be important in facilitating such policy development. (Pages 178 and 179)

The Commission did however make the case for including the cost of externalities into the price of potable water if we were going to get the appropriate investment in water recycling;

Indeed, to the extent that potable water is underpriced because of the failure to take account of environmental externalities associated with its delivery, current levels of recycling are likely to be sub-optimal. This is another reason to work towards the goal of ensuring that the price of water reflects its true economic cost (including, as far as possible, the costs of environmental externalities). (Page 179)

There are strong parallels between the approach taken between water and energy, a point that the Commission readily acknowledged in its recommendations. The requirement for a suite of policy measures is also critically important for tackling greenhouse emissions in the energy market and driving energy efficiency outcomes.

The BCSE is concerned with the limited scope of the Commission's Inquiry into energy efficiency. And whilst the Commission must deal with the scope that it is provided we believe that it is critically important that the Commission, as part of its Inquiry into Energy Efficiency clearly articulates this limited scope.

Unless (i) benefits captured beyond individuals or businesses and (ii) environmental externalities are considered in the development of policy responses then the level of investment in energy efficiency will be sub-optimal. This will then place a needless additional burden on other sectors of the economy to deliver greenhouse abatement – or energy supply at higher net cost to the economy.

The Commission itself acknowledged the importance, and the high stakes involved in getting the policy framework right in its NCP Discussion Draft;

A key test of the effectiveness of the MCE energy market reform program will be its impact on investment over the next decade. The energy industry estimates that over this period, investment of \$37 billion will be required to ensure that energy needs are met (MCE 2003a). Investment of this scale has significant implications for the efficient allocation of resources across the economy. Given the long lead time involved in bringing new generating capacity online, it is also important to get the timing, location and nature of investment decisions right. (Page 167)

The Commission also recognised (in its NCP Discussion Draft) the important role that the National Framework for Energy Efficiency can play and the role of the Commission's Inquiry into Energy Efficiency;

The Commission strongly endorses the need to reduce regulatory fragmentation and improve certainty about future policies in this area (whatever the most appropriate responses might be). With significant new expenditure required in the energy sector in coming years, Australia can ill-afford regulatory arrangements that discourage efficient and timely investment. (Page 173)

In the Commission's view, the capacity of current CoAG greenhouse processes to address this issue in a timely manner is questionable. For example, there appears to have been very little progress in further developing the National Greenhouse Strategy. Accordingly, the Commission considers that CoAG should give priority to developing a more effective process for achieving a national approach to greenhouse gas abatement (see chapter 10). The National Framework for Energy Efficiency being developed and implemented under the auspices of the MCE might have a role to play in this regard. Also, many of the issues that would be relevant to achieving better outcomes in this area are currently being considered as part of the Commission's inquiry into energy efficiency. (Page 173)

Defining Energy Efficiency

The *Issues Paper* (p.11) defines energy efficiency as 'maintaining the level of useful output or outcome delivered while reducing energy consumption'. It goes on to acknowledge that, when considering the cost-effectiveness of energy efficiency improvement, a technical definition differs from an economic one. Where the output is defined in economic terms, possible trade-offs between the costs of other inputs and energy use, as well as variations in profit margins (which affect economic output per physical unit of output) may mean that increasing the economic output per unit of energy and increasing the physical output per unit of energy are not the same thing. This difference can lead to confusion, as discussed in Pears (2004), a copy of which has previously been provided on CD to the Commissioners.

The *Issues Paper* also notes that it is possible to consider energy efficiency in energy supply, as well as at end use. The overall energy efficiency of energy supply and use can be considered by using *primary energy* (the amount of raw energy harvested) per unit of useful output as an indicator. Using primary energy takes into account all conversion, delivery and point-of-use losses. This is particularly important where different types of energy sources are being compared. For example, on-site cogeneration (production of heat and power on-site) typically increases end-use energy per unit of useful output, but reduces primary energy per unit of useful output, because energy that would normally be wasted at the power station is utilised in processes on the site.

BCSE strongly recommends that the Productivity Commission should use primary energy as its measure when evaluating energy efficiency improvement.

It should also be noted that, apart from where a high proportion renewable energy is being used, changes in greenhouse gas emissions from energy efficiency improvements and fuel switching at point of use are (within about 30%) roughly equivalent to changes in primary energy consumption. The difference is due to the variation in greenhouse intensity per unit of energy of the various primary fuels – oil, gas and coal. So using greenhouse impacts as an indicator of energy efficiency is actually much closer to the primary energy efficiency than using end-use efficiency, as it takes into account conversion and delivery losses. For example, using resistive electric heating instead of gas uses about 25% less end-use energy, but generates around three times as much greenhouse gas and also uses about three times as much primary energy if average grid electricity is used. So using end-use energy as an indicator can send quite perverse signals about overall energy use.

Indeed, one of the problems BCSE identified with the NFEE analysis was that it relied upon end-use energy to set policy priorities. This led to a greater focus on large industry, which uses a high proportion of gas, coal and oil at point of use, than would have been justified if primary energy or greenhouse gas emissions had been used as the criterion. Much of the energy used in the commercial and residential sectors is in the form of electricity. As greenhouse intensive coal accounts for 80 per cent of power generation in Australia, improving efficiency in the commercial and residential sectors would have the greatest greenhouse pay-offs.

The 'Efficiency Gap' and rational behaviour

The gap between identified potential for cost-effective energy efficiency improvement and actual response is often described as the 'efficiency gap'. The Commission asks to what extent this gap results from rational response (such as hidden transaction costs), real world circumstances and inertia such as sunk costs of plant and equipment.

The attached Allen Consulting Group report shows clearly that, while part of the efficiency gap can be linked to rational behaviour, a substantial part of it results from the impact of barriers such as market failures, behavioural norms, imperfections within and between organisations, and so on.

Actions of governments have the potential to address both the 'rational' and 'irrational' aspects of the energy efficiency gap. Since 'rational' application of, for example, a high discount rate reflects a perception of a high level of risk, government actions that reduce risk, or perception of risk, can shift the threshold for action. Government action can also overcome barriers and impediments that would otherwise block adoption of energy efficiency.

The scope for cost-effective energy efficiency improvements in firms, households, sectors and industries

The scope for cost-effective energy efficiency improvements is substantial and, with appropriate policy support, this potential can be increased.

Indeed, it can be argued that there is little point debating the extent of the scope for cost-effective efficiency improvement: it is demonstrably large, and it has the potential to grow as costs fall, technology improves and we become smarter at capturing the opportunities. Well-structured policy can be designed so that it adapts as potential improves – then no-one has to 'best guess' what the potential for savings is, the market can work it out.

A well-designed energy rating scale can also reward better performers – as long as there is room on the scale for them. One of the problems with our star rating schemes for appliances and buildings has been that we keep running out of stars because the public servants who set the scales do so with advice from industry – who habitually underestimate the scope for efficiency improvement. For example, a recently developed Turkish refrigerator would score 7 or 8 stars on Australia's six star energy rating scale. And the mandatory minimum performance for houses in California and some European countries is 7-8 stars on Australia's 5-star house rating scale.

BCSE jointly sponsored the recent *Clean Energy Futures* study (Saddler et al, 2004). In this study, it is estimated that energy efficiency measures could halve the projected baseline energy growth to 2040. The criteria used for these measures were that they had to be commercially available today, and that they would be cost-effective under the conditions and energy prices expected in 2040. The study was deliberately very conservative with regard to energy efficiency, but still showed that it had a very important role to play. A copy of this study together with the communications summary is included as part of our submission.

Studies for the UK Government and the Intergovernmental Panel on Climate Change also show large cost-effective potential for energy efficiency. Copies of these studies have previously been provided to the Commissioners on CD.

The economic benefits and costs

Studies such as those mentioned above typically consider the direct savings on energy bills when assessing the cost-effectiveness of energy efficiency measures. But experience shows that there are

often substantial non-energy benefits from energy efficiency measures, such as improved comfort, productivity, increased production capacity, and so on. For example, one US study showed that when non-energy benefits of energy efficiency measures in the steel industry were considered, the average payback period was cut from 4.2 years to 1.9 years (Worrell, 2004).

Many of the costs of energy efficiency measures are associated with transaction costs, high prices (often due to low production volume and lack of mainstream acceptance). These costs can be reduced by effective policy intervention by government. A good example of the potential is the introduction of Minimum Energy Performance Standards for household refrigerators. The cost-benefit study for the Regulatory Impact Statement showed that MEPS was cost-effective, despite assumed increases in appliance price. In reality, showroom prices of MEPS compliant refrigerators are actually similar to those of competing products. Further, the Australian Greenhouse Office has shown that the appliance and equipment efficiency program has delivered large energy savings and greenhouse emission reductions at a cost of -\$30 per tonne – this is equivalent to around a one year payback period. Clearly it would still be cost-effective to drive much more aggressive energy efficiency improvements.

Effect on greenhouse gas emissions

Again, the Commission's attention is drawn to the *Clean Energy Future* study for a conservative view of the greenhouse benefits of cost-effective energy efficiency measures.

A key issue that arises here is the dynamics of implementation of energy efficiency. For example, Australia's newest and probably most energy efficient pulp and paper mill, VISY's Tumut mill, has a low greenhouse footprint through a combination of energy efficiency measures and cogeneration. Yet other Australian mills are quite large generators of greenhouse gas emissions. This reflects their age of 20-50 years, and the older technologies they use. Distortions in the taxation system that offer 100% tax deductibility for maintenance and repair, but only standard depreciation rates for upgrades in energy efficiency and cogeneration, encourage the industry to remain in the Dark Ages of technology.

The important role that energy efficiency and cogeneration can play in the cost effective reduction in greenhouse gas emissions is discussed in the *Clean Energy Future* study (has been provided to the Commission as a separate document).

Impact of 'Rebound Effect'

A discussion of the "rebound effect" is included in Appendix 2.

The BCSE believes that impacts rebound impacts from improving energy efficiency have been overstated. There are a number of possible outcomes of improving energy efficiency ranging from large rebound effects to large amplification effects. Policies, education and information can influence the outcome. For example, driving aggressive mandatory energy efficiency standards with quite long payback periods diverts money towards investment in energy efficiency and away from other economic activity, reducing the rebound effect. Through changing the behaviour of product and service suppliers, it can also transform the outcome into an amplification effect. Promoting investment in businesses that offer energy efficient products and services can build this sector of the economy, displacing businesses that deliver inefficient alternatives.

It is also important to recognise that economic models often incorporate past relationships between sectors so that they may overstate rebound effects. For example, if in recent history energy intensive activity has grown faster than the rest of the economy, then allocating money freed up by energy savings across the economy based on past experience will 'drive' more rapid growth of energy intensive industry in the modelling when there may be no other reason to expect such growth. This

seems to be a significant factor in modelling the impacts of response to climate change on the Australian economy.

Private and social costs of achieving these benefits

If these benefits are captured, there is some potential for the conventional energy supply sector to suffer costs. However, as BP and Shell have shown with regard to oil, and Origin Energy is showing with regard to non-transport energy, smart businesses will re-position themselves to profit – as long as they can see the direction of change.

In some cases, poorly-structured policy could impact adversely on some groups, causing equity problems. For example, a broad increase in the price of energy can impact on those not in a position to adopt energy efficiency measures. But application of a new energy pricing framework to those who buy new homes (or cars) and who renovate means that these households are in a position to invest in efficiency measures that will allow them to avoid costs.

Barriers and their impacts

Many papers have addressed these issues, for example Greene and Pears (2003), which has been provided to the Commissioners on CD. The attached report by the Allens Consulting Group includes a detailed discussion of barriers and policy measures to address these.

These barriers are pervasive, and have a very major impact on adoption of energy efficiency. The *Issues Paper* identifies many of the barriers and discusses their potential impacts on energy efficiency improvement.

Rationale for Government Intervention

Government intervention is warranted in many cases because:

- If appropriate policies were applied and market distortions removed, then the market could deliver energy efficiency improvement. But this will require government intervention to create new mechanisms;
- Some distortions such as rural energy price subsidies, lack of price signals to buyers of airconditioners where smart meters are not available and prices do not reflect full cost, the outcomes of historical subsidies to fossil fuels, taxation mechanisms (including discrimination against investment in efficient technologies and against small projects that compete with large supply-side projects eligible for taxation incentives), and so on are unlikely to be fully removed in the short term. So there is a case for compensating policy support to be applied – this requires Government action;
- Where failure to capture energy efficiency opportunities in one sector would increase costs of compliance with other policies (such as greenhouse policies) for other sectors and for society overall, Government should act in the interests of society
- If individuals and businesses are being harmed (either in financial or other ways) by their failure to capture energy efficiency measures, governments may act to reduce harm;
- Where widespread action would reduce the costs for individuals (both now and in the future) – for example, governments have traditionally required households to contribute to the cost (and even mandated connection) to sewage schemes and electricity grids in order to share the burden and maximise the benefits; and
- If costs that are not included in present prices should be considered – eg carbon costs

Costs and benefits of government intervention

To date, the cost of government intervention to support energy efficiency has typically been trivial in comparison with the benefits. The demonstrated benefits of appliance energy efficiency schemes relative to their costs (hundreds of millions of dollars per annum by 2010), alone, could offset costs of hundreds of millions of dollars a year in implementation of household and business energy efficiency programs.

The key issue here is that we need effective and efficient policies. As noted earlier, if we design policies to be effective, and to respond to real developments, then we can ensure that benefits always exceed costs. For example, the cost of rural energy subsidies is hundreds of millions of dollars per year. So aggressive energy efficiency measures in rural areas can cut this cost. The cost due to businesses replacing failed equipment with inefficient equipment instead of upgrading to energy efficient equipment is also large: so either fixing the tax system (for example, by requiring the Tax Office to allow efficiency upgrades consistent with Australian Standard recommended performance or performance levels set by the Australian Greenhouse Office to be tax deductible as if they were direct replacements) or providing equivalent incentives for upgrades would be small in comparison with the benefits, because business applies very short payback period criteria to such investments relative to the average for return for business.

Organisational barriers and the cost of overcoming them

It has been well documented that there is a myriad of internal barriers to adoption of cost-effective energy efficiency measures, see paper provided to the Commission on CD by BCSE.

Further, the cost of government action to overcome barriers is small or may even increase revenue. Even when one looks at the cost of very intensive interventions, such as DITR's now defunct Energy Efficiency Best Practice Program's Big Energy Project workshops, which could cost more than \$50,000 per business, it can be seen that the businesses generally recovered the total cost of the BEP process from energy savings within less than a year or two – so tax revenue from the increased profitability would deliver net benefit to government income within less than 6 years. EEBP addressed barriers within organisations. Indeed, when it was discovered at one site that multi-million dollar energy savings from pipe insulation were not being achieved because the maintenance team incurred the costs but the boiler house gained the savings, the barriers due to the existence of separate cost centres and poor communication were stark. Or when \$250,000 per year could be saved through reduction in boiler standby losses by requiring operations staff to ring the boilerhouse at a dairy processing plant before calling for steam, questions really had to be asked about how well Australian business is managing energy!

Organisational and cultural barriers also exist within government, particularly within economic and industry portfolios. Examples of the kinds of barriers arising from the culture within government include:

- Increase in tax deductions for exploration for oil with no matching incentive for people to invest in cars and trucks that use less oil
- Energy supply projects eligible for 'large project' status and associated benefits while large numbers of small energy efficiency investments fail to gain matching benefits
- The assessment of innovation potential in the Government's recent White Paper on energy categorised all energy efficiency as 'fast follower' status instead of 'market leader' – presumably this will influence allocation of RD&D funds away from energy efficiency and towards other areas designated to have greater potential.

Within business, a particular cultural barrier seems to be the focus on cashflow over net benefit to the business. Some, like Hugh Morgan, CEO of the Business Council of Australia, describe this as 'short termism' that is leading to loss of long term value in Australian business.

In this context, it is not surprising if a finance manager prefers to repair equipment than to upgrade its efficiency, or even invest in more efficient (and probably more productive) replacement equipment. The repair can claim 100% tax deductibility that year, and leaves cashflow looking good while the CFO can claim (s) is a success. But the alternative investment is more likely to secure a successful future for the business – but the business can only claim depreciation.

Another cultural issue is that capital funding is treated very differently from recurrent funding. Further, where the recurrent cost of energy is relatively small for most businesses, capital investments in new equipment are seen as major issues. In a context where technical staff are generally not very good at putting strong business cases, and energy is a minor issue, it is not surprising that there is a reluctance to invest in energy efficiency.

Policy options - coordination

While coordination of energy efficiency policy and programs potentially reduces the costs and time spent in delivery and enhances compliance, the reality is often far from this.

Greene and Pears (2003 – copy provided on CD) document the very long delays and failures in delivery of energy efficiency programs when attempts have been made to coordinate and drive programs nationally. For example, while Victoria and NSW introduced appliance energy labelling in the mid 1980s, it was only the late 1990s when the scheme achieved national regulatory status.

Institutional issues that must be dealt with if coordination is to be beneficial include:

- It is imperative that national processes do not lead to "lowest common denominator" outcomes rather than 'best practice', as leaders compromise in response to jurisdictions that are less committed;
- increased influence of vested interest groups and reduced influence of community also occur as the process shifts towards the national level. The reality is that the strongest supporters of energy efficiency tend to be dispersed – they include energy users, community groups and small businesses. These groups struggle to compete against the powerful nationally organised groups and institutions who play critical roles in national processes; and
- problems with allocation of adequate resources also occur commonly in national processes, as each jurisdiction tries to capture maximum benefits at minimum cost.

Policy Directions

The Business Council for Sustainable Energy has identified five broad elements needed for an effective energy efficiency strategy, these are set out below. An important first step however is to commit to energy efficiency targets.

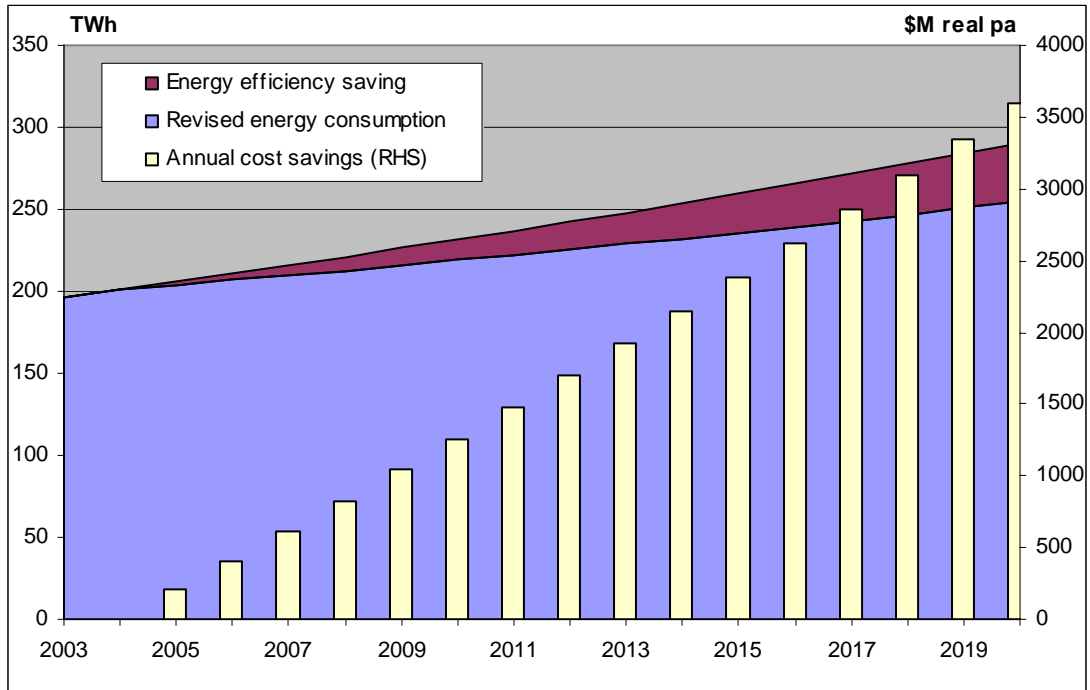
Implementing an energy efficiency target

An energy efficiency target can be stated in a number of different ways. As a starting point growth in energy consumption needs to be significantly reduced, a target to halve growth in consumption is roughly equivalent to the outcome in the Clean Energy Future study where energy consumption growth should be limited to a minimum 25 per cent increase in 2040 compared to 2001. Given that

electricity supply dominates greenhouse emissions a separate target needs to be established for electricity use. In addition interim targets also need to be established.

BCSE has undertaken some preliminary modelling to quantify the impacts of limiting the growth in electricity consumption. Based on assumptions included in the Energy White Paper (June 2004), a one percent per annum reduction in energy consumption to 2020 would result in cumulative energy savings of 36 TWh per annum by 2020 with a resultant saving in electricity cost to consumers of \$3.6 billion in 2020 (2004 dollars).

Impact of 1% per annum energy efficiency improvement



1. **Introduce broad-based market greenhouse price signal**

This is consistent with the Commission’s recommendations in its assessment of National Competition Policy.

There are two major types of signal can be used, preferably in combination;

- A greenhouse market signal, such as a comprehensive emissions trading scheme can provide a significant signal to large energy consumers. However, to limit administrative cost and complexity, emissions trading will focus on large emitters and energy conversion facilities and, as such, will be seen by smaller consumers as just a small increase in energy price. This is likely to have little impact on their behaviour. Further, for business development reasons, energy suppliers may prefer to try to limit their greenhouse costs by reducing the greenhouse intensity of their energy, rather than by encouraging customers to buy less of the product they sell. So, while emissions trading is important, it is unlikely to be sufficient to drive energy efficiency at point of use.
- An energy efficiency certificate trading scheme, such as the ‘white’ certificate schemes being developed overseas, or a scheme focused on energy suppliers, for example a scheme similar to the NSW Greenhouse Abatement Scheme (with fair treatment of demand side action). Creation of a tangible market in energy efficiency certificates, especially one that offers deeming (that is, creates certificates covering the lifetime of the efficiency

measure) at time of installation provides a way of focusing attention on energy efficiency. Deeming also provides a way of reducing the negative impact on adoption rates due to application of high discount rates by investors, as it provides a lifecycle benefit 'up front'

2. Make energy markets work for customers:

- (i) It is now widely recognised that reformed energy markets are failing to facilitate active involvement from the demand side. This is leading to over-investment in supply-side solutions. Price signals to energy customers should reflect their impact on network investments. Benefits provided by energy efficiency investments should be rewarded. DSM solutions to meet energy demand of all levels of sophistication should be rewarded equally with network solutions, through the following measures:
- Require electricity distributors to develop strategies and implement pricing approaches that encourage energy efficiency and implementation of greenhouse abatement activities;
 - Charge customers for the impact that they have on electricity system costs, specifically on a peak demand² basis.
 - Require distribution businesses to provide a series of standard offer rates that are available to energy efficiency, and other demand management options (including embedded generation). This would take the form of a negative congestion price that would be available for any activity that resulted in a reduction of power consumption. This creates a standard forward price, to which energy efficiency and DSM proponents would respond.
- (ii) Establishment of Demand Side Management Fund to support the development and implementation of demand side and local generation alternatives to network augmentation. Financing for the DSM fund could be sourced from a number of areas, including as a proportion of future capital expenditure a \$/kWh charge or as \$/kW on peak power needs. The funds need to be administered by an organisation independent of the distribution businesses and government.
- (iii) Remove distortions beyond energy markets that work against energy efficiency. For example, installation of an airconditioner for a business attracts the higher depreciation rate for machinery, while installing building improvements such as double glazing attracts the lower depreciation rate for buildings. And, of course, the cost of the extra electricity wasted by the airconditioner is tax deductible. Similarly, where a business replaces or repairs faulty equipment with similar equipment, it can claim the cost as maintenance, and receive a full tax deduction in that year. But if they upgrade efficiency, the Tax Office considers this to be a capital investment, so the business can only claim depreciation. For businesses focused on cash flow, this is a major barrier.

3. Regulate for minimum energy performance in the built environment.

It is now accepted by State and Commonwealth Governments, and by the building industry itself, that regulation is essential if building energy performance is to be improved. However, regulation should extend beyond just the building envelope: the NSW Government's BASIX system provides a useful model of how this could be done.

² In the Charles River Associates report for Integral Energy it was found that customers without air conditioners were subsidising customers with them to the tune of \$80 to \$100 million per annum. The cost to add network related to peak demand was found to be \$91 per kW per annum (page 26 of the report). The contribution of customers with air conditioners was about \$1 per annum.

Further, it is critical that regulation includes mechanisms for ensuring accountability based on actual performance. The Australian Building Greenhouse rating Scheme's commitment agreement provides a model for linking development and construction of buildings to accountability for performance, and this approach must be applied more widely. There is also an urgent need to apply regulation to renovations and existing buildings.

The Ministerial Council on Energy's has agreed to introduce requirements for disclosure of energy performance at time of resale and leasing. However, it is important that this disclosure goes beyond a design-based building thermal rating (such as EERSOP in ACT) and reflects the efficiencies and likely running costs of fixed equipment such as water heaters, lighting and space conditioning, as well as any on-site generation such as PV. These factors feed into energy bills, so that an effective disclosure mechanism could play an important role in improving the competitiveness of business tenants, and improving equity for residential tenants. It is also desirable that there be incentives to move beyond basic compliance with regulations.

In addition, first home buyer grants could be linked to building and equipment energy efficiency, and could scale down as house size increases beyond a reasonable area. Incentives play a useful role in rewarding innovation and sending a signal to the community that the government supports excellence.

4. Drive a more energy efficient manufacturing industry.

The energy efficiency performance of Australian business is not outstanding, indeed the NFEF claimed that it is below average for developed countries. While Australia's relatively low energy prices account for part of the explanation, programs such as Energy Efficiency Best Practice and state government programs have shown that there is substantial potential for cost-effective savings, many of which also add to business success by improving product quality or plant productivity. A combination of requirements for implementation of economic energy efficiency measures (based on experience of programs such as EPA Victoria's greenhouse requirements for industrial licence holders) and information, analysis and demonstration are needed. Appropriate policy measures would include:

- Mandatory requirement for large energy users to undertake energy audits and report on performance, be required to undertake investment if meets minimum four year pay-back.
- Development of cogeneration targets and incentives to support the assessment and implementation of cogeneration
- Support the funding of feasibility studies for cogeneration and innovation in energy efficiency based on the SEAV Business Energy Innovation Initiative (BEII) model.
- Re-institute funding support for the successful Energy Efficiency Best Practice Program that worked on an industry basis to improve energy efficiency.

5. Develop the emerging energy services industry.

This means building capacity within energy consuming businesses, suppliers and installers of products and services. To achieve this requires a multi-faceted approach that includes creating sustained demand for energy efficient goods and services by driving commercialisation, innovation and regulation, while providing training and education. The attached Allens Report provides a detailed discussion of the importance of developing industry capacity and capability as a way to reduce costs long term.

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Attachments to this submission:

Allen Consulting Group Report – “The Energy Efficiency Gap – Market Failures and Policy Options”

Clean Energy Future for Australia

Productivity Commission

Preliminary Assessment

National Competition Policy and Beyond

Media Release, Wednesday 27 October 2004

Impact of 'Rebound Effect'

The following discussion has been extracted from Pears (2004) with the author's permission.

In broad terms, there are two dimensions to the 'rebound' effect:

Technological/cultural rebound: as a result of application of the energy efficient technology, the level of service provided increases: this may result from one or both of an increase in technological capacity to deliver service (eg a water-saving showerhead means you can shower longer before running out of hot water) and a change in affordability of using energy (heating my home is cheaper, so I will heat to a higher temperature). At the extreme, this can lead to a situation where additional investment in more energy-intensive equipment occurs because of the increased technological capability. For example, the owner of a space-heated home may find that, when it is insulated, the space heater can heat most of the home, so (s)he may then invest in a central heating unit in the (probably correct) belief that it will not cost too much more to run and the house will be very comfortable. Another example is where introduction of LCD flat panel monitors leads users to specify larger screen size and/or multiple screens.

Economic rebound: if saving energy saves money (after the cost of the measure has been repaid), then that money will flow through the economy, which may lead to additional energy use.

Technological/cultural rebound

Technological/cultural rebound is a complex phenomenon. Often the energy saving action is 'blamed' for changes that simply reflect underlying trends anyway. For example, each generation of new computers since the desktop computer became available has included larger screens, and multiple screens have begun to be adopted as new software has supported this feature. In that sense, the performance of the LCD screen should be judged against the existing trend, not the product it replaced. Similarly, there are strong trends towards whole house, all year comfort conditioning of houses. With showers, trends towards multiple bathrooms and smaller households have been leading to installation of larger capacity hot water services (and 'continuous flow' units) that are less likely to run out of hot water when people have long showers, regardless of energy efficiency strategies. Base demand for an energy service can also be influenced by cultural values (for example, in times of drought, people take shorter showers) and other unrelated factors, such as trends in hair length and introduction of combined shampoo/conditioner products.

So, when considering this form of rebound effect, it is more appropriate to look at the issue as an outcome of cultural values (which are amenable to change via education and information programs) and evolution of demand for services that involve energy use. In developing scenarios for the future, it is appropriate to assume that people will seek higher levels of comfort and amenity, but these trends have upper limits. For example, house size is constrained by many factors, while the length of a shower is constrained by the need to go to work or the tendency for skin to shrivel up.

Economic rebound

The term economic rebound effect is really only one side of the coin. The reality here is that the overall energy outcome depends on the energy intensity of the activity that is reduced and saves money, relative to the energy intensities of the activities on which the saved money is spent. A number of outcomes are possible:

If the money saved flows through the economy and is allocated to more energy intensive activity than that avoided, total energy consumption increases. This is a critical issue in some economic models. As an extreme example, if a household energy consumer saves a dollar on energy and uses this to buy an ingot of aluminium (about the most energy intensive thing it's possible to do) then the energy consequences are significant. The householder's dollar saving is the outcome of saving 7 kilowatt-hours of electricity. However, spending a dollar on aluminium involves allocating around 30 cents of that dollar to electricity use, but at a price of about 3 cents/kilowatt-hour – an increase in energy use in the aluminium industry of 10 kilowatt-hours would occur. So the net outcome is an *increase* in energy consumption of 3 kWh, a very significant rebound effect.

If the money saved is used to buy more energy-consuming equipment (for example, buying an extra heater), then direct energy use will increase but, since only a proportion of the purchase and ongoing costs of the new activity are covered by the energy saving, the household's expenditure on energy will increase at the expense of expenditure on other activities, and energy use elsewhere in the economy driven by that household's expenditure will decline. Since energy consumers often buy energy-consuming equipment with little regard for its long-term energy costs, quite large rebound effects may occur. This option often includes an element of technological/cultural rebound, as discussed above, which may further increase the size of the rebound effect.

If the full cycle (i.e. considering all flows through the economy) energy intensity of the activity on which the money saved through energy efficiency is spent is similar to the intensity of the energy supply sector, there will be a negligible rebound effect, because the same amount of energy is being used throughout the economy by the dollar, whether it is used to buy energy for the householder or for the alternative service.

If the money saved is spent on a lower energy intensity activity (such as hiring a DVD or paying for cable TV), then there may actually be a savings *amplification* effect, as the level of indirect energy use in the economy will be reduced by the shift in expenditure, while the household will continue to use less energy due to the efficiency improvement.

If the money saved is invested in other energy saving measures (for example, if the person is so happy with their high efficiency fridge that they use their savings to buy other energy efficient appliances when they would otherwise not have done so) then there is a larger amplification effect because they save even more. Further, it is likely that widespread behaviour of this kind will influence the behaviour of manufacturers who are more likely to improve the efficiency of their products and services in order to maintain market share. Since the energy cost of energy efficient appliances is usually similar to or less than that of inefficient appliances, and one is substituting for the other, there should be limited or beneficial indirect energy impacts.

If the money saved is invested in infrastructure used to manufacture energy saving equipment or systems (for example, the person invests savings in an insulation company or a company that makes energy efficient products) then an even larger amplification effect occurs, because the manufacture and delivery of energy efficient products and services displaces inefficient ones.

The point of discussing these various possible outcomes of improving energy efficiency is to highlight the fact that they can vary from large rebound effects to large amplification effects. Policies, education and information can influence the outcome. For example, driving aggressive mandatory energy efficiency standards with quite long payback periods diverts money towards investment in energy efficiency and away from other economic activity, reducing the rebound effect. Through changing the behaviour of product and service suppliers, it can also transform the outcome into an amplification effect. Promoting investment in businesses that offer energy efficient products and services can build this sector of the economy, displacing businesses that deliver inefficient alternatives.

It is also important to recognise that economic models often incorporate past relationships between sectors so that they may overstate rebound effects. For example, if in recent history energy intensive

activity has grown faster than the rest of the economy, then allocating money freed up by energy savings across the economy based on past experience will 'drive' more rapid growth of energy intensive industry in the modelling when there may be no other reason to expect such growth. This seems to be a significant factor in modelling the impacts of response to climate change on the Australian economy.

The Allen Consulting Group

The Energy Efficiency Gap

Market Failures and Policy Options

November 2004

Report to the Business Council for Sustainable Energy, the Australasian Energy Performance Contracting Association and the Insulation Council of Australia and New Zealand

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Contents

<i>Executive summary</i>	<i>iv</i>
<hr/>	
Chapter 1	11
<i>Introduction</i>	<i>11</i>
1.1 Report objectives	11
1.2 Structure	12
<hr/>	
Chapter 2	13
<i>The Energy Efficiency Gap</i>	<i>13</i>
2.1 Defining energy efficiency and the energy efficiency gap	13
2.2 Trends in energy efficiency in the Australian economy	17
2.3 The 'efficiency gap' in Australia	22
<hr/>	
Chapter 3	25
<i>Market failures impeding energy efficiency</i>	<i>25</i>
3.1 Energy market issues	25
3.2 Markets for energy efficient technologies and services	30
3.3 Barriers that are not market failures	31
3.4 Barriers that represent market failures	33
3.5 Barriers that represent organisational failures	36
3.6 Conclusions	42
<hr/>	
Chapter 4	44
<i>Cost effective policy for energy efficiency</i>	<i>44</i>
4.1 The key barriers to energy efficiency	45
4.2 Policy options	47
4.3 Analysis of policy options	47
4.4 Relative prices	49
4.5 The information gap	55
4.6 Organisational failures	60
4.7 Conclusions	70
<hr/>	
Chapter 5	72
<i>Costs and benefits of improving energy efficiency</i>	<i>72</i>
5.1 NFEE study	72
5.2 Sectoral considerations	74
5.3 Conclusions	75
<hr/>	

Executive summary

This report was commissioned by the Business Council of Sustainable Energy (BCSE), the Australasian Energy Performance Contracting Association (AEPCA), and the Insulation Council of Australia and New Zealand (ICANZ), to assess whether there is a rationale for policy intervention to improve investment in energy efficiency in the stationary energy sector in Australia.

Project objectives

The objective of this report is to identify, for the stationary energy sector, the:

- extent of the 'energy efficiency gap';
- barriers and failures in the markets for energy and energy services that might be contributing to the energy efficiency gap;
- policy options to address market failures that are impeding cost effective investment in energy efficiency; and
- costs and benefits of overcoming the energy efficiency gap.

Defining energy efficiency

Energy efficiency for the purposes of this report is defined as maintaining or increasing the level of useful economic output delivered per unit of energy consumption. In this context, this report considers whether cost-effective reductions in energy consumption are available given existing levels of economic output, or alternatively, whether cost effective increases in economic output are available given existing levels of energy consumption.

This definition of energy efficiency leads us into an understanding of the 'energy efficiency gap'. The energy efficiency gap is defined as the potential energy efficiency that is precluded by the possible existence of market failures. The existence of market *failures* by definition implies that there is potential for cost effective policy to overcome the market failure and thereby improve economic welfare. In contrast, there are also market *barriers* impeding uptake of energy efficiency that are common to other markets in the economy, which are not amenable to policy intervention.

Key market and organisational failures impeding uptake of energy efficiency

A range of barriers in the market for energy efficiency are identified (Table ES.1). In addition, there are also barriers in the market for energy, which is a key substitute for investments in energy efficiency. To the extent that policies are available to reduce these barriers in a cost effective manner that raises overall economic welfare, then the barriers can be considered to be market failures.

Table ES.1

BARRIERS IN THE MARKET FOR ENERGY EFFICIENCY

Category	Particular instance
Barriers that may represent market failures	<ul style="list-style-type: none"> • Public good attributes of information associated with energy efficient technologies • Positive externalities of adopting energy efficient technologies • Adverse selection in energy services markets • Moral hazard & principal-agent relationships in energy services markets • Split incentives in energy services markets
Barriers that may represent organisational failures	<ul style="list-style-type: none"> • Imperfect information on organisational energy use • Moral hazard & principal-agent relationships within organisations • Split incentives within organisations
Barriers that may represent rational behavior	<ul style="list-style-type: none"> • Heterogeneity • Hidden costs (e.g. overhead costs, disruption) • Risk (technical or business) • Access to capital

Source: S.Sorrell, J.Schleich, S.Scott, E.O'Malley, F.Trace, U.Boede, K.Ostertag and P. Radgen, 2000, *Barriers to Energy Efficiency in Public and Private Organisations*, SPRU Environment and Energy, www.sussex.ac.uk/Units/spru/environment/research/barriers.html, p26.

Key market or regulatory failures warranting consideration for policy intervention to improve uptake of energy efficiency include:

Related to issues of incorrect relative prices:

- Incorrect relative prices in markets for energy:
 - Regulated energy prices set below the incremental costs of generation, transmission and distribution, particularly for peak loads;
 - Inadequate institutional arrangements for considering energy efficiency as an alternative to network augmentation;
- Lack of incorporation of externalities in energy pricing;

Not related to issues of energy prices:

- Information failures;
 - Imperfect information, including under-provision due to public good aspects;
 - Asymmetric information, including adverse selection;
 - Principal/agent problems, including split incentives;
- Multiple decision makers;
 - Firm/agent external organisational constraints; and

- Firm/agent internal organisational and bounded rationality constraints.

Policy options for energy efficiency

Good policy should aim to close the energy efficiency gap by addressing market failures at source, cost effectively. In light of the key barriers outlined above, policies therefore could aim to:

- ensure appropriate relative prices;
- overcome information failures;
- reduce organisational barriers and bounded rationality preventing uptake of cost effective energy efficiency.

Relative prices

Improving relative price signals for energy efficiency relates largely to improving the price regulation of the supply of energy, however, policies to address environmental externalities are also important. Key measures include:

- more efficient price signals for the consumption of energy, particularly congestion pricing;
- improved processes and incentives for consideration of load management as alternatives to network expansion; and
- incorporating environmental externalities related to greenhouse gas emissions in energy prices.

Improved congestion pricing, and load management as an alternative to network augmentation, are judged to have relatively small impacts on uptake for energy efficiency. Nevertheless, there are valid reasons for undertaking these measures on other grounds (for example, more efficient markets for energy through load shifting, better network capital utilisation etc).

Policy action to address the environmental externalities of greenhouse has potential to increase average energy prices and result in improved energy efficiency. Nevertheless, while large energy users are likely to respond reasonably efficiently to changes in relative prices for energy, smaller users may not — to the extent that there are other non-price market failures impeding uptake of energy efficiency.

Information failures

Markets for energy are susceptible to information failures. As a result, end users lack awareness of many cost effective opportunities. The most powerful and direct policy mechanisms to address information failure include:

- government funding for information provision;
- energy performance disclosure;
- codes and standards; and
- transforming markets, including developing an energy services industry.

The existence of information gaps in relation to energy efficiency is well accepted. As a result, all the policies measures outlined above to encourage information provision — bar policies to specifically develop an energy services industry — already have been adopted within Australia. Given their low cost and utility in directly addressing information failure and bounded rationality, they should continue to be part of any package to optimise investment in energy efficiency.

Organisational failures and bounded rationality

Individuals (and by extension also firms) can lack the capacity to assess energy efficiency opportunities adequately due to problems of bounded rationality.¹ Firms can also suffer from organisational failures due to a lack appropriate systems and incentives for considering energy efficiency opportunities. High transactions costs associated with implementing energy efficiency also contribute to the lack of uptake.

'Transforming the market' for energy efficiency services and products has the potential to deliver cost effective demand side alternatives. Market transformation policies would aim to achieve a self-sustaining change in end-users' ability to implement cost effective investments in energy efficiency. An external industry supplying energy efficiency services could be an important part of this policy strategy, reducing transactions costs and therefore helping to overcome both internal and external organisational constraints.

However, the primary barriers to energy efficiency originate in a lack of awareness, bounded rationality and inappropriate incentives structures for firms and individuals. The range of secondary market failures related to inappropriate relative prices compounds these problems.

Optimal policy approaches for energy efficiency should target these primary market failures, thereby raising demand for energy efficiency services. With demand for energy efficiency established, it is likely that the supply of energy efficiency services could expand readily to meet the increased demand.

Key mechanisms to address firms' and individuals' behaviour include:

Voluntary mechanisms

- voluntary agreements for energy efficiency;

Price based mechanisms

- tax exemptions or subsidies for energy efficiency products;
- subsidies for energy services delivery and market transformation.

Regulation (control) mechanisms

- minimum energy performance standards (MEPS);
- government leadership;
- mandatory energy efficiency audits and implementation requirements; and
- tradable energy efficiency targets.

¹ 'Bounded rationality' refers to the limits individuals have in formulating and solving complex problems and in processing information.

Voluntary agreements, MEPS, government leadership and the mandatory audits/implementation approach work to directly influence end user behaviour. However, voluntary agreements and the mandatory audits/uptake approach are less suitable for smaller consumers. Nevertheless, both these policies can be considered as mechanisms to improve energy efficiency outcomes for larger companies.

MEPS are a key option to address directly the identified awareness and bounded rationality problems of smaller end users. However, while MEPS are important, they do not help to change the underlying organisational and behavioural failures. Targeting these failures directly for smaller consumers is difficult.

Incentives for energy efficiency offer a second best solution. Key incentive mechanisms include taxes and subsidies for energy efficiency products, subsidies for delivery of energy services to end users, and mandatory sourcing of energy efficiency through energy efficiency targets, for example applied to energy retailers. The latter two approaches can be similar, in that they both can involve an energy charge to raise funds, and then apply the funds to encouraging increased uptake of energy efficiency. However, subsidising delivery of energy services is likely to have lower costs of implementation, be easier to establish, and is likely to be more flexible in response than the mandatory targets approach.

Costs and benefits of improving energy efficiency

In the Australian context, the most recent and comprehensive large scale assessment of opportunities for energy efficiency at current prices are the studies conducted for the National Framework for Energy Efficiency (NFEE). The NFEE phase 2 estimates are extremely conservative. Even at this conservative level, the NFEE studies suggest that there are opportunities to deliver energy reductions within the next decade of around 10 per cent — across the residential, commercial and industrial sectors — at internal rates of return exceeding 50 per cent.

The pay-off is large. General equilibrium economic modelling of the NFEE estimates indicates that the adoption of 50 per cent of the identified energy-saving improvements leads to a range of economic, social and environmental benefits. GDP is just under \$1 billion higher than otherwise by year 12, while employment and environmental outcomes are improved (Table ES.2).

Table ES.2

SUMMARY OF ECONOMIC IMPACTS OF IMPROVED ENERGY EFFICIENCY^a

<i>Macroeconomic variable</i>	<i>Change relative to base case (year 12)</i>
GDP (\$m)	975
Real Private Consumption (\$m)	724
Employment (persons)	2,600
Greenhouse Gas Emissions (Mt of CO ₂ -e)	-9.5
Energy Use (petajoules)	-75.5

^a Relates to the 50 per cent – low scenario.

Source: MMRF-GREEN.

Many studies have suggested that a range of 'hidden' costs serve to reduce these highly favourable investments. For example, a recent comprehensive study by Science and Technology Policy Research Unit at the University of Sussex found that salary overheads for energy managers can be a significant hidden cost, but also questioned whether this practice was rational.

In the case of the NFEE phase 2 estimates, transactions costs of 7.5 per cent were included in the estimates. This, combined with their extremely conservative nature, mean that even if there are significant hidden costs that have not been accounted for, the overall returns are still likely to remain high compared to other standard internal rates of return in the economy. (Recall that the internal rates of return of the identified energy efficiency opportunities are in excess of 50 per cent.) Furthermore, the returns to the economy from the overall expansionary effects of the measures are estimated to add a further 4.5 per cent to the first round savings. This provides a further buffer against 'hidden costs'.

Conclusions and recommendations

Given the diverse market failures outlined above it may be difficult to rely on a single policy instrument to achieve cost effective uptake of energy efficiency. Rather, a package of policy instruments that selectively targets key market failures is required. The utility of the package approach is further supported by the heterogeneous nature of the markets for energy services (residential, commercial, industry and energy-intensive end users).

The following package of policies is likely to offer the most cost effective approach to overcome the energy efficiency gap:

- energy market pricing and institutional arrangements that reward cost effective investments in energy efficiency and provide a signal on the need to address the emerging greenhouse externality;
- information disclosure through labelling and cost effective minimum energy performance standards for appliances, equipment and buildings;
- mandatory energy efficiency audits and uptake for larger firms in the mining, manufacturing and services sectors;
- competitive sourcing of energy efficiency products and services that aims to:
 - increase awareness of opportunities and reduce bounded rationality and organisation barriers, particularly for smaller end users;
 - transform the market to improve the energy efficiency of appliances, equipment and buildings; and
 - reduce transactions costs of adopting energy efficiency goods and services by developing the energy services industry.

Finally, it is a key weakness for policy analysis that most empirical studies of energy efficiency are based on *ex ante* estimates — that do not follow up after the policy has been implemented to establish the extent to which actual savings are achieved, or the costs of implementation. Consequently, there is very little insight into the true extent of hidden costs that might explain the lack of uptake of energy efficiency opportunities. This points to the importance of conducting rigorous follow-up evaluation of actual costs and savings achieved in any future policies or programs, and also the value of identifying what market failures were overcome, and how. The competitive sourcing approach provides the flexibility to pilot sectoral policy approaches, evaluate outcomes — and then fine tune the approaches in response to the success or otherwise in addressing the primary organisational and behavioural failures.

Chapter 1

Introduction

In November 2002 the Ministerial Council on Energy (MCE) endorsed a proposal for the development of a National Framework for Energy Efficiency (NFEE) to define future directions for energy efficiency policy and programs in Australia. This response recognised the need for a significant improvement in energy efficiency in Australia.

The NFEE aims to 'unlock the significant but un-tapped economic potential associated with the increased implementation of energy efficient technologies and processes across the Australian economy to achieve a major enhancement of Australia's energy efficiency performance'.²

In August 2004, the MCE agreed to the implementation of nine policy packages constituting the first stage of NFEE, and to the investigation of broad-based incentive measures that could be considered for inclusion in a second stage.³ The second stage of the NFEE is to be developed in the context of the Productivity Commission's inquiry into energy efficiency, which is due to report in 2005.

The Productivity Commission inquiry into energy efficiency results from a request from the Australian Government for it to examine and report on the 'economic and environmental potential offered by energy efficiency improvements which are cost-effective for individual producers and consumers'.⁴ The Commission was also asked to consider the barriers and impediments to improved energy efficiency. The terms of reference for the Inquiry encompass both supply side (electricity generation and other primary energy conversion) and demand side (end use) efficiency. Both stationary energy use and energy used in transport are included in the terms of reference.

1.1 Report objectives

This report was commissioned by the Business Council for Sustainable Energy, the Australasian Energy Performance Contracting Association, and the Insulation Council of Australia and New Zealand to assess whether there is a rationale for policy intervention to improve investment in energy efficiency in the stationary energy sector in Australia. The report will inform these organisations' submissions to the Productivity Commission's Inquiry.

The objective of the report is to identify, *for the stationary energy sector*, the:

- extent of the 'energy efficiency gap';
- barriers and market failures that might be contributing to the energy efficiency gap;
- policy options to address market failures impeding cost effective uptake of energy efficient opportunities; and

² Ministerial Council on Energy 2004, *Communiqué*, 27 August

³ Ministerial Council on Energy 2004, *ibid.*

⁴ Productivity Commission 2004, *Inquiry into Energy Efficiency: Issues Paper*, www.pc.gov.au.

- costs and benefits of overcoming the energy efficiency gap.

1.2 Structure

The remainder of this report is structured as follows.

Chapter 2 defines the term 'energy efficiency gap', and identifies the difference between a market barrier and a market failure. The Chapter also presents evidence on Australia's relative performance in investing in energy efficiency, and recent evidence on opportunities to improve energy efficiency.

Chapter 3 considers market barriers and failures in the market for energy services that could explain the energy efficiency gap. It also considers related barriers originating in the market for energy that have bearing on the market for energy services. The Chapter concludes by identifying the market failures that are likely to be contributing to under-investment in energy efficiency in Australia.

Chapter 4 assesses policies for addressing the key market failures identified in Chapter 3. It concludes with a preferred package for future policy action to improve resource allocation through investment in energy efficiency.

Chapter 5 concludes the report by considering the costs and benefits of taking action to address under-investment in energy efficiency.

Chapter 2

The Energy Efficiency Gap

It is frequently asserted that there exist significant, cost-effective opportunities for increasing energy efficiency that fail to be adopted as common practice. This is true within Australia and abroad, and has long perplexed economists and policy makers alike. Why do people not invest in more energy efficient housing, for example better insulation, when it is in their economic interest to do so? Why do consumers overlook energy efficient appliances that will save them money in the long run?

This chapter indirectly canvasses some of these driving questions and sets out the context for a discussion of potential obstacles to the uptake of energy efficiency opportunities. Specifically, this chapter frames the ‘energy efficiency gap’ problem within Australia by:

- defining precisely what is meant by ‘energy efficiency’ and an ‘energy efficiency gap’;
- exploring trends in energy efficiency in Australia compared with other IEA member countries; and
- examining existing evidence about a potential energy efficiency gap in Australia.

This provides the foundation for an in-depth discussion of factors impeding energy efficiency uptake and potential solutions in subsequent chapters.

2.1 Defining energy efficiency and the energy efficiency gap

The term ‘energy efficiency’ can be deceptively simple. As noted by the Productivity Commission, energy efficiency can mean many things to different people.⁵ In order to conduct a useful examination of the issue, as well as any potential impediments to its uptake, we must first make plain the definition of energy efficiency — highlighting not only what energy efficiency is, but also what it is not.

Energy efficiency, for the purposes of the Productivity Commission’s Inquiry into Energy Efficiency, is defined as ‘maintaining or increasing the level of useful output or outcome delivered, while reducing energy consumption.’ Added to this, the Productivity Commission also adopts an economic approach to energy efficiency, noting that:

There is often a trade-off between using less energy and using more of another input. Many different combinations of energy and other inputs might be ‘technically’ efficient ways of producing a given level of output. An economic approach to the efficient use of energy takes into account the costs of all inputs, in order to discover which technically efficient combination of inputs is the least cost way of producing a given output.⁶

⁵ Productivity Commission, 2004, *Energy Efficiency Issues Paper*, www.pc.gov.au p 11.

⁶ Productivity Commission, 2004, *ibid*, p 11.

In line with these observations, energy efficiency for the purposes of this report is defined as maintaining or increasing the level of useful economic output delivered per unit of energy consumption. In this context, this report considers whether cost-effective reductions in energy consumption are available given existing levels of economic output, or alternatively, whether cost effective increases in economic output are available given existing levels of energy consumption.

This definition of energy efficiency leads us into an understanding of the ‘energy efficiency gap’. Like the definition of energy efficiency, the definition of a gap can be more complex than it appears at first glance.

The assertion that there is a gap implies that there is some optimal level of energy efficiency uptake — meaning, equivalently, an optimal application of energy savings capital equipment and services — and that the actual uptake of energy efficiency opportunities differs from this optimal rate of diffusion. For example, the Productivity Commission has defined the energy efficiency gap in the following way:

The term ‘energy efficiency gap’ describes the difference between the most energy efficient processes and technologies available and those actually in use.⁷

This seems plain enough. However, the definition of the gap becomes less clear when one attempts to identify what should optimally be taken up by industry and consumers. To say simply that a more energy efficient process or technology becomes available does not necessarily imply that it is optimal for society to adopt this practice. For example, this definition ignores some of the subtleties drawn out in the Productivity Commission’s earlier definition of energy efficiency in that it does not consider the economics underpinning the uptake of available technologies versus those actually in use.

Thus in order to define the energy efficiency gap, we need to examine the different concepts of optimality, which are developed by considering the different types of impediments slowing or preventing the uptake of energy efficiency. The diffusion of energy efficiency improvements may be impeded by:⁸

- *Market failures* — There are many potential theoretical barriers to the uptake of energy efficiency options. Even noting that the diffusion of energy efficiency improvements is a gradual process like the diffusion of any other technology, there appear to be potential market failures slowing the observed diffusion rate, including:
 - failures in energy markets, such that consumers are not subject to appropriate price signals for energy, including for environmental externalities, and therefore lack proper incentives to invest in energy efficiency as a substitute for energy;
 - imperfect information; and
 - organisational failures due to multiple decision-makers, both inside the firm and in markets for energy efficiency.

⁷ Productivity Commission, 2004, *ibid*, p 10.

⁸ The existence or non-existence of barriers to energy uptake is discussed in greater detail in subsequent chapters. Nevertheless, for the purposes of defining the energy efficiency gap, we need to identify some of the potential factors slowing or preventing the adoption of improved energy efficiency practices.

In the case of market failure, a cost effective policy response, which is shown to result in a better social outcome, may be an appropriate tool for increasing the diffusion rate of energy efficiency measures.

- *Market barriers or impediments that are not market failures* — Some market barriers that might slow the diffusion of more energy efficient technologies or processes are *not* market failures. Impediments of this type that might contribute to the energy efficiency gap include:
 - uncertainty about future energy prices and hence the potential savings from an investment in energy efficiency, resulting in individuals applying a higher discount rate than is typically used to show the existence of a gap (although if there is scope for governments and/or others to act in ways that are cost-effective to reduce the level of perceived risk and hence the discount rate applied, then this could be classed as a market failure);
 - the non-account of intangible differences between goods, such as differences in qualitative attributes between more and less energy efficient products;
 - hidden costs excluded from studies that show an energy efficiency gap, such as costs of adoption;
 - heterogeneous outcomes for different consumers, in that while the process may be shown to be cost-effective on average, there will be populations for which the adoption is not cost-effective due to different behaviour or usage patterns;
 - constraints on capital; and
 - inertia in adoption behaviour that is widespread across all economic activities.

To the extent that the energy efficiency gap exists as a result of market barriers that are not market failures, policy responses are not required.

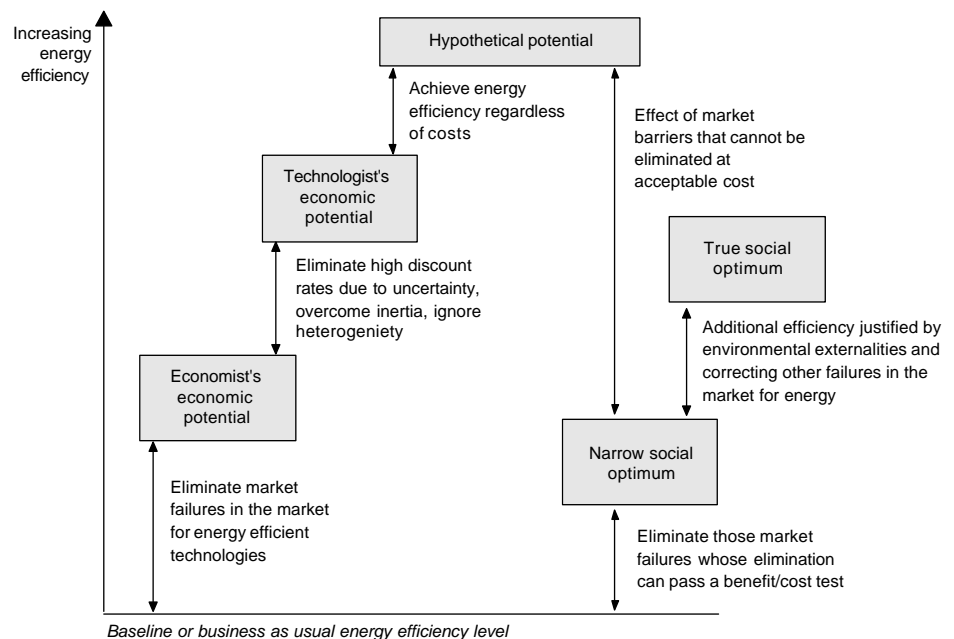
Hence what is optimal depends on which market failures one believes to be present and preventing the uptake of more energy efficient technologies or processes, and whether these market failures could feasibly be overcome.

Figure 2.1 below illustrates the different potential definitions and corresponding size of the energy efficiency gap. The horizontal axis represents the theoretical observed rate of energy efficiency diffusion. The vertical y-axis shows increasing levels of energy efficiency diffusion; the higher up on the axis, the greater the uptake of available energy efficiency opportunities. Using this Figure as a road map, we can explore alternate definitions of optimality. Starting from the bottom left, the Figure shows the economist's conception of optimality — where the elimination of any existing market failures will raise the observed rate of uptake by some corresponding amount.

If one also considers other potential market barriers, which are not market failures but still impede the spread of energy efficiency technologies, then the potential size of the energy efficiency gap is increased. This is articulated as the technologist’s conception of optimality (and corresponding definition of the energy efficiency gap). If the Productivity Commission were to ignore the cost effectiveness of adoption, then this would be the appropriate definition of the energy efficiency gap. However because the Commission is also concerned with overall economic welfare and hence the costs of adoption, the economist’s definition of optimality and associated energy efficiency gap estimation is more appropriate.

Figure 2.1

ALTERNATE CONCEPTIONS OF OPTIMALITY AND ‘ENERGY EFFICIENCY GAPS’ IN THE MARKET FOR ENERGY EFFICIENT TECHNOLOGIES



Source: Adapted from A.B. Jaffe and R.N. Stavins, 1994, The Energy Efficiency Gap: What Does It Mean?, *Energy Policy* 22 (10), p 808.

Figure 2.1 also includes the potential impact of reforming energy markets to achieve efficient relative prices, such as ensuring appropriate cost reflective pricing signals for energy. This is an important consideration for optimum uptake of energy efficient technologies, although is not an explainer for the energy efficiency gap *at current prices*.

On the right hand side, Figure 2.1 examines social optimality. The narrow social optimum in the market for energy efficiency technologies is defined as the rate of energy efficiency uptake that would be observed if all barriers that were deemed to be irrational on a cost-benefit basis were eliminated — that is, if people adopted all measures that would leave them economically better off given the current pricing environment (for example, where greenhouse gases are not priced). In addition, we are also interested in getting energy prices right, implying that the narrow social optimum should include cost effective removal of market failures in the market for energy. The ‘true’ social optimum would include the additional efficiency diffusion that would likely be seen if the negative externalities associated with greenhouse gas emissions were also priced.

Therefore caution needs to be applied in defining the energy efficiency gap. In light of the focus on cost-effective reductions in energy consumption for a given level of output, we would characterise the energy efficiency gap for the purposes of the Commission's Inquiry according to the economist's definition of an energy efficiency gap — that is conceptually equal to the potential uptake of energy efficiency precluded by the possible existence of market failures. The application of the cost-effectiveness criteria indicates that the Productivity Commission's inquiry will result in a presentation of means by which Australia's rate of improvement in energy efficiency might be brought into line with the narrow social optimum, but specifically excluding externalities relating to climate change.

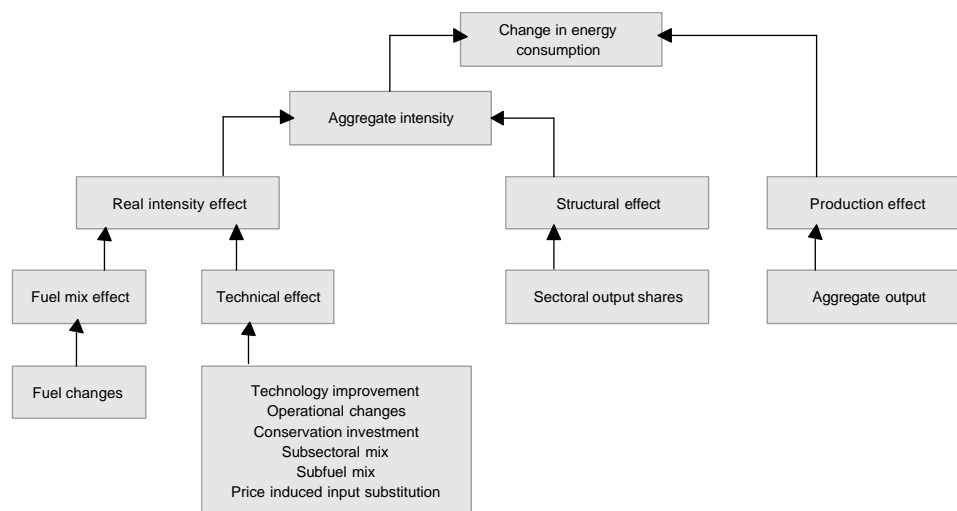
By excluding externalities relating to greenhouse gas emissions, the Terms of Reference of the Commission's Inquiry limit consideration of energy efficiency options to a sub-set of those that could feasibly be cost-effective, both at the private and societal level.

2.2 Trends in energy efficiency in the Australian economy

Building on this conceptual framework for understanding the possible existence of an energy efficiency gap, we now consider trends in energy efficiency improvements in Australia. It is first important to distinguish that changes in aggregate energy use are not the same as changes in aggregate energy efficiency. Figure 2.2 shows the components of changes in aggregate energy use, showing changes in energy efficiency to be a sub-component influencing movements in aggregate energy consumption.

Figure 2.2

FACTORS OF CHANGES IN ENERGY USE



Source: Adapted from ABARE, 2003, *Trends in Australian Energy Intensity: 1973-74 to 2000-01*, report for the Ministerial Council on Energy.

As the figure highlights, changes in energy use over time are explained by:

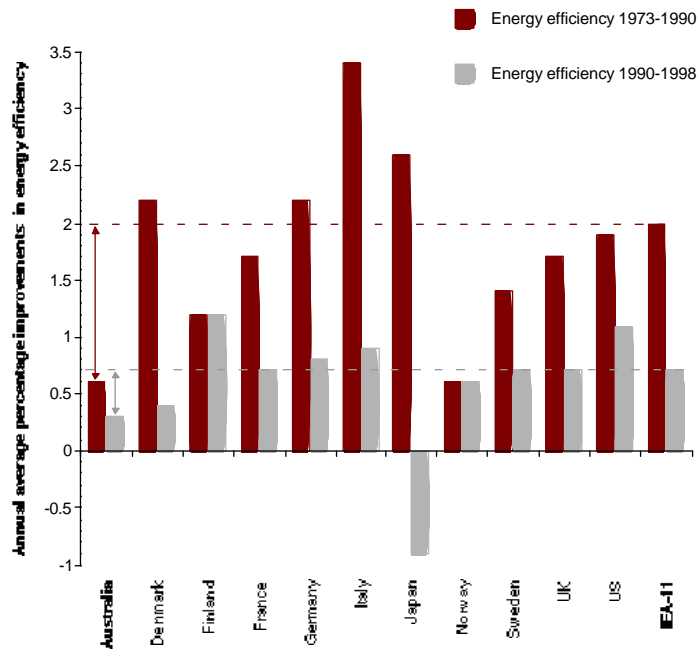
- Changes in the level of economic growth — the *production* effect. To the extent that economic activity expands or contracts, energy use will also increase or decrease, respectively, all other things being equal.
- Shifts in the composition of the economy to or from energy intensive activities — the *structural* effect. Different industries require different levels of energy per unit of economic output, and further over time the structure of economies will change as different industries grow or decline as a proportion of total economic activity. As the mix of industries in an economy shifts, so will the overall economy's total need for and usage of energy per unit of economic output.
- Changes to fuel input choices — the *fuel mix* effect. Inputs for economic activity have different energy values. Some fuel types have very high energy content and potential conversion efficiencies. As the use of fuel inputs shifts from lower conversion efficiency to higher conversion efficiency fuels, its usage of primary energy will decrease for a given level of useful energy output. Conversely, as the use of fuel inputs shifts from higher energy content to lower energy content fuels, its aggregate usage of energy will increase.
- Changes to alternative, efficient technical practices — the *technical* effect. The technical effect captures all changes due to improved technology, component uses or optimal operational practices. Thus if a process is developed that allows an output to be produced using less energy, this change will be included in the technical effect.

It is with the last effect — the technical effect — with which this discussion is primarily concerned. Trends in aggregate Australian energy efficiency diffusion are measured by movements in this parameter.⁹

In order to gain a sense of Australia’s progress in energy efficiency uptake, it is useful to benchmark its rates of diffusion against other international jurisdictions — specifically International Energy Agency (IEA) member countries. These countries — which include the United Kingdom, the United States and other European countries — share similar socio-economic and technological development pathways and therefore represent an appropriate sample set against which to measure Australia’s relative performance in energy efficiency uptake.

Figure 2.3

AVERAGE ANNUAL IMPROVEMENTS IN ENERGY EFFICIENCY BY IEA MEMBER COUNTRIES — FROM 1973-1990 AND 1990-1998



Source: The Allen Consulting Group, adapted from information available in F. Unander, 2003, *From Oil Crisis to Climate Challenge: Understanding CO₂ Emission Trends in IEA Countries*, prepared for the IEA.

⁹ However, the Productivity Commission do say that they are interested in the efficiency of conversion on the supply side. This is where cogeneration and fuel switching have a potential influence on overall economic energy efficiency (defined as value of economic output per unit of energy input).

The data reveals that Australia has seen some uptake of technical energy efficiency opportunities, but at a far slower rate than many other IEA member countries (Figure 2.3 — note that this data covers all energy use including transport energy).¹⁰ The arrows in the figure show the average annual lag in Australian technical energy efficiency uptake compared with the average for the IEA. Over the period from 1973 to 1990, Australian energy efficiency improved by 0.6 per cent per annum on average, compared with average technical energy efficiency improvements of 2.0 per cent per annum for the IEA average. Similarly, Australian energy efficiency improved at an average annual rate of 0.3 per cent from 1990 to 1998, while the IEA average showed member countries improved by 0.7 per cent per year on average.

There may be many reasons for the relatively slow uptake of energy efficiency improvements. For example, it could be a product of the low energy costs that Australia has historically enjoyed relative to other IEA member countries: these low energy costs may have weakened incentives to invest capital in energy saving technology. Further, there may be a greater disparity of likely outcomes among Australian consumer groups than in other IEA member countries, which tend to have more densely concentrated population groups. Or there may be relatively higher hidden costs associated with energy efficiency opportunities in Australia, which may be a recursive function of the historically slow rate of energy efficiency uptake.

While Australia has been behind its IEA counterparts in absolute energy efficiency improvements, it is joined by the other IEA countries in an overall slowdown of energy efficiency improvements from the 1973-1990 period to the 1990-1998 period. The uniform slowdown in energy intensity reductions among the IEA member countries surveyed has been attributed to energy price variations, particularly for oil. Energy price rises in the late 1970s and early 1980s associated with the oil shocks are argued by the IEA to have contributed to the relatively higher average annual percentage increase in energy efficiency improvements in the 1973-1990 period, while conversely, falling energy prices and rising incomes in the 1990s are argued to have combined to weaken the impetus for energy efficiency improvements.

The IEA's argument for the consistent decline in energy efficiency diffusion across its member states sheds some light on why Australia's rate of energy efficiency uptake has also been trending downwards. Aside from declining oil prices in real terms, this period coincided with a significant period of electricity market restructuring, in particular, a move to competitive markets. Prices for electricity declined for residential users, and even more for business. Declining energy prices will tend to increase energy use and decrease investments in energy efficiency (through substitution effects and production expansion effects).

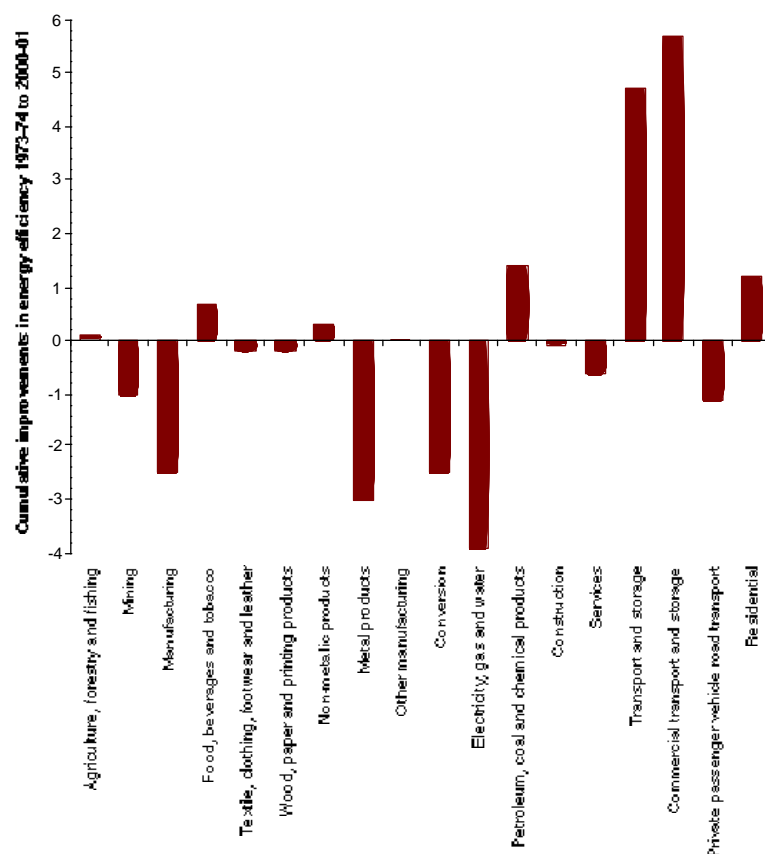
Investigating further, we can see that several key sectors have been influencing Australia's aggregate energy efficiency diffusion profile. ABARE data reveals that cumulative technical efficiency of energy use decreased from 1973-74 to 2000-01 in the following key sectors (Figure 2.4):

¹⁰ Countries included in survey: Australia, Denmark, Finland, France, Germany, Italy, Japan, Norway, Sweden, the United Kingdom and the United States. These are the countries for which the IEA has consistent time series data with detailed energy and activity data going back to 1973. These countries together accounted for more than 80 per cent of IEA member country CO₂ emissions in 2001. See F. Unander, 2003, *From Oil Crisis to Climate Challenge: Understanding CO₂ Emission Trends in IEA Countries*, prepared for the IEA, p 15.

- technical energy efficiency in the *mining* sector declined by 1.0 per cent;
- technical energy efficiency in the *manufacturing* sector declined by 2.5 per cent;
- technical energy efficiency in the *metals* sector declined by 3.0 per cent;
- technical energy efficiency in the *utilities* sector — which, according to ABARE classifications, includes electricity, gas and water sectors — declined by 3.9 per cent; and
- technical energy efficiency in the private passenger vehicle road transport sector declined by 1.1 per cent.

Figure 2.4

CUMULATIVE IMPROVEMENTS IN TECHNICAL ENERGY EFFICIENCY FOR MAJOR SECTORS OF THE AUSTRALIAN ECONOMY — 1973-74 TO 2000-01



Source: Ibid, ABARE, 2003,

This decline in technical energy efficiency significantly countered the positive technical energy efficiency improvements seen in the transport and storage (including commercial), residential, and petroleum, coal and chemical products sectors: 5.7, 4.7, 1.2 and 1.4 per cent improvements were estimated, respectively, for these sectors.

Thus the picture for energy efficiency in various sectors of Australia's economy is mixed, but has the overall result of less aggregate improvement in energy efficiency diffusion compared with other comparable countries.

2.3 The 'efficiency gap' in Australia

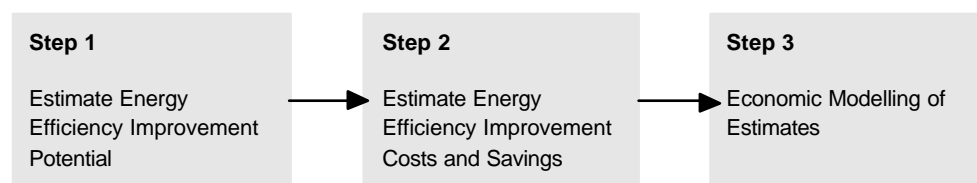
Synthesizing the theoretical framework for the existence of an energy efficiency gap and the evidenced lags in energy efficiency uptake in Australia compared to other IEA countries, a key consequential question becomes: is there any evidence to show the existence of a gap in Australia?

The most recent estimates of the potential energy efficiency gap in Australia were conducted for the Sustainable Energy Authority of Victoria, as a part of the work program for the National Framework for Energy Efficiency (NFEE).¹¹ The aim of this work was to develop comprehensive estimates of energy efficiency improvement-potential curves for each sub-sector of the Australian economy and to compare this with an estimated baseline or business as usual rate of energy efficiency uptake. This work was conducted in three stages (Figure 2.5):

- *Step 1* — Estimate the potential for energy efficiency improvements;
- *Step 2* — Estimate the costs and benefits for each of these identified improvements; and
- *Step 3* — Estimate the aggregate energy efficiency improvements that could feasibly be seen if the more energy efficient technology or process were to be adopted.

Figure 2.5

THREE STEP PROCESS FOR ESTIMATING POTENTIAL ENERGY EFFICIENCY IMPROVEMENTS



Source: SEAV

Step 1 is of particular use for understanding the potential energy efficiency gap within Australia. This step involved examining lists of specific energy efficiency measures, ranked in order of increasing simple payback periods. No energy efficiency improvement measure was considered that had a simple payback period of more than four years. An estimate of the baseline, business-as-usual uptake of energy efficiency was also developed. In total, three levels of energy efficiency improvement potential were considered at current energy prices:

- *Technical Energy Efficiency Improvement Potential* — this included all measures that were technically possible for a specific energy service. This was conducted for a range of sub-sectors within the residential, commercial and industrial stationary energy end-use sectors.
- *Economic Energy Efficiency Improvement Potential* — for this level of possible improvements in energy efficiency, the technical potential of

¹¹ See The Allen Consulting Group 2004, *Economic Impact Analysis of Improved Energy Efficiency: Phase 2 Report*, Report for the Sustainable Energy Authority of Victoria, www.seav.gov.au — the material in this section follows closely Appendix 2 of this report.

different measures were also constrained by taking into account standard financial considerations. For this work it was generally based on simple paybacks from energy savings, for a number of scenarios. It assumes that as long as the economic criteria are met, the energy efficiency improvements could be implemented. That is, it assumes that potential market failures or barriers precluding the uptake of these energy efficiency improvement measures are overcome.

- *Market Rate of Energy Efficiency Uptake* — this is the expected rate of energy efficiency improvements that are likely to be delivered by the market, that is, the baseline, business as usual level.

The NFEE Step 1 methodology then derived an estimate of the net energy efficiency improvement potential — or conversely, the ‘energy efficiency gap’ — by subtracting the expected Market Rate of Energy Efficiency Uptake from the Economic Energy Efficiency Improvement Potential. Stepping back to the conceptual model of alternate definitions of the potential energy efficiency gap, it is clear that this work roughly estimates the narrow social optimum of energy efficiency diffusion and the corresponding energy efficiency gap, at current prices.¹²

Over the period from 2005 to 2014 NFEE estimates indicated that net technical energy efficiency improvements of between two and 35 per cent were possible for various sectors of the Australian economy (Table 2.1). Thus the available evidence suggests that the energy efficiency gap in Australia could be significant within certain sectors of the Australian economy.

It supports the view that a significant proportion of the relatively poor performance of Australia compared to other countries is unlikely to be explained simply by differences in energy prices. First, the NFEE opportunities are assessed for electricity and for gas at current Australian prices. Given that Australia's energy prices tend to be cheaper than in other countries, and that therefore we would tend to have a more limited set of cost effective opportunities for energy efficiency improvement, the size of the identified opportunities becomes even more significant. Secondly, the assessment of opportunities for the NFEE process was conservative — the average of the simple paybacks of the estimates in Table 2.1 was 2.4 years, which equates to an average internal rate of return of more than 50 per cent. This is an extremely high rate compared to hurdle rates elsewhere in the economy, and indicates that most of the identified savings were within the bounds of hurdle rates that often are quoted as acceptable for non-core investments. Together then, the evidence tends to point to factors other than relative prices as a cause.

What the above estimates do not cast light on is whether there are other factors impeding uptake that are rational. As noted above, these might include hidden costs of adoption, including uncertainty over performance. We consider the potential of these other factors as a cause in what follows in this report, as well as the potential contribution of market failures such as lack of information and organisational constraints.

¹² Although to the extent that the estimates are ex ante estimates, and do not incorporate hidden costs, then they will overstate the opportunities. Hidden costs are discussed in more detail in later chapters.

Table 2.1

SUMMARY OF EEI POTENTIAL ESTIMATES

Sector / Case Studies	Energy Efficiency Improvement Potential	
	Electricity	Gas
Industrial sector		
Agriculture — estimated	5.0%	5.0%
Mining	8.4%	1.8%
Manufacturing	11.4%	6.9%
Food, Beverages & Tobacco	13.8%	11.0%
Textile, Clothing & Footwear — estimated	6.3%	6.3%
Wood and Paper Products — Pulp and Paper Manufacturing	13.5%	9.8%
Chemicals (ex petroleum) — Basic Chemicals	12.1%	8.4%
Non-Metallic Minerals — Ceramics and Cement	6.0%	10.3%
Iron and Steel	9.3%	17.2%
Alumina and Aluminium	12.8%	0.0%
Other Metals — estimated	3.0%	3.0%
Machinery and Equipment — estimated	6.3%	6.3%
Other Manufacturing — estimated	6.3%	6.3%
Construction — estimated	6.3%	6.3%
<i>Industrial sub-total</i>	<i>10.7%</i>	<i>9.1%</i>
Commercial sector		
Wholesale and Retail Trade	14.7%	7.1%
Accommodation, Cafes and Restaurants	6.2%	34.1%
Communication Services	4.4%	23.3%
Finance, Insurance, Property and Business Services	11.1%	11.1%
Govt. Administration, Education, Health and Community Services	9.4%	4.3%
Culture and Recreation, Personal Services	5.3%	39.5%
<i>Commercial sub-total</i>	<i>10.1%</i>	<i>11.0%</i>
Residential sector (electricity and gas)	11.9%	

Source: SEAV, reproduced in The Allen Consulting Group, 2003, *Economic Impacts of a National Energy Efficiency Target*, prepared for SEAV.

Chapter 3

Market failures impeding energy efficiency

Chapter 2 discussed the difference between market barriers and failures that might theoretically exist to impede the diffusion of more energy efficient technologies and practices in Australia. This Chapter identifies that it is theoretically possible that there may be plausible impediments to the uptake of energy efficiency that are not market failures — including the potential for significantly high rates of discounting and other hidden costs.

To highlight the differences, Chapter 2 briefly canvassed some of the potential barriers or failures that may prevent the optimal uptake of energy efficiency. This chapter expands on these previous observations by discussing whether consumer choices — and by implication, the energy efficiency gap — are rational.

The Chapter starts by considering market failures in the market for energy, with particular reference to the implications for relative prices. It then considers barriers and failures in the markets for energy efficiency services. The Chapter concludes by summarising the potential market failures preventing cost effective uptake of energy efficiency.

3.1 Energy market issues

This section explores the impact of the current energy market structure on incentives for adopting more energy efficient technologies and practices. It charts reforms to Australian energy markets, highlighting the impact of these on the incentives for energy efficiency uptake. The discussion limits itself to the theoretical impediments to energy efficiency improvements; it does not comment on the possible complexity or net benefits of these reforms.

It is important to note at the outset that energy markets have bearing on energy efficiency largely through the influence on prices for energy.¹³ Inefficiencies in terms of a misallocation of resources, including in relation to energy efficiency, can occur to the extent that energy prices are inefficient. The 'energy efficiency gap' is usually taken to refer to failures *at current prices for energy*. However, failures in energy markets influence *relative prices* for energy, and also therefore investments in the 'substitute' energy efficiency product or service. We therefore consider energy markets in this relative price context first, before going on to consider potential impediments in market for energy efficiency goods and services, which are not dependent on price. It is also worth noting that energy market issues are most significant for large energy users, as they are the end users most likely to be influenced by energy prices.

Energy market reform in Australia

Energy markets in Australia have undergone a substantial transformation in the past decade as policy makers have sought to remove legislative and regulatory barriers to competition in order to improve the efficiency of the energy industry.

¹³ While energy prices are the key driver, there are also institutional issues related to energy market decisions that can preclude efficient investment in energy efficiency — for example, in relation to network augmentation decisions. Chapter 4 considers these issues in more detail.

In the main, the reform program in Australia, started in 1991 by the Council of Australian Governments, has been focused on the restructuring of the supply side of the market, which has resulted in increased competition in electricity and gas markets. In electricity, these changes saw the vertical disaggregation of state-owned monopolies and the creation of the National Electricity Market (NEM) in December 1998 — a wholesale market for the supply of electricity to retailers and end-users in Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory. There has been a general decline in real electricity prices across the NEM as a result.¹⁴ Other states have also experienced real price declines in response to corporatisation of former government utilities. On the gas side of the market restructuring also resulted in a mild reduction in prices.¹⁵

In 2002, The Parer Report explored issues of demand side involvement for the electricity side of the energy market, and found that there has been relatively low demand side participation in the NEM due to:¹⁶

- the supply side focus of NEM information systems;
- the inability of load-reducing market participants to capture the full value of their market actions; and
- the insulation of residential customers from time-of-use price signals.

Influence of current market structure on energy efficiency diffusion rates

As a result of incomplete reform processes, a range of energy market inefficiencies remain. The majority of these are related to regulatory failures in the governance of markets or inadequate transitional arrangements. Against this reform backdrop we consider the current market structure and its influence on rates of energy efficiency uptake, first for gas and then for electricity.

Gas markets — influence of reforms to date

During the Australian natural gas market's initial development phase through the 1960s and 70s, monopoly gas producers and utilities negotiated long-term supply agreements that supported gas infrastructure and market development. Gas competed with other fuels in end-use markets but gas-on-gas competition was completely absent at both wholesale and retail levels.

¹⁴ While on average electricity prices have fallen since the 1990s, the character of the price decreases varies by jurisdiction and by sector. For example, real electricity prices in South Australia have risen on average compared with other NEM jurisdictions. Similarly, while on average real electricity prices fell for households and businesses from 1990-91 to 2002-03 (by roughly 18 per cent), this average change masks a real rise in energy prices for households during that period of (on average) three per cent. Energy prices for businesses fell by on average 25 per cent. The trends in Australian real electricity prices have been further affected by the introduction of the Goods and Services Tax (GST) in 2000. The GST has been included in prices paid by households for all infrastructure services other than water, however the input tax rebate system exempts businesses from the GST. See Productivity Commission, 2004, *Review of National Competition Policy*.

¹⁵ From 1990-91 to 1997-98, gas prices fell on average by one per cent. Breaking this down by sector reveals that gas prices for businesses fell by roughly three per cent while price increases for the housing sector increased by three per cent. See Productivity Commission, 2004, *Review of National Competition Policy*.

¹⁶ W. Parer, 2002, *Towards a Truly National Energy Efficiency Market*, Council of Australian Governments Energy Market Review, Chapter 6.

Since the introduction of downstream competition during the 1990s, the legacy of long-term agreements has continued to provide the majority of supply and to set the benchmarks for wholesale gas prices. The key transactions in the gas wholesale market are long-term contracts between producers and buyers such as retailers, generators and large industrials. These contracts will reflect the full cost of usage, including the regulated costs of transmission pipeline capacity. The activities of producers and buyers in this primary market are unregulated, though some retailers' prices for smaller customers are capped by state governments. The transmission sector is regulated under the National Third Party Access Code for Natural Gas Pipeline Systems promulgated in 1997. Many transmission pipelines in Eastern Australia are covered by the Code and their tariffs are regulated by the ACCC.

In terms of energy efficiency incentives, the small number of suppliers participating in the market has tended to provide upward support to gas prices, such that prices tend to exceed marginal costs of production. For example, the Parer Report noted:

The degree of supply competition in Australia's eastern markets is still weak — particularly compared to Western Australia. This is reflected in lower gas prices in Western Australia.¹⁷

If anything, by raising relative prices of energy above their economically optimal level, and constraining supply, this will have result in over signalling of the need for investments in energy efficiency in downstream gas use.

On the other hand, to the extent that gas can increase efficiencies in end use, and supplies on reasonable terms are constrained by lack of adequate competition, then end use efficiency is affected where inefficient alternatives are adopted. A key example of this is the stated difficulties by proponents of cogeneration projects to secure long term supplies of gas on reasonable terms. Cogeneration provides a major opportunity to increase the energy efficiency of electricity generation and heat raising.

With large players able to trade pipeline capacity in gas transmission pipelines among themselves, there are also theoretically adequate incentives for these major players to invest in cost effective energy efficiency measures as alternatives to increasing pipeline capacity. However, many transmission pipelines and (for all practical purposes) all gas distribution systems are not capacity constrained, and unlike in the electricity market, additional demand does not create requirements for balancing. As a result, appropriate signals for demand management are less crucial.

For these reasons — that pricing more than reflects costs of production and that there are adequate price signals for demand side management — the remainder of this section focuses more on the electricity portion of Australian electricity markets. This is likely to be a larger contributor to the potential energy efficiency gap than the gas side of the market.

¹⁷ W. Parer, 2002, *ibid*, p190.

Electricity — influence of supply side and other implemented reforms on energy efficiency incentives

Supply side reforms that have fostered an increasingly competitive environment for the generation sector have also contributed to declining prices for electricity in Australia. Similarly, the introduction of full-retail contestability in some jurisdictions is also working to increase retail competition and encourage lower prices for energy. These reforms, while removing some inefficiencies in pricing, are also likely to have weakened incentives for consumers to invest in energy efficiency opportunities. Chapter 1 illustrated a decline in the uptake of energy efficiency across IEA member countries, which was generally attributed to reform-induced energy price reductions. From an economist's perspective, this fall in efficiency investment in response to declining energy prices is a rational outcome, and does not require any regulatory response.

However, a significant component of the price decline was due to the overhang in generation capacity, particularly in NSW, which resulted in electricity prices below long run marginal cost (LRMC).¹⁸ If, as a result, misplaced expectations of price falls have developed, then there will be commensurate under-investment in energy efficiency. This is irrational, and over the longer term, will result in a misallocation of resources based on unreal future price expectations.

Further, despite the broad thrust towards improving competitive efficiency in the Australian market over the past decade, many consumers still have highly averaged prices that do not signal the costs of use on a time and location basis.

Because consumers have little information about the costs of using energy at times of peak demand or when the network is congested, and because some jurisdictions still impose caps on the price for energy, the market operates inefficiently — leading to high cross subsidies between user-types, dead weight loss, and muted incentives for energy efficiency uptake. While the current response of the industry and end use consumers therefore is rational within the current constraints, there remains scope for eliminating such inefficiencies and improving the overall allocation of resources. Chapter 4 considers these issues in more detail.

Externalities

Externalities refer to the costs and benefits from energy consumption that are not factored into the energy choices of consumers. Air pollution is commonly cited as a negative externality associated with energy consumption – though, of course, the adverse social impact can vary according to the type of energy consumed (eg. fossil fuel, renewable, etc) and the location of emissions.

To the extent that negative externalities are associated with energy consumption, economists would argue that the cost of energy is under-estimated in the market, and private decision-making will lead to over-use of this resource and excessive levels of consumption.

¹⁸ Wholesale prices fell below \$15 per MWh in the NEM in the late 1990s as a result. The supply overhang in NSW is now receding, resulting in prices approaching LRMC.

Box 3.1

EXAMINING ENERGY EXTERNALITIES: THE ExternE PROGRAM

The ExternE project is the first comprehensive attempt to use a consistent 'bottom-up' methodology to evaluate the external costs associated with a range of different fuel cycles. The European Commission launched the project in collaboration with the US Department of Energy in 1991. The EC and US teams jointly developed the conceptual approach and the methodology and shared scientific information for its application to a range of fuel cycles. During this first phase the EC side concentrated on the nuclear and coal fuel cycles which together were expected to raise most of the fundamental issues.

Work in the EC continued with a second phase of the project under the JOULE II programme. In January 1996, phase III of the ExternE project began, with country reports available from the end of 1997.

The main objectives are to apply the methodology to a wide range of different fossil, nuclear and renewable fuel cycles for power generation and energy conservation options, and a series of National Implementation Programmes to implement the methodology for reference sites throughout Europe. The methodology is also being extended to address the evaluation of externalities associated with the use of energy in the transport and domestic sectors and a number of non-environmental externalities such as those associated with security of supply.

Source: <http://externe.jrc.es/overview.html>

Owen (2004) lists the following energy sector 'spill-overs' that need to be taken into account in determining the true 'social' cost of energy¹⁹:

- solid wastes;
- liquid wastes;
- gaseous and particulate air pollutants;
- risk of accidents;
- occupational exposure to hazardous substances;
- noise; and
- others (e.g., exposure to electro-magnetic fields, emissions of heat).

Similar lists of impacts have been developed, and in some cases quantified, through the ExternE Project sponsored by the European Commission to examine the full life cycle impacts of different power generation technologies (see box 3.2). For instance, the study for the United Kingdom estimates that inclusion of non-greenhouse externalities would add around 10 per cent to prevailing production costs for low emission technologies such as gas, nuclear and certain renewable technologies (wind energy was found to have the smallest negative spillover implications) and add more than 50 per cent to the costs of electricity produced from coal and oil. Inclusion of notional greenhouse costs significantly amplifies the additional cost impost borne by fossil fuels.²⁰

¹⁹ Owen A.D. (2004), 'Environmental Externalities, Market Distortions and the Economics of Renewable Energy Technologies', *The Energy Journal*, 25(3), pp. 127-156.

²⁰ AEA Technology 1998, *Power Generation and the Environment – a UK Perspective*, Vol 1, commissioned report under the ExternE project, No. AEAT 3776, Oxfordshire, p. ix.

These results cannot be translated to Australia because of differences in location, demographics and background environment, and comparable comprehensive Australian studies are not available. However, they serve to highlight the potential implications that environmental factors can have for market energy prices, and subsequent consumption decisions. To the extent that externalities are not factored into energy prices, then there will be a corresponding under-investment in energy efficiency.

Other distortionary policies in the market for energy

Government policies can also have a direct influence on national and regional energy prices and the competitiveness of major energy consumers. Such influences can take the form of taxes, subsidies, regulations and concessions that affect the relative cost of resources and production options within Australia.

A variety of arrangements exist at a State and Commonwealth level that can impact on energy use. Fuel excise arrangements are a high profile example of these, and have recently been a focus for reform as part of the policy initiatives announced in the Commonwealth government statement on 'Securing Australia's Energy Future'.

Potentially distorting tax and subsidy arrangements affecting relative prices for energy efficiency investments include:

- historic subsidies paid to energy infrastructure in pursuit of economic development — while this is a sunk cost, it has contributed to the culture of 'build and generate', and also perhaps to the unrealistic expectations for energy prices in the future (as noted above);
- non-uniform taxation treatment of plant and equipment replacement and upgrades that create incentives to keep older equipment longer than might otherwise be the case:
 - repair of existing assets is deductible in the year the expenditure is incurred;
 - improvements to pre-September 1999 assets are eligible for accelerated rates of depreciation;
 - post-September 1999 assets are not eligible for accelerated rates of depreciation;
- concessional treatment for upstream energy investment, but not for investments in energy efficiency.

Taxation is a complex area beyond the scope of this report. While taxation is unlikely to be a significant element influencing the energy efficiency gap, it does warrant consideration as a potential impediment.

3.2 Markets for energy efficient technologies and services

As discussed above, it is possible that failures in the market for energy encourages over-consumption of energy and weakens incentives for energy efficiency uptake, through the influence on relative prices. Here, we discuss potential barriers and impediments in the market for *energy efficiency* goods and services, which could contribute to the energy efficiency gap *at current prices*.

As discussed in Chapter 2, there is a key distinction between barriers and impediments that can be classed as market failures, and hence warrant policy intervention, and those that do not. A useful summary is developed by Sorrell et al, who have undertaken the most exhaustive examination of the existing literature on the potential causes of the energy efficiency gap to date (Table 3.1). In this section we consider each of the summary categories in turn.

Table 3.1

BARRIERS TO ENERGY EFFICIENCY

Category	Particular instance
Barriers that may represent market failures	<ul style="list-style-type: none"> • Public good attributes of information associated with energy efficient technologies • Positive externalities of adopting energy efficient technologies • Adverse selection in energy services markets • Moral hazard & principal-agent relationships in energy services markets • Split incentives in energy services markets
Barriers that may represent organisational failures	<ul style="list-style-type: none"> • Imperfect information on organisational energy use • Moral hazard & principal-agent relationships within organisations • Split incentives within organisations
Barriers that may represent rational behavior	<ul style="list-style-type: none"> • Heterogeneity • Hidden costs (e.g. overhead costs, disruption) • Risk (technical or business) • Access to capital

Source: S.Sorrell, J.Schleich, S.Scott, E.O'Malley, F.Trace, U.Boede, K.Ostertag and P. Radgen, 2000, *Barriers to Energy Efficiency in Public and Private Organisations*, SPRU Environment and Energy, www.sussex.ac.uk/Units/spru/environment/research/barriers.html, p26.

3.3 Barriers that are not market failures

The first category we consider are those in the last row of Table 3.1 — barriers that 'may represent rational behaviour'. These are the barriers that are common to decision making elsewhere in the economy, and hence do not warrant special attention in the context of the market for energy efficiency.

The most important of these, and perhaps most disputed, are the hidden costs of adopting energy efficiency investments — that may not be picked up in engineering/financial evaluations that are typically conducted as part of energy audits. While it is possible to test the importance of hidden costs empirically, there are very few studies that have done so. As Sorrell et al note:

The relevant empirical questions for hidden costs are:

- what is the magnitude of the hidden costs associated with an energy efficient investment (a *cardinal* approach)?

- are their instances where the hidden costs associated with an energy efficient technology are comparable with those of an inefficient technology, but where the latter are still predominantly chosen (a *ordinal* approach)?

Both questions may be tested empirically, but the research design must be comprehensive to ensure that all factors are taken into account. Unfortunately, there are relatively few examples in the literature. One example of a cardinal approach is the 1994 study by Hein & Blok. This found the search and information costs of a range of energy efficiency investments to form between 3% and 8% of the total investment cost. Levine et al (1994) provide a much cited example of an ordinal approach. They studied a number of energy efficient technologies that were: i) commercially available; ii) identical to inefficient technologies in the quality of service provided; iii) highly cost effective; and iv) apparently free of any hidden costs. Despite this, inefficient technologies with a somewhat lower capital cost were generally preferred.²¹

In their detailed study of barriers impeding uptake of energy efficiency, Sorrell et al noted that salary overheads could be a key hidden cost if time constraints in considering energy efficiency investments are to be overcome (see Box 3.5 below). Nevertheless, Sorrell et al question the extent to which salary costs should be considered as part of the decision process, noting 'that given the wide range of tasks within energy management, it seems hard to justify loading all the salary overhead costs onto energy-saving investment projects'.²²

The potential importance of hidden costs for cost effective policy suggests that any programs designed to improve uptake of energy efficiency should have a clear *ex post* evaluation process built in, to ensure that the *ex ante* estimates of benefits and costs are evaluated, and true *ex post* returns estimated.

Other rational barriers include:

- heterogeneity — where despite an energy efficiency investment being cost effective on average, it is not cost effective for all users due to their specific characteristics;
- risk — to the extent that energy efficiency investments are discounted for risk at the same rate as investments of equivalent risk elsewhere in the economy, leading to excessively high discount rates;
- access to capital — to the extent that energy efficiency investments are constrained by capital scarcity in similar fashion to investments of equivalent return elsewhere in the economy.

There is contention as to whether some of these barriers are actually more pronounced in the market for energy efficiency. Some have argued that both discounting for risk and rationing of capital are excessive for energy efficiency investments, and are therefore symptoms of more pervasive irrational reluctance to adopt cost effective energy efficiency. If this were the case, then these barriers could represent market failures. For example, in relation to access to capital, Sorrell et al noted:

²¹ S.Sorrell, J.Schleich, S.Scott, E. O'Malley, F.Trace, U.Boede, K.Ostertag, P. Radgen, 2000, *Barriers to Energy Efficiency in Public and Private Organisations*, SPRU Environment and Energy, www.sussex.ac.uk/Units/spru/environment/research/barriers.html, p39.

²² S. Sorrell et al 2000, *ibid*, p170.

... as with the observation that organisations have strict investment criteria ... this [lack of capital] largely restates the problem to be explained rather than providing an explanation. In the higher education sector, there were constraints on borrowing imposed by public sector rules. But in mechanical engineering and brewing there was practically no evidence that the case study organisations had difficulties in obtaining capital at reasonable rates - as would be the case with a capital market failure ... Instead, the restrictions on capital were self imposed through a reluctance to take on additional borrowing²³ it does not follow from this that the reluctance to borrow represents rational behaviour.

3.4 Barriers that represent market failures

There are a range of barriers that are consistent with the neo-classical economics interpretation of market failures, which are generally accepted as being important in markets for energy efficiency. These contribute, to a greater or lesser degree, to the slower diffusion rates observed for new energy efficiency technologies.

Information: incompleteness and asymmetries

Energy efficiency investment may be hindered by the existence of imperfections or asymmetries in the markets for information. This results in households and firms having insufficient information to enable them to make efficient decisions on investments in energy efficiency. As a result, they under-invest in energy efficient technologies, processes and products and consume more energy than is socially optimal.

Within the residential sector, there is often a pervasive ignorance about energy efficiency opportunities. This limited awareness and interest in energy costs and reducing energy expense is in part due to the 'secondary' and 'invisible' characteristic of appliances and other energy efficiency goods and also to the small proportion of energy in total expenditure. Energy is prima facie taken for granted. However, it is also generally accepted that ignorance about the net benefits of energy efficiency investments are due to incompleteness and asymmetry of information in energy markets.

Incomplete information in the market for energy efficiency goods and services arises due its public good characteristics (Box 3.2).²⁴

Asymmetric information arises where sellers of energy efficient technologies, products or processes have superior information to buyers. In the residential sector, this situation may arise between a house owner and tenant, or between a home builder and home owner. This can result in problems of adverse selection, where buyers are unable to distinguish between product characteristics. Akerlof demonstrated that such a market can quickly collapse or simply reduce to the selection of low-quality products.²⁵

Decisions by consumers not to invest at the optimal rate of energy efficiency uptake may be 'rational' in the context of these market failures. However this is not a socially optimal outcome, and will result in under-investment in energy efficiency opportunities. Further, from a perspective of private cost-effectiveness, consumers are failing to capture the optimal level of benefits.

²³ S. Sorrell et al 2000, *ibid*, p171.

²⁴ Public good characteristics mean that the costs associated with sharing information are rarely excessive. However, simply providing information does not ensure that it is utilised. Interventions in this area need to consider the optimal targeting of information and advice to affect behaviour.

²⁵ This is the classic 'lemons market', first explained by Akerlof in 1970.

Box 3.2

PUBLIC GOODS

Public goods are an externality with two distinctive features. One person's consumption does not reduce the amount available for someone else (non-rivalry) and no one can be kept from sharing in the consumption of the good (non-excludability). As Stavins and Jaffe observe:

... information has important public good attributes: once created it can be used by many people at little or no additional cost. It may be difficult or impossible for an individual or firm that invests in information creation to prevent others who do not pay for the information from using it. It is well known that such public goods will tend to be underprovided by ordinary market activity.

The existence of public goods (and more often mixed goods with a large public element) gives rise to the free rider problem – whereby an individual lacks the incentive to pay for a good if that payment has no effect on the quantity of the good he or she may consume. Since it pays everyone to free ride, no revenue can be raised from the sale of a public good that is privately provided. In such a situation, no public goods would be privately provided. The responsibility for providing public goods thus rests with government.

Source: The Allen Consulting Group and Stavins and Jaffe 2004, op. cit., p 805.

The industrial and commercial sectors also are vulnerable to the same information failures as for the residential sector. Firms or other agents lack full incentive to invest in information about energy efficiency opportunities due to public good characteristics of that information — and where firms do invest in energy efficiency, firms have an incentive to protect this information from other firms in order to gain a competitive advantage through a more nimble cost structure.

In addition, a range of studies, such as the Bureau of Industry Economics (1994) survey of industrial motor users, have identified significant levels of uncertainty among industrial energy users about the energy performance characteristics of alternative technologies — that could be readily and cost effectively alleviated through appropriate government action on their behalf.²⁶

The inherent 'shareability' of information means that it can be difficult for information providers to capture all of the benefits from its creation and provision. In such circumstances it is likely to be under-provided, and hence the level and quality of information reaching individual energy users can be diminished. From a policy perspective, the capacity for information to be produced and used over and over again by several users without diminution represents a powerful rationale for policy intervention in this area.

Principal-agent problems

The principal-agent phenomenon arises in part from information asymmetries, and leads to difficulties for the consumer in achieving optimal levels of energy efficiency. Well known examples can be found in the building industry, where cost minimisation objectives can mean different things for the construction company (which will focus on up-front equipment costs) and the occupant (who has an interest in running costs) (Box 3.4).

²⁶ Bureau of Industry Economics 1994, *Energy Labelling and Standards*, Australian Government Publishing Service.

Box 3.3

PRINCIPAL-AGENT PROBLEMS FOR ENERGY EFFICIENCY

Architects, engineers, and builders, who generally seek to minimize first [initial] costs, select the energy technologies that homeowners and apartment dwellers must use. In this case, the consumer's best interest would be better met by selecting technologies based on life-cycle costs. Similarly, industrial buyers choose the technologies that are used in the production process and are mainly concerned with availability and the known dependability of standard equipment.

.... Lovins (1992) describes how typical fee structures for engineers and architects cause incentives to be distorted, thereby penalizing efficiency. Interviews with more than 75 design professionals and analysts showed that the prevailing fee structures of building design engineers are based on a percentage of the capital cost of the project. Such fee structures are pernicious because additional first costs are typically needed to enable the installation of superior heating, ventilation, and air-conditioning systems that reduce operating costs. These additional expenditures beyond the typical "rule-of-thumb" equipment sizing used by most engineers result in a net penalty for designers of efficient systems. Even though this type of fee structure has been strongly discouraged in the United States since the early 1970s, both the designer and procurer of design services still generally base their fee negotiation on percentage-of-cost curves.

.... Another example of misplaced incentives is the landlord-tenant relation in the buildings sector. If a landlord buys the energy-using equipment while the tenants pay the energy bills, the landlord is not incentivised to invest in efficient equipment unless the tenants are aware of and express their self-interest. Thus, the circumstance that favours the efficient use of equipment (when the tenants pay the utility bills) leads to a disincentive for the purchase of energy-efficient equipment. The case that favours the purchase of efficient equipment (when the landlord pays the utility bills) leads to a disincentive for the tenants to use energy efficiently.

Source: M.A. Brown 2001, Market Failures and Barriers as a Basis for Clean Energy Policies, *Energy Policy* 29 (2001) 1197-1207.

In the case of split incentives affecting residential or commercial leases, it is feasible for more energy efficient buildings to be specified and contracted for between the landlord and the tenant. For example, the tenant may contract for the landlord to undertake building improvements and agree to pay a slightly higher rent. At the same time, the tenant will be better off, saving a greater amount in energy bills than the rent increase. However, the prospects for a contractual solution of this type will be influenced by the time horizon of occupancy, and hence the ability of the landlord to recoup the capital expense through higher rents over time. The landlord may be reluctant to enter into contractual arrangements overcoming the split incentive if he or she does not believe the next tenant will value the investment in energy efficiency and hence pay a corresponding rental differential.

There are also 'moral hazard' situations that arise where the seller uses information asymmetry to extract unfair commercial advantage from the consumer. For example, if sales people can regularly convince customers to buy bigger (and more expensive and energy intensive) models than they actually need, they are unlikely to support provision of improved information. In this case, the provision of information works against the interests of a supplier.

Externalities from energy innovation

Often those that adopt new technologies act as leaders to others, and lower the risks and uncertainties for those who would follow (Box 3.4). The process of technological development and innovation is a well known pathway for those seeking competitive advantage, and can occur across the full range of economic activities including energy use. An innovator will often have an incentive to try to keep secret their technological successes and failures — at a potential cost not only to their direct rivals but also to other organisations that might benefit from their experiences. On the other hand, innovators must often accept that, as soon as their product is put on sale, competitors will purchase and analyse its features, then incorporate them into their products, usually with sufficient differences to avoid patent claims. Thus, innovators can find it difficult to capture the full advantage of their work. Where the choice for R&D priorities lies between an invisible technical improvement such as energy efficiency and a visible improvement such as aesthetics, the latter may be preferred because it is more visible.

Box 3.4

USE OF CONCRETE EXTENDER IN THE 60L BUILDING

Refurbishment of the 60L building in Melbourne by the Business Council for Sustainable Energy aimed to demonstrate cost effective energy efficient technologies.

One option for significantly reducing life cycle energy use was to use a concrete with higher level of extender. There was considerable opposition to this from both concrete manufacturers, builders and regulators, who lacked information on the performance of the new concrete. However, following considerable investment of time by the BCSE — to establish the case for extender concrete and convince the various stakeholders — the high extender concrete was eventually approved and used in the 60L building.

This provided a demonstration effect (to builders) and overcame regulatory barriers (building code requirements) such that now, 2 years later, 30 per cent of the commercial construction market in Melbourne uses the high extender concrete.

Source: Business Council of Sustainable Energy

Governments typically support research and development and limited duration patenting within economies as a means of promoting information flow and the provision of property rights that allow technological pioneers to earn a return on their investments.

Policies that promote demonstration of new technologies and provision of information on energy use and efficiency opportunities can help generate these positive externalities and accelerate the diffusion of new technologies within the economy.

3.5 Barriers that represent organisational failures

A further range of potential failures preventing efficiency uptake of energy efficiency occurs in the difficulties of coordinating complex activities. These arise because implementation of energy efficiency will often involve multiple decision makers. Organisational economics suggests that many of these difficulties are rooted in the transactions costs of using market based mechanisms, and also in the problems of organisations and the 'bounded rationality' of individual agents.

Organisational failures external to the firm

As observed by Golove and Eto, the complexity of organising energy efficiency across a chain of players can allow small imperfections to combine to create a market failure:

An intriguing illustration of the magnitude question [of the energy efficiency gap] examined from the point of view of transaction costs suggests that market barriers can sometimes accumulate and reinforce one another the idea of chains of market barriers refers to small imperfections, any of which individually represents an insignificant distortion to efficiency, but which in combination are of a magnitude sufficient to be considered a market failure. ... The chain of market barriers phenomenon explicitly recognizes that there are series of decisions, actions,²⁷ and transactions between the production of goods and their ultimate sale to the end user.

For example, the householder seeking to build or extend their home will need to coordinate with the building designer, equipment suppliers, the local council, and their builder, to install successfully energy efficient features. While it is true that this complexity is a feature of the home building process, if any party in this chain of coordination lacks interest in the energy efficiency option, then optimal investment in energy efficiency can become much harder to achieve.

Transaction costs

Transaction costs — including search costs — are the administrative costs of making and implementing a purchase decision. The transaction costs involved in investing in a new technology can be substantial. Further, the existence of transactions costs may also render some energy efficiency opportunities that are marginally profitable using ‘appropriate’ discount rates unprofitable. In the case of energy efficiency, the lack of a well developed energy services industry that organises products and information for end users can increase the transactions costs of trying to implement energy efficiency.

Organisational failures internal to the firm

Similar issues of external coordination also arise for firms — for example when occupying a new building or when installing new plant and equipment. At the same time, the larger firm has even greater problems, as significant coordination may also be required inside the firm.

Because of the complex organisational structure of many firms, internal information asymmetry also can arise in the context of their day to day operations. The complex decisions that must be made by organisations are in fact made by a diverse set of individuals making up the firm. In some cases, this may result in private agents making decisions that maximise their own welfare, rather than the welfare of the company — this is the classic agency problem within economics and theoretically may be observed when it comes to energy efficiency investments.

De Canio highlights this aspect in his analysis of barriers to energy efficiency, citing a range of reasons why uptake of energy efficiency by firms might be less than optimal:

²⁷ W.H. Golove and J.H. Eto 1996, *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency*, LBL-38059, eetd.lbl.gov/ea/EMP/ee-pubs.html, p32.

The individuals making up a business firm may all be rational seekers after their own interest, but the outcome of their collective action may be suboptimal. The logic of collective action is such that, in general, 'rational, self-interested individuals will not act to achieve their common or group interests. This principle applies to private sector corporations as well as to government bureaucracies or political collectives. The presence of public goods, externalities, and the clash between individuals' private incentives and the good of the whole all combine to produce outcomes that fall short of what could be obtained if all the resources of the group were deployed by a single guiding intelligence.

... It follows from these considerations that deviations from full profit maximization should not be surprising. Indeed, a long standing and respected tradition in economic thought holds that business organizations can only approach or approximate profit maximizing behaviour, because of the complexity of the environment they face and limitations on the decision making resources they command. The most famous proponent of this view is Herbert Simon, the Nobel laureate who pioneered the notion that 'satisficing' rather than 'maximizing' is descriptive of how firms actually operate.

... Under this view of the operation of the firm, a understanding of the forces that lead to any particular pattern of behaviour (regarding, say, energy management) could only be obtained by a careful, microlevel examination of the actual decision making processes of the firms themselves. It would be necessary to see, in specific instances, exactly what sort of informational, computational and organisational constraints were faced by particular firms in order to understand why they did or did not make particular investments.²⁸

As a result business managers may be reluctant to invest in projects where a potentially negative outcome may adversely impact on their own welfare. Thus if the benefits of an investment are difficult to quantify and estimate to a reasonable degree of certainty, or do not show a short-term positive outcome (such that they are likely to gain credit), then the manager may under-invest in energy efficiency. The owner of the business or the senior executive, lacking information about why the decision was made, will not be able to intervene to ensure that an investment is taken that is an economically rational decision.²⁹

Some decision-makers, such as managers, may also confront perverse incentives in relation to energy efficiency measures. For example, if energy efficient measures involve a long payback period, but a manager's performance is assessed over a shorter period, it may not be in the manager's interest to invest in energy efficiency, despite it being optimal from the firm's perspective. This may be compounded where managers do not have the expertise to assess the future prospects of a potential energy efficient investment, as there is greater risk inherent in adopting the measure.

Within an organisation, this strong emphasis on quick returns may be fuelled by managerial rotation practices that, on the one hand, keep managers interested and engaged in their work, but, on the other hand, likely privilege investments with shorter payback periods than may otherwise be the case. This is likely to be amplified by tying managerial compensation to short term performance targets. To the extent, too, that managers are risk averse, managers will be deterred from investing in projects where there is any uncertainty in the performance of the investment. Where managers fail to invest in investments that are profitable but have longer payback periods than is targeted, this is an 'irrational' decision in that it will fail to fail to maximise profit for shareholders.

²⁸ S.J. De Canio 1993, Barriers Within Firms to Energy Efficient Investments, *Energy Policy*, September, p 906 – 914.

²⁹ RA Lambert, 1986, 'Executive effort and Selection of Risky Projects,' *Rand Journal of Economics*, Vol 17, No 2, Spring 1986.

Box 3.5

THE SPRU BARRIERS PROJECT

The most highly developed assessment of barriers to uptake of energy efficiency was undertaken by the Science and Technology Policy Research Unit at the University of Sussex. The primary objective of the project was to link empirical results to a systematic theoretical framework using ideas from several traditions. The validity of these ideas was then tested using in-depth case studies of energy decision-making in a number of representative organisations. A total of 46 case studies are used, drawn from the higher education, brewing and mechanical engineering sectors in three countries - Germany, Ireland and the UK.

The research results suggest very strongly that, considering capital and operating costs alone, there are a large number of highly cost effective efficiency opportunities in all the organisations studied. The research therefore supports the results of engineering-economic models in pointing to the existence of a wide range of barriers.

One of the strongest messages is the importance of staff time constraints. If salary overheads are required to be recovered from investment projects, stringent payback criteria for the capital cost alone can often be justified. But while it is hard to justify loading all salary overhead costs onto investment projects, it is difficult to state what proportion of costs should be treated in this way. A second strong message is the importance of limited access to capital. This reflects both an overall reluctance to borrow and the low priority given to energy efficiency within internal capital budgeting procedures. This can be explained through a combination of difficult business situations, perceptions of risk associated with increased gearing and the strategic priorities of management. But assessment of whether this is rational will depend upon judgements about the future business situation, the response of the financial market to increased gearing, and movements in interest and exchange rates.

A third strong message is that there is more than one plausible explanation for the adoption of strict investment criteria. These include: recovery of salary overhead costs; responding to business risk; monitoring & control problems in principal-agent relationships and the financing risk associated with increased gearing.

The results show that the majority of observed behaviour can be explained using economic theory - additional concepts from behavioural theory and organisational theory do not significantly aid understanding. However, there is considerable value in replacing traditional economic assumptions about decision-making with that of 'bounded rationality', where individuals make decisions subject to severe constraints on attention, resources and their ability to process information. An important consequence of this is that energy efficiency may be ignored even if the individual or department is paying the energy bill and even if they are relatively well informed. Generally bounded rationality provides a limit to what can be achieved through correcting market and organisational failures.

The most important barrier - salary overheads and time constraints - does not provide a rationale for policy intervention. However the importance of this barrier may be reduced by changing the ratio of energy to employment costs through revenue neutral energy taxation. Such measure can be legitimated with reference to environmental externalities and can have an impact that is out of proportion to its effect on costs alone.

Other barriers can be seen as creating a systematic bias against energy efficiency. While energy efficiency and energy supply provide alternative means of supplying energy services, the transaction costs of purchasing the former greatly exceed those for the latter. This is compounded by bounded rationality in individual decision making and failures in organisational decision making owing to problems in transmitting information between individuals and departments. Taken together, these provide a strong case for government intervention, both to correct failures in the market for energy services and to improve organisational decision-making. Through such measures governments can help organisations to make economically efficient decisions which benefit both themselves and society at large.

Given the diversity of barriers in different contexts a wide ranging policy mix is recommended, with initiatives at the organisational, sectoral, national and international level. For example, possible measures in the higher education sector include: improved reporting and benchmarking of university energy consumption; reform of university purchasing procedures; promotion of energy service contracting; market transformation programs for technologies such as motors; and a series of measures within the construction industry, including the use of partnering and integrated design.

Source: www.sussex.ac.uk/Units/spru/environment/research/barriers.html#outputs

Uncertainties in the performance of energy efficiency investments are also likely to be driven by owners of commercial and industrial firms. Some economists³⁰ have theorised that owners set the hurdle rate for investments significantly higher than is actually required by the underlying cost of capital as a ‘premium’ to ensure that only profitable projects are undertaken and as a guard against managerial ‘slack’.

Evidence on the 'micro-level examination of the actual decision making processes of firms' is thin on the ground. Programs that have analysed corporate processes and the associated decision-making on energy efficiency are the United Kingdom's and the Australia's Energy Efficiency Best Practice Program, and the SPRU BARRIERS project (Box 3.5). These programs have shown that a lack of resources dedicated to examining energy efficiency, and a lack of capacity to deal effectively with information where it is available, have led to significant cost-reducing opportunities being overlooked. To quote Rigby:

The UK's major energy efficiency programme of the last decade, the EEBPp (Energy Efficiency Best Practice programme), has been widely regarded as the canonical example of an approach which addresses market failures that result when insufficient or inappropriate information impedes the diffusion of energy efficiency technologies and techniques to all those who have an economic interest in using such information. OECD publications on energy efficiency policy cites the UK as a leading example of such an information programme, giving as the reason for its need the low level and poor quality of information about energy efficiency technologies. However, the development and delivery of this Programme has seen considerable attention given by the civil servants required to implement it to the skills, abilities and resources that individual firms require to install, configure and operate energy efficiency technologies and techniques. While therefore “dealing with market failure” has been a popular shorthand for the model of Programme operation, in practice, the Programme managers have relied upon broadening and deepening capacities of firms and also modifying the practices of those supplying firms with technologies and techniques.

Information shortages for firms appear often not to be so important for technology choice and implementation as the resources of the firms themselves. A key theoretical distinction which is made between firms' specific and common information costs also proves to be difficult to observe in practice. The operationalisation of this major piece of the UK's energy efficiency policy therefore suggests that the notion of market failure based on informational problems of the market, while a useful construct, is problematic. The empirical work reported here on the implementation of Energy Efficiency Best Practice programme suggests that programme managers evaded the rhetorical requirements of policy and were able to deal with the capabilities of firms. (Consequently, energy efficiency information provided by government is not a pure public good.)³¹

What this suggests is that firms (and by extension also individuals) first lack the capacity to assess energy efficiency opportunities adequately, and secondly, lack appropriate internal systems and incentives to do so.

Bounded rationality

For the small energy consumer, the situation is not helped by energy comprising a small proportion of expenditure for the householder — consumers are often more informed about upfront costs than ongoing costs, which can tend to lead to irrational decision making. Furthermore, behavioural theory highlights that 'bounded rationality', or inability to process information, which is compounded by constraints on time and attention, and can also lead to less than optimal decision making. This adds to existing inertia to change, preventing uptake.

³⁰ R. Antle and GD Eppen, 1985, 'Capital rationing and organizational slack in budgeting,' *Management Science*, Vol 31, No 2, p163-174.

³¹ J. Rigby 2002, *When Rhetoric Meets Reality — Implementing Policies Based on Market Failure: Some Observations from the Development and Delivery of the UK's Energy Efficiency Best Practice Program*, University of Manchester PREST Discussion Paper 02-10, les.man.ac.uk/PREST.

In economics, satisficing is behaviour observed when a person or organisation attempts to achieve at least some minimum level of a particular variable — but which does not strive to achieve its maximum possible value. As noted above, this can reflect the difficulties of internal organisation, but it can also reflect ‘bounded rationality’: persons that exhibit bounded rationality’ experience ‘limits in formulating and solving complex problems and in processing (receiving, storing, retrieving, transmitting) information’³² This behaviour is likely to be a major component in the potential gap that may exist for the residential sector, where private agents have relatively limited resources to examine potentials for increasing their financial returns for all investments (Box 3.6).

Box 3.6

UPFRONT COSTS AND BOUNDED RATIONALITY

An irrational focus on upfront costs is one of the primary candidates for slow rates of energy efficiency uptake, and is symptomatic of bounded rationality. Consider the example of an investment in more energy efficient water heating. In Perth, it is possible to make an investment in a gas boosted solar water heating unit for \$4,200 (ignoring any potential Mandatory Renewable Energy Target rebates). This is a \$3,000 increase over the alternative gas storage water heating technology, which costs customers an average of \$1,200 for the unit. Taking a purely rational perspective, consumers should prefer to invest in the more expensive gas boosted solar water heating unit because they could borrow money on their home loan and pay less interest and principal than the actual savings in energy they make — the annual cost of financing the \$3,000 difference on a hypothetical 25 year home loan would be approximately \$236 at prevailing market rates, while the annual energy savings in gas would be \$300. Thus, in rational terms, the consumer would be better off even in the first year of investment, by \$64 dollars.

However relative to their total income these savings are likely to be quite small. From a bounded rationality perspective, the agent will work towards saving money on their expenditure, but may not be willing to outlay upfront costs to eke out the extra \$64 dollars in savings per year, which over a 25 year life would be worth roughly \$1,000 if discounted at an appropriate opportunity cost of capital (here a riskless four per cent).

In addition, the impact of the size of the upfront investment in energy efficiency on the decisions made by the consumer should not be ignored. Take again, the example of the \$3,000 investment. It is plausible that many consumers have a threshold above which a cash outlay is considered a ‘major’ investment. The thought process, when deciding on whether to invest in energy efficiency is likely to start with a consideration of what they might reasonably do with such a ‘major’ outlay of cash — say, invest in equity stocks or aesthetic housing improvements. Consumers tend to ascribe to these investments far higher expected rates of return.

The consumer then considers the feasible basket of investments toward which he may allocate this ‘major’ cash outlay, including the investment in energy savings. While economics would argue that rational investors should discount the expected stream of cash flows at the opportunity cost of capital for the next-best alternative investment of *comparable* risk — it may be that consumers do not adopt this approach. Rather, they may discount the future savings expected for the energy efficiency investment using an opportunity cost of capital for the other, alternative investment that they could feasibly make with such a substantial cash outlay — the investment in equity or the home improvement. This would have the effect of making the relatively riskless cash flows associated with the energy efficiency investment appear relatively unattractive — especially if one were to add in the effect of potential transaction costs (researching what the price of gas will be for the next 25 years, calculating the returns compared with other investments) and the potential influence of satisficing. This would be the action of an ‘irrational’ agent and economic theory would suggest that this should not happen in reality.

Source: The Allen Consulting Group

³² Williamson, Oliver (1981). ‘The Economics of Organization: The Transaction Cost Approach’. *American Journal of Sociology*. Vol 87, pp. 533.

Bounded rationality of individuals is also an issue for firms, as the theory of bounded rationality originated in examinations of the firm's true profit maximisation behaviours. Within the commercial and industrial sectors, satisficing behaviour may also be a contributing factor in the poor uptake of more energy efficient technologies and practices. In fact the most common application of the concept of bounded rationality or satisficing in economics is in the behavioural theory of the firm, which, unlike traditional accounts, postulates that producers treat profit not as a goal to be maximized, but as a constraint.

Under these theories, although at least a critical level of profit must be achieved by firms, this is accomplished by setting priorities using approximations rather than exact first order condition maximisation calculations. Firms accomplish this by looking for 'satisfactory goals rather than optimal ones,' dividing global goals into many sub-goals, or 'divide up the decision making task among many specialists.'³³ In part, at the commercial and industrial level, because complex organisational structures are devised to manage complex investment decisions, it is likely that firms fail to make 'optimal' investments. In this sense, even if all the agents are rational decision makers, the organisation may be an imperfectly formed structure, such that information and calculations about investments are sub-optimal (though generally satisfactory or difficult to identify as non-equilibrium outcomes). This provides opportunity for policy — as Paton notes:

... opportunities for firms to harbor inefficiencies abound. Conventional economic theory — if properly attuned to these inefficiencies — could provide potentially valuable methods for approximating the efficiency frontier against which the efficiency of actual firms could be estimated.³⁴

3.6 Conclusions

Based on the literature, a range of barriers to investing in energy efficiency have been identified. To the extent that policies are available to reduce these key barriers in a cost effective manner that raises overall economic welfare, then the barriers can be considered to be market failures.

In this context, key market or regulatory barriers warranting consideration for policy intervention include:³⁵

Related to issues of incorrect relative prices:

- Incorrect relative prices in markets for energy:
 - Regulated energy prices set below the incremental costs of generation, transmission and distribution, particularly for peak loads;
 - Inadequate institutional arrangements for considering energy efficiency as an alternative to network augmentation;
- Lack of incorporation of externalities in energy pricing;

³³ S.J. DeCanio, 1993, 'Barriers within Firms to Energy-Efficient Investments', *Energy Policy*, p 907.

³⁴ B. Paton 2000, Efficiency gains within firms under voluntary environmental initiatives, *Journal of Cleaner Production*, 9 (2001), p 176.

³⁵ This distinction between market failures related to relative prices and to other factors draws from the analysis in Energy Modeling Forum 1996, *Markets for Energy Efficiency*, EMF Report 13 Volume 1, www.stanford.edu/group/EMF/home.

Not related to issues of energy prices:

- Information failures;
 - Imperfect information, including under-provision due to public good aspects;
 - Asymmetric information, including adverse selection;
 - Principal/agent problems, including split incentives;
- Multiple decision makers;
 - Firm/agent external organisational constraints; and
 - Firm/agent internal organisational and bounded rationality constraints.

Chapter 4

Cost effective policy for energy efficiency

Economic theory suggests that overall economic welfare is maximised when the costs and benefits of actions undertaken by individual agents in the economy are aligned with the 'social' costs and benefits of those actions. In this context, optimal policy for energy efficiency should aim to close any divergences between the marginal social costs and benefits and the marginal private costs and benefits of investing in energy efficiency, where it is cost effective to do so.

The net social benefits of investing in energy efficiency may diverge from the net private benefits where there are market failures —affecting either the uptake of energy efficiency goods and services directly, or arising indirectly from within the market for energy (given that energy is a substitute for energy efficiency goods and services).

As noted in Chapter 2, impediments to uptake of energy efficiency, that cannot be overcome cost effectively, are not classed as divergences between net social and private benefits. Examples of these types of impediments include features common to day to day decision-making in all markets across the economy, such as high discount rates (related to risk) and scarcity of resources, including capital. However, to the extent that these barriers are more pronounced in markets for energy efficiency compared to largely equivalent investments in the rest of the economy, and can be overcome cost effectively, they may justify intervention.

The cost effectiveness requirement recognises that there can be costs to intervening in markets, and the possibility of regulatory or other government failures when intervening. As a result, careful design of any policy intervention is required at the outset. Ex post follow-up and evaluation is also important, to assess outcomes and ensure that ex ante expectations for policy are met.

The notion that there are net social benefits from cost effective intervention does not necessarily imply that all individuals will be better off, but rather that the benefits for those individuals in the economy who are better off outweigh the costs to other individuals and the costs of intervention, leading to an overall net social benefit. It is worthwhile noting that overcoming market failures in energy efficiency is likely to be of benefit to many, leaving very few worse off. In this sense, cost effective improvements in energy efficiency are likely to be close to the Pareto ideal for improvements in economic welfare.

Economic theory further suggests that the costs of intervention can be minimised by adopting first-best policies. First-best policy involves making an appropriate policy intervention as close as possible to the point of divergence.³⁶ For example, a first best policy to overcome an information failure would provide the information directly. Where a first best policy is not available due to constraints on the form of intervention, or where other market failures exist, it is still possible to design a policy that is welfare improving, even if welfare is not optimised.³⁷ In the case of an information failure affecting energy efficiency, a second-best policy might involve subsidising uptake of energy efficiency.

In summary, a first best approach to reduce market failures impeding investments in energy efficiency should aim to overcome directly the barriers causing the divergence in benefits, as close as possible to their source, where it can be demonstrated that the benefits of intervention outweigh the costs, including the costs of intervention.

4.1 The key barriers to energy efficiency

Chapter 3 identified a range of key market or regulatory barriers impeding uptake of energy efficiency, including:

Related to issues of incorrect relative prices:

- Incorrect relative prices in markets for energy:
 - Regulated energy prices set below the incremental costs of generation, transmission and distribution, particularly for peak loads;
 - Inadequate institutional arrangements for considering energy efficiency as an alternative to network augmentation;
- Lack of incorporation of externalities in energy pricing;

Not related to issues of energy prices:

- Information failures;
 - Imperfect information, including under-provision due to public good aspects;
 - Asymmetric information, including adverse selection;
 - Principal/agent problems, including split incentives;
- Multiple decision makers;
 - Firm/agent external organisational constraints; and
 - Firm/agent internal organisational and bounded rationality constraints.

³⁶ Intervening further from the point of divergence imposes additional by-product distortions, reducing the economic efficiency of the intervention (for example see W.M.Corden 1974, *Trade Policy and Economic Welfare*, p. 28).

³⁷ This is the 'theory of second best', whereby second-best policies improve welfare but do not deliver the optimum outcomes associated with first-best policies.

To the extent that policies are available to reduce these key barriers in a cost effective manner that raises overall economic welfare, then the barriers can be considered to be market failures. The rest of this chapter considers policy options to address each of these barriers, and assesses whether intervention is likely to be welfare enhancing.

Table 4.1

POLICY MECHANISMS

Type	Description
Control mechanisms	
C1	Mandatory sourcing of energy efficiency
C2	Energy efficiency license conditions for electricity businesses
C3	Integrated resourced planning
C4	Energy efficiency and load management as alternatives to network expansion
C5	Monopoly regulation and pricing ³⁸
C6	Codes and standards (building codes, MEPS)
C7	Licences, permits and trading schemes for greenhouse gas emissions
Funding mechanisms	
F1	Public benefits charge for energy efficiency
F2	Financing of energy efficiency by electricity businesses
Support mechanisms	
S1	Sustainable energy training schemes for practitioners
S2	Energy centres
S3	Creating entrepreneurial energy organizations
S4	Developing the ESCO industry
S5	Promotion of energy efficiency by industry associations
S6	Aggregating electricity purchases to achieve energy efficiency
S7	Voluntary agreements for energy efficiency
Market mechanisms	
M1	Taxes on energy
M2	Tax exemptions, subsidies and incentives for energy efficiency
M3	Providing consumption information on customers' electricity bills
M4	Communicating pricing and other information for energy efficiency
M5	Energy performance labelling
M6	Developing an energy efficiency brand
M7	Cooperative procurement of energy efficiency appliances and equipment
M8	Energy performance contracting
M9	Competitive sourcing of energy services
M10	Competitive sourcing of demand-side resources
M11	Demand side bidding in competitive markets

Source: E. Vine, J. Hamrin, N. Eyre, D. Crossley, M. Maloney, G.Watt 2003, Public policy analysis of energy efficiency and load management in changing electricity businesses, *Energy Policy* 31 (2003) 405-430.

³⁸ 'Revenue regulation' has been changed in this paper to 'Monopoly regulation and pricing' to reflect a broader set of options.

4.2 Policy options

A useful list of generic policy mechanisms available to address market barriers and failures for energy efficiency is outlined by Vine et al, sorted according to the method of operation of the mechanism (Table 4.1). Policy options range from support mechanisms that provide expertise and information, through to more stringent market fiscal and regulatory (control) approaches.

4.3 Analysis of policy options

Having identified the key barriers and market impediments in Australia working against energy efficiency, and the range of available policy mechanisms, we are in a position to assess what mechanisms might improve energy efficiency in a cost effective way in Australia.

As noted above, good policy should aim to close the energy efficiency gap by addressing failures at source, cost effectively. In light of the key barriers outlined above, policies could therefore aim to:

- ensure appropriate relative prices;
- overcome information gaps;
- reduce organisational, bounded rationality and transactions cost constraints preventing uptake of cost effective energy efficiency.

A range of barriers was identified earlier in the paper. Each of the foregoing three key objectives for action to improve energy efficiency has the potential to help address a range of the identified barriers, including the primary identified barrier (Table 4.2).³⁹

Policy intervention for energy efficiency can be evaluated in terms of the overall effectiveness in improving energy efficiency, as well as its impact on economic efficiency and equity:

- effectiveness — does the instrument improve energy efficiency;
- efficiency — is the increased energy efficiency achieved economically (does not necessarily imply the most technically efficient solution from an engineering perspective);
 - relative benefits of the policy outcomes in terms of overcoming market failures;
 - budgetary and other cost impacts;
 - by-product distortionary impact; and
- equity
 - is the burden distributed fairly;
 - and by implication, is the policy politically feasible.
- dynamic efficiency — an instrument might be preferred if it is not only effective in meeting a specified goal, but if it provides incentives to

³⁹

The list of barriers addressed in Table 4.2 draws on that set out in Vine et al 2003 op. cit.

encourage further efficiency, is adaptable to changing economic circumstances and helps adjust to long-term trends in technology, consumer tastes and the broader market..

In what follows, policy interventions first are discussed in detail, then at the end of each section, a brief evaluation of each intervention is made in terms of the criteria listed above.

Table 4.2

GROUPING ACTIONS WITH BARRIERS

Action to address EE gap	Key market or regulatory failure
Ensure appropriate relative prices	<ul style="list-style-type: none"> • Poor incentives from monopoly regulation, including inadequate price signals for end use • Inadequate institutional arrangements for considering energy efficiency as an alternative to network augmentation • Lack of incorporation of environmental externalities related to greenhouse in energy pricing
Overcome information gaps	<ul style="list-style-type: none"> • Imperfect information • Public good under-provision • Information asymmetries • Principal/agent problems • Information search costs, lack of awareness or data on energy efficiency opportunities <p><i>also</i></p> <ul style="list-style-type: none"> • Views of upper management • Lack of available expertise to advise on implementing energy efficiency • Performance uncertainties
Reduce organisational constraints preventing uptake of cost effective energy efficiency	<ul style="list-style-type: none"> • Multiple decision makers • High transactions costs in implementation • Inadequate attention to market transformation, particularly during energy market restructuring • Lack of energy efficiency industry <p><i>also</i></p> <ul style="list-style-type: none"> • Product or service unavailability • Inseparability of product features • Lack of legal or contract precedent • Limited investment capital available for energy efficiency • High initial cost • Increased product choices in energy efficiency

Source: The Allen Consulting Group

4.4 Relative prices

As noted in Chapter 3, relative prices are a contributor to a lower than optimal rate of uptake of energy efficiency, although the response by end users —to use more energy in the face of energy prices below socially optimal levels — is perfectly rational. As such, 'the energy efficiency gap', which refers to neglect of energy efficiency investments that are cost effective at current prices, is not influenced by relative prices. Nevertheless, relative prices are included in the policy prescription because of the longer term value to foster appropriate price signals in energy markets. To the extent that current prices for energy are too low, corrective policy will result in an increased uptake of energy efficiency in the future.

Improving relative prices relates largely to the regulation of the monopoly elements of the supply chain of energy, however, policies to address environmental externalities are also important. Key measures include:

- more efficient price signals for the consumption of energy;
- improved processes and incentives for consideration of load management as alternatives to network expansion; and
- incorporating environmental externalities related to greenhouse gas emissions in energy prices.

Improved price signals

As noted in Chapter 3, reform of energy markets has been underway in Australia for a number of years. Governments have made significant progress developing appropriate market and regulatory arrangements, but scope for improvement remains. For example, the NSW Independent Pricing and Regulatory Tribunal (IPART) found in their 2002 review of demand management:

A range of barriers ... to implementing network driven demand management options have been identified. Some of the most important of these relate to the regulatory environment. In NSW, revenues and average network prices are regulated by the Tribunal, so network investment decisions are made within a regulated environment, not a competitive one. Within this environment, DNSPs [distribution network service providers] have responsibility for setting network charges. Currently, network tariffs are largely uniform throughout a distribution area and do not signal peak or location costs to consumers. This means end users do not have an incentive to modify their behaviour in ways that would reduce capacity constraints.⁴⁰

This lack of efficient pricing will have a bearing on decisions on uptake of energy efficiency by consumers, as greater use of energy is a substitute for investment in energy efficiency.⁴¹

⁴⁰ Independent Pricing and Regulatory Tribunal of NSW 2002, *Inquiry into the Role of Demand Management and Other Options in the Provision of Energy Services Final Report*, www.ipart.nsw.gov.au, p76.

⁴¹ Lack of efficient pricing also influences decisions in relation to distributed energy resources more generally — including solar hot water, renewables such as photovoltaics, and domestic scale cogeneration.

A key problem in energy markets relates to the current rapid growth in peak loads, particularly use of air conditioners on hot summer days. Appropriate pricing of electricity in peak periods would reduce the implicit subsidy received by consumers installing air conditioning, which is currently a major driver of the rapidly increasing summer electricity peak across much of Australia.⁴² In turn, by facing the true costs of their adoption of air conditioning, consumers will have greater incentive to consider more efficient appliances, as well as cost effective alternatives to keeping cool, such as improved building shells.

Box 4.1

MANAGEMENT OF PEAK LOAD GROWTH IN NEW ZEALAND

In New Zealand concerns over the cost of system augmentations at both the distribution and transmission levels have created considerable interest in the cost signalling role of network charges. For some years now two South Island distributors, Dunedin Electricity and Orion New Zealand, have used a form of congestion pricing to signal the cost of network demand constraints. This approach involves:

- a separate congestion period charge is applied at times when demand on the network (coincident demand) is high
- the charge is based on the long run incremental cost of those network elements sized to meet coincident system demand; separate congestion charges are applied to distribution and transmission network use
- the charges apply to electricity used during declared congestion periods when demand on the network reaches levels at which the distributor is required to control load; the timing and duration of the congestion periods is determined by the level of coincident demand, allowing real time demand responses from customers
- information provision and market activation programs are used to support the price signal; customers and retailers are provided with regular updates on the likelihood of congestion conditions emerging; notice of an impending congestion period is provided through a range of media
- for customers with compliant metering a ripple control signal is sent out; in combination with the advance notice of a congestion period provided by the distributor, this allows demand responses, either automated or manual, to be triggered
- congestion periods only apply during the months of peak demand; network areas are designated as either winter peaking or summer peaking.

Both Dunedin and Orion use the congestion charge in combination with fixed charges and capacity charges. The congestion charges are significant. Currently Orion recovers approximately 45 per cent of its distribution network revenue from this source.

As Dunedin comment in their pricing statement:

By signalling demand constraints in this way, Dunedin Electricity is able to defer the need for investment in more capacity which is a very expensive alternative. Load is controlled only when the network loading is approaching the network's capacity. Consumers do not have to respond every time the signal is sent. Many will respond only when it suits, however the rewards for responding are substantial.

Since introducing congestion period pricing in the mid-1990s, Orion has recorded minimal growth in system peak demand. Consequently its customers have been spared the expense of peak driven additions to distribution and transmission network capacity. Interestingly these pricing approaches have been developed by the distributors without the need for any regulatory prompting.

Source: East Cape 2002, *Efficient Network Pricing and Demand Management*, IPART Research Paper No 18, www.ipart.nsw.gov.au.

⁴² CRA estimated that a 1Kw increase in air conditioning load that is run for 24 cumulative hours a year (during peak hot summer demand periods) will receive a subsidy — quantified as the difference in marginal revenue that should be earned over the period to cover capacity expansion and the actual marginal revenue earned — of \$91.15. The average new household air conditioner uses 4 Kw, so the potential subsidy is \$365. The air conditioner would need to be run for 2,170 hours to recover marginal costs fully. (Charles River Associates 2003, *Impact of Air Conditioning on Integral Energy's Network*, Consultancy Report prepared for Integral Energy, www.ipart.nsw.gov.au/submiss/ENR_DNSPs_03/).

IPART, for example, have in response flagged that they will encourage trials of congestion pricing to address peak load issues. By extending appropriate time of use pricing arrangements to smaller commercial and household customers (many larger customers already face time of use pricing), it is possible to influence consumer behaviour and significantly attenuate growth in peak demand through congestion pricing (see Box 4.1).

Metering is an important element facilitating time of use pricing. Advances in technology now make it cost effective to offer interval metering to even small customers. For example, Victoria recently has mandated the full roll-out of interval meters to all customers. In taking that decision, the Essential Services Commission noted that:

Interval meters have strong potential to improve the efficiency of the electricity market. These benefits arise from avoided generation, transmission and distribution capacity costs (demand management) the demand management benefits are likely to provide the capacity and incentive for customers to manage their electricity consumption more efficiently. The efficiency of the electricity markets increases when customers respond to high price signals by reducing their demand for electricity or shifting their use to lower priced times. In this way, the market would benefit from the reduced need for capacity to meet otherwise higher peak demands.⁴³

However, it is clear that substantial effort will be needed to access the full benefits of interval metering. As the Ministerial Council on Energy User Participation Group note:

The work undertaken to date suggests that the full benefits of interval metering would only be harnessed if both distribution and retail charges were based on time-of-use data and the wholesale electricity market settled on the basis of this information.⁴⁴

Nevertheless, interval meters present a promising approach to delivering increased cost reflectivity in energy prices, and improved signals to consumers for alternatives to energy consumption.

Where interval meters are not widely available, consideration can be given to varying tariffs to better reflect peak loads, for example through seasonal or increasing block tariffs, or to more comprehensive approaches such as those adopted in New Zealand (Box 4.1).

In similar fashion to peaks, many consumers in more remote locations do not face the full cost of the network services used to deliver energy because network prices tend to be averaged across the whole network. While this is a political decision to address equity for regional users, it is feasible that community service obligations could be paid explicitly as a lump sum compensation, allowing remote locations to face the full price for their energy. End users would then have greater incentive to take cost effective actions that improved the efficiency of energy use.

Finally, unnecessary retail price regulation that shields consumers from the true costs of energy provision also discourages investment in cost effective energy efficiency. As retail markets become progressively more competitive, the need for price regulation should diminish.

⁴³ Essential Services Commission 2004, *Mandatory Rollout of Interval Meters for Electricity Customers: Final Decision*, www.esc.vic.gov.au.

⁴⁴ Ministerial Council on Energy Standing Committee of Officials 2004, *Improving User Participation in the Australian Energy Market: Discussion Paper*, User Participation Working Group, www.industry.gov.au.

In summary, improved pricing in energy markets has a clear potential to deliver better economic outcomes. Many of these benefits arise from the direct benefits of reduced network capital requirements to deliver consumers' energy needs. However, there is also the indirect benefit in terms of signalling appropriate investments to alternatives to energy consumption, such as end user energy efficiency. While non-cost reflective energy prices may not be the most important market failure affecting investment in energy efficiency, it is a contributor.

Load management as an alternative to network expansion

Regulatory arrangements for distribution network service providers (DNSPs), particularly price capping arrangements, can create barriers to demand side actions. This is because DNSPs do not receive full recompense for demand side actions under network pricing structures.⁴⁵ IPART, for example, have recognised this and have adopted a range of mechanisms to improve incentives for network driven demand management.⁴⁶ These include DNSPs being able to:

- pass through demand management costs, up to the avoided distribution costs;
- recover foregone revenue as a result of demand management programs.

Box 4.2

ENERGY EFFICIENCY AS AN ALTERNATIVE TO NETWORK EXPANSION

Over the past four years, electricity consumption in Castle Hill area in Sydney has increased by 32 per cent, and is forecast to grow by a further 54 per cent over the next 10 years. Integral Energy is the local electricity distribution company. Because of the continued rapid development of the Castle Hill district, Integral forecasts that it will need to spend more than \$3 million to expand the Castle Hill electricity substation within two years. Integral is examining ways in conjunction with the NSW Department of Energy and Utilities (DEUS) to reduce strain on the network, and to defer the need for an upgrade on the Castle Hill substation, by reducing the demand for electricity during the peak periods. A reduction in peak demand by 1,350kVA is required (approximately 4% of the peak electrical load on the local network).

Some of the initiatives for the Castle Hill Demand Management Project include:

- Castle Towers Shopping Centre:
 - better use of a Building Management System to ensure equipment is only turned on when it is needed;
 - more efficient lighting in common areas;
 - use of a monitoring system in the car park to ensure exhaust fans are only used when needed;
- Bi-Lo Supermarket
 - improved use of existing air-conditioning controls;
 - upgrading air-conditioning equipment by installing more efficient compressor valves as well as equipment to reduce the humidity and temperature of air being drawn into the system from outside;
 - installing lighting controls to allow more efficient use of existing lighting system; and
 - optimised controls for refrigeration.

Integral are willing to pay up to \$150 per KVA of reduced load. This provides a revenue stream for DEUS to implement the project, as well as provide a \$60 per KVA 'bounty' to subsidise the uptake of the energy efficiency initiatives.

Source: Department of Energy, Utilities and Sustainability 2004, *Fact Sheet: Electricity Demand Management in Castle Hill*, www.energysmart.gov.au

⁴⁵ Independent Pricing and Regulatory Tribunal of NSW 2002, op. cit.

⁴⁶ Independent Pricing and Regulatory Tribunal of NSW 2004, *Treatment of Demand Management in the Regulatory Framework for Electricity Distribution Pricing 2004/05 to 2008/09*, www.ipart.nsw.gov.au, p1.

Among other things, these arrangements provide scope for DNSPs to contract for energy efficiency as an alternative to network augmentation, in constrained sections of the network, where it is cost effective to do so (see Box 4.2). The demand from DNSPs for energy efficiency in these areas has the potential to add to the incentives for individual consumers and firms to adopt cost effective energy efficiency, further affecting relative prices between energy supply and energy efficiency.⁴⁷

Environmental externalities

To the extent that major energy production and industrial facilities are required to address environmental issues as part of their licensing processes, then the costs of that control of environmental impacts will be included in energy prices.

Environmental impacts currently controlled in Australia include local ambient air quality and the release of air toxics. Emission of scheduled pollutants must meet the standards of the relevant National Environment Pollutant Measures, administered by the Environment Protection and Heritage Council.⁴⁸

However, a major environmental impact omitted from energy pricing in most jurisdictions in Australia relates to the greenhouse gas emissions associated with energy production and use. A first best approach to dealing with emissions of greenhouse gas emissions is to put a price on emissions, commensurate with the marginal damages caused. However, there is considerable uncertainty as to the impacts of climate change and the associated damages. Despite the uncertainties, global action to mitigate greenhouse gas emissions is underway under the auspices of the United Nations Framework Convention on Climate Change (UNFCCC).

Australia has chosen to meet its greenhouse objectives independently of the international actions proposed under the Kyoto Protocol to the UNFCCC (which include provision for 'flexibility mechanisms' such as emissions trading). The Commonwealth Government has committed not to introduce domestic emissions trading, which would put a price on carbon, in advance of 'effective longer-term global action on climate change'.⁴⁹

⁴⁷ For example, two firms out of twenty major industrial enterprises that participated in a survey of demand side response implemented energy efficiency as a long term load management strategy. Firms in this survey had the expectation that retailers should offer demand side programs compared to other market participants such as DNSPs and generators. This expectation was in part raised by retailers already having approached firms offering demand side initiatives and/or that retailers were likely to have the best understanding of their business operations. The surveyed firms expected retailers to provide:

- technical expertise in load reduction technologies;
- assistance in identifying and scooping demand side opportunities on the customers site; and
- a sufficiently attractive incentive to make participation worthwhile.

PHB Hagler Bailly 2002, *Survey of Demand Side Participation in the National Market*, prepared for the National Electricity Code Administrator, www.neca.com.au.

⁴⁸ For the details of National Environment Pollutant Measures, see the Environment Protection and Heritage website: www.ephc.gov.au.

⁴⁹ Commonwealth of Australia 2004, *Securing Australia's Energy Future*, Energy Task Force, Department of Prime Minister and Cabinet, www.pmc.gov.au, p25.

The exception is in NSW, where the Greenhouse Gas Abatement Scheme (GGAS) creates a mechanism to reduce the greenhouse gas intensity of electricity production and use. This mechanism has been estimated to raise the price of electricity in NSW by around \$3 per MWh, although the price impact will be less to the extent that the provisions in the GGAS for demand side contributions are successful.⁵⁰

By raising the price of energy supply, such as for electricity and gas, emissions charges help to close or 'internalise' the environmental externality in energy pricing, and work to reduce energy use by changing relative prices. In response, investment in energy efficiency will increase, although the amount of change will depend on the elasticity of energy demand. This 'demand side' response will tend to be most pronounced for large users of energy, such as major industrial facilities, who have a more elastic demand for energy (at least in the long run). Smaller residential and business consumers tend to be less affected by relative prices, given that energy bills are a small proportion of their overall costs.

The existence of other market failures will also tend to mute the impact of relative price signals. Nevertheless, the existence of even small emissions charges can have important signalling effects that help to influence behaviour in the short term, and over the longer term, induce significant technological response.

Relative prices — evaluation

Improved pricing and load management as an alternative to network augmentation are judged to have relatively small impacts on uptake for energy efficiency (Table 4.3). Nevertheless, the first two options tend to have low costs as there are valid reasons for undertaking these measures on other grounds (for example, more efficient markets for energy through load shifting, better network capital utilisation etc). Addressing environmental externalities in greenhouse has potential to increase average energy prices significantly, and result in long run dynamic benefits through induced technical change. In the short term, however, other non-price market failures may retard optimal energy efficiency response to greenhouse pricing (and also other price reforms relating to energy markets).

Table 4.3

ASSESSMENT OF POLICIES TO IMPROVE RELATIVE PRICES

Mechanisms	Impact on EE	Benefits to end users	Cost to budget	Political feasibility	Dynamic benefits
Improved energy price signals	Small	Moderate	Small	Moderate	Large
EE alternative to network expansion	Small	Moderate	Small	High	Moderate
Environment Externalities	Moderate	Potentially Large	Small	Moderate	Large

Source: The Allen Consulting Group

⁵⁰ National Economics 2004, *Impact of Greenhouse Policy on Electricity Demand*, A Report for the National Electricity Market Management Company, www.nemmco.com.au/nemgeneral/410-0046.pdf.

4.5 The information gap

Markets for energy are susceptible to information failures. The most powerful and direct policy mechanisms to address information failure include:

- government funding for information provision;
- energy performance disclosure;
- codes and standards; and
- transforming markets by developing an energy services industry.

Government funding for information

Due to public good characteristics and other market imperfections information on energy efficiency can tend not to be provided to an economically efficient level.⁵¹ In the case of energy efficiency, private markets for information also tend not to develop because energy expenditure is often small, while the transactions costs of accessing the information are relatively large.

Governments can address this problem by funding the provision of information on energy efficiency products and services directly. This helps to reduce the costs of information access and search for individuals, thereby improving their decision making and increasing the efficiency of resource allocation in the economy.

However, simply providing information does not ensure that it is utilised. Sorrell et al draw on behavioural studies to note:

.... The effectiveness of information depends on more than its availability and content.' (Stern, 1994). In other words, the form of information is crucial. Five elements of information in particular are important:

- Information should be specific and personalised. e.g. individual energy audits will be more effective than general information on cost saving opportunities.
- Information should be vivid. For example, a US study showed that people who viewed a video about implementing domestic energy saving measures were significantly more likely to cut energy use than those who received the information in writing (Winett et al., 1982, p24). Similarly, demonstration of tangible success with a technology is likely to have far more persuasive power than a sales pitch - hence the emphasis in government information programmes on technology demonstration schemes.
- Information should be clear and simple.
- Information should be available close in time to the relevant decision.
- Feedback should be given on the beneficial consequences of previous energy decisions if subsequent efficiency measures are to be encouraged (Seligman et al, 1981).

Of particular importance is the implications such observations have for the design of energy efficiency programmes. The empirical studies of residential energy decision making suggest that people's responses to information are complex: 'Human learning processes and the effective coupling of energy information to incentives are complex topics⁵² that remain poorly understood in the energy conservation area.' (Lutzenheiser, 1993, p 255).

⁵¹ Other information failures can relate to a) lack of available information; b) the cost of gathering information; c) the accuracy of information; and d) the ability to act upon or use the information.

⁵² S.Sorrell, J.Schleich, S.Scott, E. O'Malley, F.Trace, U.Boede, K.Ostertag, P. Radgen, 2000, *Barriers to Energy Efficiency in Public and Private Organisations*, SPRU Environment and Energy, www.sussex.ac.uk/Units/spru/environment/research/barriers.html, p48.

Interventions in this area therefore need to consider the optimal targeting of information and the form of advice to affect behaviour. Successful programs that have adopted such targeted approaches include:

- the Commonwealth Government's Energy Efficiency Best Practice Program — resulted in extensive cost effective improvement in industrial energy efficiency in targeted sectors; and
- Travel Smart program — a program influencing commuter choice of transport mode.

Training and education can also help to overcome information failures. Again, the role of governments in funding education and training recognises the extensive public good characteristics.

Energy performance disclosure

Energy performance labelling and associated energy performance disclosure initiatives address information failures directly. Energy efficiency goods and services can be more susceptible to information failure than other goods and services in the economy because energy efficiency tends to be an unobservable product characteristic. Hence consumers are unable to judge performance until after they have consumed the product, and even then can have difficulties assessing performance if they lack adequate metering arrangements. Credible and accessible labelling helps to overcome the information asymmetry problems that impede informed choice, and to address the public good characteristics of the information search process.⁵³

Labelling can be either voluntary, or mandated by governments. Mandating labelling through comprehensive regulation can improve the consistency and brand recognition of the information, thereby building credibility and trust and increased response by the consumer. Australia has had appliance labelling in various guises for over a decade (Box 4.3).

In the case of buildings, development of energy rating tools and mandatory disclosure of energy performance are a key first step in helping to develop awareness of energy performance, improve information flows (and thereby facilitate appropriate contracting to overcome split incentives), create an asset value for energy performance (that can then be reflected in sale prices) and drive innovation by building designers.

The benefits of labelling can outweigh the costs by a significant margin. For example, the Regulatory Impact Statement for the nationally coordinated scheme for household electrical appliances in Australia suggested that the program has a benefit cost ratio of 1.8 at a discount rate of 8 per cent, with the annual energy savings for consumers approximately three times the annual cost of administering the program.⁵⁴

⁵³ As noted in Chapter 3, asymmetric information is one possible explanation for why energy efficiency opportunities are not adopted. Where buyers of energy efficient technologies, products or processes find it difficult to access information on product performance, problems of adverse selection (where the buyer decline to pay for the product feature) or even principal-agent problems (where a supplier may not supply the product feature, despite the consumer having paid for it) can arise.

⁵⁴ George Wilkenfeld and Associates 1999, *Regulatory Impact Statement: Energy Labelling and Minimum Energy Performance Standards for Household Electrical Appliances in Australia*, www.energyrating.gov.au/library/index.html.

Minimum Energy Performance Standards

Minimum Energy Performance Standards (MEPS) work to remove from the market equipment and building designs with the worst energy performance. Better performing appliances or building designs often cost no more than poorer designs, and in many cases offer equivalent or better features to those eliminated. Hence, MEPS can be a very cost effective policy for improving energy efficiency and overall economic welfare.

MEPS help to overcome information and other failures by helping to:

- remove the need for consumers to invest time and other resources to ensure that products with significant economic lives, such as water heaters, do not have energy costs that quickly erode initial purchase price differentials;
- address some of the split incentives problem, for example by ensuring that landlords install insulation in a rental houses or that commercial buildings have efficient lighting; and
- overcome the 'market for lemons' adverse selection problem, by providing a signal to manufacturers that energy improvement is a valued product feature, thereby encouraging innovation and helping to transform the market.

Like labelling, national approaches to MEPS have been gathering pace in Australia since the 1990s (Box 4.3). This is because labelling and MEPS tend to be complementary measures. Together MEPS and labelling can be effective in transforming the rate of diffusion of energy efficiency innovations through the economy. Labelling tends to empower consumer choice, leading to 'demand pull' for improved energy efficiency, whereas MEPS eliminate the poorer performing products and induces 'supply push' through manufacturing innovation.⁵⁵

National approaches to labelling and MEPS help to reduce the complexity of meeting multiple requirements across differing jurisdictions, using different ratings tool. For example, Victoria and NSW have adopted more stringent residential buildings standards than those in the national Australian Buildings Code, albeit based on different measurement tools:

- Victoria has adopted a mandatory 5 star standard based on the First Rate tool;
- NSW has developed BASIX, which rates new residences according to a range of sustainability indicators, including energy and water use.

While there are clear benefits in a national approach for reducing compliance costs, there is also the question of whether the national approaches become a 'lowest common denominator' requirement. For example, the Australian Building Codes Board notes that mandatory national buildings standards will be of 'an appropriate minimum and ... cost effective'.⁵⁶ While local communities should have the ability to choose more stringent requirements, it is clear that efficiency is served if consistent ratings tools for evaluating standards are used. Hence it is unfortunate that there is a current proliferation of ratings tools and an associated 'war of the ratings tools'.

⁵⁵ See for example, North American Energy Working Group 2001, *North American Energy Efficiency Standards and Labelling*, www.eere.energy.gov

⁵⁶ Commonwealth, State and Territories of Australia 2001, *Energy Efficiency in Buildings: Directions Report*, www.abcb.gov.au, p13.

Box 4.3

LABELLING AND MEPS IN AUSTRALIA

Mandatory energy performance labelling for appliances has been in operation in Australia in one form or another since the mid 1980s. A nationally coordinated scheme for major appliances was agreed in 1992, but was not fully adopted until 2000. The Energy Rating label has two main features:

- a star rating which gives a quick comparative assessment of the model's energy efficiency; and
- a comparative energy consumption (kwh/year) rating which provides an estimate of the annual energy consumption of the appliance based on the tested energy consumption and information about the typical use of the appliance in the home.

Australia's national Minimum Energy Performance Standards (MEPS) program commenced with standards for refrigerators, freezers and electric storage water heaters in 1999. Since then the scope of the MEPS program has been steadily expanded and a rolling update program for the existing standards commenced.

- MEPS programs are implemented through coordinated state based regulation for technical standards, with offences and penalties for lack of compliance.
- National standards ensure that costly differences do not arise between state based requirements.

Mandatory standards for the ratings of new residential and commercial buildings are being implemented through the Australian Building Code. Development of ratings tools for residences and commercial buildings is a key prerequisite for buildings energy ratings, and available tools now include:

- NAThers, and more recently Accu-rate and First Rate for residences; and
- Australian Buildings Greenhouse Ratings tool developed by SEDA and the Green Star ratings tool developed by the Green Building Council.

Recognition of the benefits of labelling and MEPS has led to the recent announcement by the Ministerial Council on Energy (MCE) that Stage One of the National Framework for Energy Efficiency will, among other things:

- extend national labelling and MEPS programs to gas appliances;
- expand the MEPS program through the introduction of new or more stringent MEPS for residential, commercial and industrial products, with a key focus on increasing the number of commercial and industrial products regulated;
- institute MEPS for government buildings;
- require mandatory disclosure of the energy performance of residential and commercial buildings;
- ensure that benchmark data is provided on consumers energy bills (thereby widening information to include a comparison of the individual's consumption with that of a standard consumer with similar characteristics).

Source: The Allen Consulting Group and Ministerial Council on Energy 2004, op.cit.

Transforming markets by developing an energy services industry

Lack of adequate provision of information on energy efficiency can be compounded by a lack of markets to organise information in a readily accessible way for consumers. Generally, adequately functioning markets for goods and services across the economy play a key role in transmitting information to consumers, for example through advertising or as part of the sales process.

In the case of energy efficiency goods and services, the current lack of information therefore can in part be related to the lack of a well-developed energy services industry supplying energy efficiency goods and services. If such an industry existed, at adequate levels of scale and scope, it could have the ability to significantly reduce the search costs of information and other transactions costs for consumers, and to package this information with the provision energy efficiency and other services (for example finance, building services etc).

In the section below on overcoming organisational and institutional constraints we consider policies to facilitate the development of the energy services industry in more detail.

Information failures — evaluation

The existence of information gaps in relation to energy efficiency is well accepted. As a result, all policies measures to encourage information provision outlined above, bar policies to specifically develop an energy services industry, have been adopted broadly within Australia. This reflects the fact that these mechanisms perform well against all evaluation criteria, with reasonably small costs and high political feasibility (Table 4.4).

These mechanisms are amenable to any market segment or product within the residential, commercial or industrial sectors. Given their low cost and utility in directly addressing information failure and bounded rationality, they should continue to be part of any package to raise investment in energy efficiency.

The final option, developing an energy services industry, comes at higher cost. While a broader evaluation is contained in the next section, Table 5.4 notes that an energy services industry could have a moderate to large effect on overcoming the information gap, with potentially large dynamic benefits for the future as overall awareness of energy efficiency opportunities is raised and as transactions costs of providing that information fall.

Table 4.4

ASSESSMENT OF POLICIES TO CLOSE THE INFORMATION GAP

Mechanisms	Impact on EE	Benefits to end users	Cost to budget	Political feasibility	Dynamic benefits
Government funding for information provisions	Low-Moderate	Low-Moderate	Moderate	Large	Low
Energy Performance Labelling	Large	Large	Moderate	Large	Moderate
Codes and Standards	Moderate	Large	Moderate	Moderate	Large
Energy services industry to overcome information gap	Moderate	Moderate-Large	Low	Large	Large

Source: The Allen Consulting Group

4.6 Organisational failures

Chapter 3 noted that key organisational barriers relate to the multiple decision makers involved in organising energy efficiency investments, concluding that the key barriers related to:

- Firm/agent external organisational constraints;
- Firm/agent internal organisational constraints and bounded rationality constraints.

Firms (and by extension also individuals) first lack the capacity to assess energy efficiency opportunities adequately, and secondly, lack appropriate systems and incentives to do so. This is a key barrier to uptake of energy efficiency.

Drawing on transactions costs theory to provide insight to the problem of organisational constraints, Sorrell et al note that:

.... transaction cost economics has much to offer in understanding barriers to energy efficiency. ... A very important point is *that transaction costs are contingent on the institutional structure*. Some structures may lower transaction costs and thereby lead to greater energy efficiency. For example, energy services companies may overcome many of the transaction costs faced by energy using firms.

In a classic paper, Coase (1960) shows that transaction costs may provide a rationale for policy measures to internalise externalities when the costs of administration and enforcement are less than the associated benefits. Intervention circumvents transaction costs by avoiding the costs of information dissemination and bargaining. The important policy question then becomes: *are there possible interventions or alternative institutional arrangements that can overcome transaction costs at positive net benefit?*⁵⁷ (Sanstad & Howarth, 1994, p815).

Box 4.4

ENERGY PERFORMANCE CONTRACTING IN NSW

The NSW Government Energy Management Program has been instrumental in driving demand for energy efficiency in NSW, thereby sustaining the NSW energy performance contracting industry.

- In the New South Wales public sector context, the funding for energy performance contracts (EPCs) by Government agencies has come from the NSW Treasury which has, since 1998, provided annually a \$20 million rolling fund from which government agencies can draw down to finance the capital upgrade.
- To be viable, an EPC project needs to be in excess of \$500,000 and to have an internal rate of return of 12 per cent or better.
- As a result of this support, in 2002 there were about \$40 million worth of EPCs in Australia, with the vast majority of these in New South Wales.

The NSW programme and associated arrangements for EPCs have created an incentive for the growth of an energy efficiency industry in New South Wales. While initial EPCs were difficult, experience gained through the NSW GEMP program has allowed the EPC approach to prosper in NSW. More recently, EPC's have been adopted by a number of local governments in NSW and also in the private sector, in part facilitated by the ready adaptability of the model contracts developed for the NSW GEMP.

Source: NSW Legislative Assembly Standing Committee on Public Works 2002, *Report on Government Energy Reduction Targets*, Report No 52/8 and The Allen Consulting Group 2003, *The NSW Government Energy Management Program: A Triple Bottom Line Analysis*, Report to the Sustainable Energy Development Authority of NSW.

⁵⁷

S.Sorrell et al 2000, op. cit.

Importantly, Sorrell et al note the role that an external 'energy services' industry could play in helping to deliver energy services, reducing both internal and external organisational constraints. An energy services industry would focus on deliver the end use needs — whether it be cool houses or furnaces — in the most cost effective manner through an optimal mix of energy carrier and end use (energy efficiency) equipment and services.

While the role for energy services industry is clear, such an industry will not thrive if there is a lack of demand for such services by firms and individuals. If the awareness of individuals and firms of available energy efficiency opportunities were raised, and the other identified market failures overcome, then an energy services industry could develop rapidly to meet the need (Box 5.5).

Market transformation

The foregoing analysis suggests that there could be an appropriate role for government to transform the market for energy efficiency — to increase the ability for the 'demand side' to compete with energy supply — by ensuring that energy end users have appropriate capability and incentive to adopt cost effective demand side alternatives. In transforming the market, policy would aim to achieve a self-sustaining change in end-users' ability to implement cost effective investments in energy efficiency.

While significant effort has been focused over the past decade to transform the supply side of the energy industry and increase competition, little concerted effort has been made on the demand side, to develop appropriate incentives for the market and thereby deliver a well-functioning competitive alternative to the supply side (perhaps with the exception of NSW).

The culture of 'build and generate' — which developed in the years when subsidising energy supply infrastructure was an economic development mechanism — has prevailed. At the same time, the energy services industry has been undermined by failures to get relative prices right; the low prices for electricity, that were the legacy of the 40 per cent over-capacity in NSW generation extant at the inception of the National Electricity Market, have also been a barrier.

Market transformation is often discussed in the context of markets for energy efficiency equipment, but the concept can apply equally to the market (or lack of it) for energy *services*, in the sense of providing a source of advice and design capability (see Box 4.5). A dynamic energy services industry could organise products and services and package these for consumers, reducing transactions costs. The energy services industry option is attractive because it is a market-based solution.

The potential pay-off to a measure that develops a sustainable energy services industry, in terms of impacts on energy efficiency, is high. Such a measure would help to deliver other key ingredients in the energy services equation:

- entrepreneurial energy organisations;
- aggregated purchases to reduce costs of appliances and equipment;
- communication of opportunities for energy efficiency and their pricing;
- development of energy efficiency brands with high consumer recognition;

Box 4.5

MARKET TRANSFORMATION

Market transformation has been the subject of extensive analysis in current discussions about how to achieve energy efficiency in a deregulated environment. NARUC (1996) recently completed a major study of Market Transformation in a Changing Utility Environment.

The NARUC study concludes that:

Transforming a market means changing the types of products or services that are offered in the market, the basis on which purchase and behavioral decisions are made, the type or number of actors in the market, or in some other way altering this set of interactions in a self-sustaining way. Market transformation is actually a result or a desired outcome, more than it is a type of program. For our purposes, market transformation refers only to those programs explicitly designed to cause changes in the structure of the market for energy efficiency products or services (e.g., new players, different rules, different prices), or in the behavior of some group of market actors, in such a way that energy efficiency is improved and the changes remain after the program has ended. Unlike traditional DSM programs, market transformation programs explicitly try to change the market so that energy efficiency products will be purchased in the future without ongoing programmatic intervention...

They note that most market transformation programs tend to involve multiple market actors, with significant activity upstream from the customer, and tend to involve longer time frames to achieve impacts. The NARUC study also provides a very detailed and useful "typography of market transformation tools," including:

- Technology Research and Development — facilitating development of a new or more efficient technology by manufacturers. ...
- Demonstrations and Field Tests — helping to demonstrate that a specific product, service or practice is ready for the market (i.e., works in the 'real world'), typically by funding, publicizing and/or disseminating results of product demonstrations or field tests. ...
- Customer Education — facilitating changes in customer attitudes and/or behavior regarding specific products or how they use energy-related equipment...
- Training — facilitating understanding of specific technologies or the benefits of specific energy-related practices among selected market actors, typically by funding development, implementation, or promotion of training programs...
- Financial Incentives — facilitating development, production, sales or use/specification of efficient products or practices in a manner that ensures sustainable changes in the market once the incentives are removed, by providing cash grants or loans to market actors (e.g., manufacturers, equipment specifiers, or dealers/distributors, builders)...
- Bulk Purchases/Market Aggregation — facilitating a relationship between large-volume purchasers interested in specific high-efficiency equipment with manufacturers of this equipment, by organizing and educating purchasers so that they can present manufacturers with their equipment purchase criteria. ...
- Branding — creating a uniform brand, seal or endorsement for high-quality, energy-efficient products and services, to increase customer/trade ally comfort with and perceived value regarding these products and services, by funding campaign development, quality testing and promotional efforts...
- Public Recognition — facilitating energy-efficient installations and practices in organizations, by offering significant publicity and/or technical assistance in exchange for organizations making significant efficient purchase/practice decisions...
- Building/Equipment Code Upgrades and Enforcement — facilitating installation of more efficient equipment and/or construction of more efficient buildings, by changing or enforcing codes in municipalities, states or the country.

NARUC notes that these tools are "building blocks," and that a typical program would include a number of these strategies. These tools serve to reduce costs of acquiring information for various market actors, to economize on information costs by establishing trust, to reduce information asymmetries, to reduce inefficiencies in decision making due to bounded rationality and quasi-rationality, to pool risk, or otherwise to reduce transaction costs.

Source: National Association of Regulatory Utility Commissioners 1996, *Market Transformation in a Changing Utility Environment*. Washington, DC, quoted in M.J.Hewett 1998, *Achieving Energy Efficiency in a Restructured Electric Utility Industry*, Center for Energy and Environment, www.mncee.org/pub.htm, p3.33

- finance for energy efficiency, for example through energy performance contracting; and
- increased product choice (and thus helping to overcome product inseparabilities).

The question then arises, are there cost-effective policy instruments to transform the markets for energy efficiency, reducing the transactions costs of adopting energy efficiency over the longer term? The analysis above related to organisational constraints suggests that the primary barrier is in the bounded rationality and inappropriate incentives structures for firms and individuals, which are then compounded by the range of other market failures including information failures, and to a lesser extent, inappropriate relative prices.

These primary barriers are the key market failures to target. As Sorrell et al note:

.... policy should have the general objective of minimising the transaction costs of improving energy efficiency - both for individuals and organisations. The key elements of this are:

- economising on bounded rationality: allowing actors to make efficient choices without requiring extensive effort in gathering and analysing information;
- aligning incentives: ensuring, as far as possible, that incentives of different groups are complementary and act in the direction of improved efficiency; and
- safeguarding against opportunism: ensuring, as far as possible, that asymmetric⁵⁸ information does not encourage decisions or actions that undermine efficiency.

If the demand for energy efficiency is optimised, then it is likely that the supply of energy efficiency services could expand readily to meet that demand.

Greenhouse considerations reprised

A key issue to note at this point is that the emerging greenhouse externality is likely to add significantly to the need to overcome these awareness and organisational failures in the future. Energy efficiency is one of the most cost effective options to mitigate emissions, and hence is one of the lowest cost ways to take precautionary action against the threat of human-induced climate change.

It is economically efficient to adopt energy efficiency options up to the marginal benefit of carbon abatement elsewhere in the economy. For example, the marginal benefit of abating a tonne of CO₂-e from the electricity generation sector is currently set at \$15 in NSW through the Greenhouse Gas Abatement Scheme, and this price is similar to the prices emerging through the Kyoto Protocol for parties that have ratified. Most predictions are that carbon prices may need to be higher again in the future in order to maintain global concentrations of greenhouse gases below dangerous concentrations.

⁵⁸ Sorrell et al 2000, op.cit.

As noted above, while emissions trading schemes are likely to influence large energy consumers, smaller consumers in the industrial, commercial and residential sector may not deliver the optimal response in response to the greenhouse price signal because of the range of organisational and other market failures. Hence, there would be an even more pronounced need to overcome market failures impeding efficient uptake of energy efficiency – which brings us back to this report. So, intervention to transform the market for energy services becomes even more compelling once the need for future significant action on greenhouse is factored in.

Mechanisms to improve awareness and overcome organisational constraints

The foregoing discussion suggests that optimal policy for energy efficiency should target the lack of awareness and organisational failures preventing optimal demand for energy efficiency.

The key is to tailor the measures to the unique nature of the awareness and organisational barriers in each sector, and the associated transactions costs of taking action. These barriers will differ for the residential, commercial, industrial and large energy user sectors (see Box 4.6 for a successful approach in the dairy industry). The following provides a brief overview of some of the most prominent instruments to achieve this. However, given the constraints of this paper, it is not exhaustive. Nor does it consider the best combination of approaches. Careful policy assessment is needed to establish the best package of policy approaches for each sector — it is unlikely that any single measure in isolation will be a 'silver bullet'. The following major measures would need to be complemented by a range of subsidiary support actions to ensure that the transformation process was achieved in a measured, sequential fashion.

That said, key institutional and market mechanisms for addressing the incentives of end users include:

Voluntary mechanisms

- voluntary agreements for energy efficiency;

Price based mechanisms

- tax exemptions and subsidies for energy efficiency products;
- subsidies to energy services delivery;

Regulation (control) mechanisms

- Minimum Energy Performance Standards;
- government leadership;
- mandatory energy efficiency audits and implementation requirements; and
- tradable energy efficiency targets.

Box 4.6

ENERGY EFFICIENCY IMPROVEMENT IN THE DAIRY INDUSTRY

A team-based approach relying on 'people know-how', combined with sound measuring and monitoring, enabled the Murray-Goulburn dairy processing company to gain bottom line savings. The company's Rochester site used around \$7 million of energy to produce 114 000 tonnes of product, including milk powder and cheese—in 2001–2002.

The project followed the Best Practice People and Processes methodology developed by Department of Industry and Resources' Energy Efficiency Best Practice programme, which had been tested successfully across a range of industries. Integral to the success of the project was the formation of an energy management team with representatives from each part of the factory, including operators, supervisors, and maintenance and boiler personnel. The approach involved:

- establishing and training a strong site-based Energy Management Team (EMT) through a series of facilitated workshops;
- developing a business plan for site-based energy efficiency projects;
- developing a strategy for the ongoing involvement of the team in energy management; and
- implementing projects.

Achievements to date include:

- Savings based on projects already implemented, amounting to \$180 000 per year with a reduction in greenhouse gas emissions of 1 536 tonnes.
- Additional short-term future savings, based on projects currently being implemented, of \$223 000 per year with a reduction in greenhouse gas emissions of 1 895 tonnes.
- Demonstrating the success of a cross-functional team approach to improving operational efficiencies—an approach Rochester plans to use as part of their waste and yield program.

Source: Commonwealth of Australia 2003, *Case Study: Dairy Processing Sector: Murray-Goulburn Cooperative Rochester Branch*, www.industry.gov.au.

Voluntary agreements

Voluntary agreements for energy or greenhouse management are a 'soft' approach to align the incentives to adopt energy efficiency within firms with the perceived social benefits. In particular, voluntary agreements secure the commitment of senior management, thereby legitimising energy efficiency within firms, and work to lift the capacity within firms to measure energy use and assess opportunities. The classic example in Australia is the Greenhouse Challenge Program, which although concerned primarily with greenhouse, has a significant focus on energy use and opportunities for abatement through efficiency. Voluntary agreements are suited to larger organisations, such as larger firms or industry associations.

Voluntary approaches are a useful step in seeking to overcome the organisational failures within firms. However, they can be susceptible to 'window dressing', with firms or government agencies doing the minimum in terms of measurement and reporting, while undertaking very few actions beyond 'business as usual'. As a result, little or no real organisation change may be effected.

More recently, the Commonwealth Government's energy white paper has mandated energy efficiency audits for large energy using firms, but has left implementation to voluntary decision. As such, the program is a mix of compulsion and voluntary decision making and marks a halfway point between the voluntary and regulatory approach.

Price Based Mechanisms

Price based mechanisms include:

- tax exemptions and subsidies for energy efficiency products; and
- subsidies for energy services delivery and market transformation.

At the outset, it is worth noting that the issues of individual and organisational failures are likely to be less amenable to strictly price based interventions. While price based mechanisms might work for energy intensive industry, for smaller firms and for the residential sector the small proportion of energy in total expenditure tends to preclude price-based intervention as an effective tool.

Box 4.7

SUBSIDISING ENERGY EFFICIENCY FUNDED BY WIRES CHARGES

Question for Program Design	Recommendations
<i>Rationale for Ratepayer Funding</i>	Capture cost-effective energy-efficiency opportunities that will be missed by the competitive market Facilitate transition to more competitive markets Ensure benefits of restructuring are shared broadly among all customers
<i>Creation of a Public-Benefit Charge</i>	Ensure competitively neutral mechanism for collecting funds
• Funding level	Establish funding based on bottom-up analysis of cost-effective energy-efficiency opportunities remaining after restructuring and an assessment of likely private-sector activities in the absence of ratepayer funding; at a minimum, continue funding at historic levels.
• Duration	Decouple sunset date from recovery of competition transition charges; establish a five-year review period over which to assess accomplishments and determine continuing need for programs.
• Rate design	Collect funds through a nonbypassable, volumetric charge .
<i>Energy-Efficiency Policy Objective</i>	Ensure that benefits to society exceed cost Target activities to areas not adequately addressed by private sector Design programs to effect lasting beneficial changes in the market
<i>Administration and Governance of Programs</i>	Systematically assess desirability of utilities, state agencies, and independent institutions to manage public-benefits funds based on: (1) institutions' past performance, current ability, and level of interest; (2) geographic scope needed to implement policies; (3) duration of funding; (4) utility conflicts of interest and ability to manage these conflicts; (5) flexibility of state procurement and hiring procedures; and (6) degree of political support for creation of new, nonutility institutions.

Source: J. Eto, C. Goldman and S. Nadel 1998, Ratepayer-Funded Energy-Efficiency Programs in a Restructured Electricity Industry: Issues and Options for Regulators and Legislators, eetd.lbl.gov/EA/EMP/

So for example, differential taxation or subsidies for energy efficiency products are less likely to be effective in driving uptake, except for energy intensive firms. While there may be justification for removing existing distortions in taxation working against energy efficiency, there are questions about the effectiveness of these instruments as a measure to influence energy efficiency choices.

In contrast, subsidising energy services delivery allows more flexibility, in that government can either directly, or competitively through third parties ('competitive sourcing'), undertake targeted programs that aim to address the lack of awareness, bounded rationality and organisational failures at the heart of the energy efficiency gap.

Subsidies for energy services delivery and market transformation programs can be funded either from general revenue, or by a non-bypassable 'network charge'. A wires charge based on the amount of electricity consumed (eg fraction of a cent per kWh) is common in the United States. These funds are then used to fund market transformation and other energy efficiency activities by either public utilities or third parties (Box 5.7).

Regulatory (control) mechanisms

The most common regulatory mechanisms used to date are Minimum Energy Performance Standards (see Information failures section above). As noted, MEPS are efficient in removing the need for smaller consumers to calculate, or even understand, the whole of life cycle costs of an energy service, while also working to transform the supply side of the market. As such, MEPS work around key barriers, rather than working directly to overcome these. For example, MEPS are a powerful tool in the face of the difficulties caused by bounded rationality. As Sanstad and Howarth note:

If consumers cannot, on average, make correct calculations regarding energy efficiency, as may be implied by the findings of high implicit discount rates, then efficiency standards may serve to replicate the correct calculations on a centralized, cost-efficient basis. Thus direct regulation may in some cases bypass the problem of bounded rationality altogether by focusing on technologies rather than behavior. By contrast, demand-side management programs aimed at residential users must confront the problem head-on, a difficulty that might account for the rather modest results achieved by many residential demand-side management programs.⁵⁹

While MEPS target the market failures at the lower end of the product spectrum, they do not provide incentive for improved energy efficiency to move beyond minimum standards. Incentive mechanisms that worked to overcome lack of awareness by consumers and organisational failures in firms would encourage increased uptake of energy efficiency across the board, not just remove the bottom quartile.

Government leadership, for example requiring government agencies to meet energy efficiency targets, combined with a range of supporting mechanisms, has also proved to be effective in changing behaviour and demonstrating the potential for energy efficiency (see Box 4.4).

⁵⁹ A.H.Sanstad and R.B. Howarth 1994, Consumer Rationality and Energy Efficiency, *Proceedings of the ACEEE 1994 Summer School on Energy Efficiency in Buildings*, enduse.lbl.gov/Projects/EfficiencyGap.html, p9.

Regulatory mechanisms to provide incentives to change firms' and individuals' behaviour include:

- mandatory energy efficiency audits and implementation requirements;
- tradable energy efficiency targets.

Mandatory audits and implementation requirements can target directly the organisational barriers in larger firms. For example, the Victorian State Environment Protection Policy — Air Quality Management program requires firms to undertake energy audits and implement projects with a payback of less than 3 years. By mandating this requirement, energy efficiency opportunities with internal rates of return exceeding 40 per cent are adopted. The measure encourages firms to develop internal arrangements energy efficiency assessments, while senior management are forced to include energy efficiency within their span of control.

However, mandatory audits and implementation requirements are less amenable to smaller firms and the residential sector because of the difficulties of monitoring outcomes to ensure compliance — there are too many entities and it is likely that non-compliance would rapidly undermine the credibility of the mechanism. There are also the difficulties of equalising the marginal cost of response and hence equity. Thus there is a need to consider an alternative mechanism for these sectors.

Mandatory energy efficiency targets for energy suppliers, such as energy retailers, are a relatively new mechanism that has been adopted in Italy and the United Kingdom as a way of driving uptake of energy efficiency. In the case of the energy retailer, the measure works by requiring the retailer to reduce their energy sales by a pre-specified amount, which is demonstrated by acquitting a corresponding amount of 'white certificates' (which represent a unit of energy saved) with the regulatory authority. The requirement is tradable, to equalise the marginal costs of compliance. In this sense, the measure is similar to the Mandatory Renewable Energy Target.

To meet the target, retailers need to initiate eligible energy efficiency activities to earn the 'white certificates' (or contract with third parties to acquire certificates). Eligible activities could include selling more efficient appliances with a deemed 'white certificate' value, subsidising upgrades to achieve higher star rated buildings and thereby earn associated deemed 'white certificates', or by reducing the energy intensity per unit of output of small manufacturing enterprises, again to create 'white certificates' at a pre-determined rate.

This mechanism has promise, but also has significant challenges. On the plus side, energy retailers are probably the best placed entities to identify cost effective opportunities for energy efficiency in their small customer base — by virtue of their energy use data and ability to benchmark customers for energy use. Energy retailers also offer a smaller number of participants to monitor for compliance. The mechanism could be a key element helping to move energy retailers from being sellers of energy to sellers of energy services. The mechanism would thus give a large boost to developing a true energy services market.

The key question is whether the mechanism will be successful in changing individuals' and organisations' behaviour, thereby overcoming the awareness and organisational failures identified as key. To the extent that the measure funds energy services companies (whether they be the retailers themselves or third parties) to approach consumers offering low transaction cost energy efficiency solutions, then the answer is yes (but it is worth noting that this could be done equally well by a competitive sourcing program subsidising similar delivery of energy services by the retailers or by third party).

The mandatory approach does have the advantage of working through the retailers, who are closest to end use customers, and by funding the mechanism through increased energy prices. One could imagine, in extremis, energy retailers giving away compact fluorescent light bulbs, while informing consumers that if they installed the light bulbs around the house, they would be better off, despite the fact that their electricity prices were increasing slightly to fund the compact fluorescent light bulbs (the price increase information could be provided on their bills).

However, to the extent that there is no inducement on consumers to change their behaviour (that is, actually install the light bulbs), then the answer is no. Sansted and Howarth observe:

... even if we agree that consumers are boundedly rational when it comes to making energy-related decisions, this fact does not necessarily provide a blanket justification for policies aimed at promoting energy efficiency. If consumers are inexpert at dealing with energy choices, this constitutes a potential barrier not only to effective market decisions but also to programs designed to improve on market outcomes. If, for example, consumers have trouble understanding how energy "works" when left to their own devices, how can they appreciate the benefits that demand-side management programs offer them? The consistent finding that information programs directed at energy use often have very limited effects (McMahon 1991) is relevant to this point. Changing people's behavior is of course feasible, but it can be very difficult and costly to accomplish. This is one true "hidden cost" that must be confronted by policy makers: limitations on consumer rationality do not simply disappear in the face of policy; indeed, they may undermine⁶⁰ efforts to fix observed imperfections in markets for energy and energy-using technologies.

Evaluation – mechanisms for awareness and organisational change

Voluntary agreements, MEPS and the mandatory audits/implementation approach directly target end user behaviour. As noted, voluntary agreements and the mandatory audits/implementation approach are less suitable for smaller consumers.

Aside from MEPS, there are limited options to address directly the identified awareness and organisational failures for smaller consumers. While MEPS are important, they do not help to change the underlying failures and do not provide incentives to increase the rate of uptake of cost effective technologies beyond the minimum standard.

This suggests a second best solution for incentives — either subsidies for delivery of energy services or energy efficiency targets for retailers — should be considered as a policy approach. Subsidising delivery of energy services is likely to have lower costs of implementation (despite potentially higher budgetary costs), be easier to establish, and is likely to be more flexible in response.⁶¹

⁶⁰ A.H. Sanstad and R.B. Howarth 1994, *ibid*, p9,

⁶¹ The subsidies approach could be used initially to test the best approaches to changing end user behaviour through a series of targeted pilots programs.

ASSESSMENT OF POLICIES TO OVERCOME AWARENESS AND ORGANISATIONAL FAILURES

Mechanisms	Impact on EE	Benefits to end users	Cost to budget	Political feasibility	Dynamic benefits
Voluntary approaches	Low	Low	Low	Large	Low
Taxes and subsidies	Low	Low	Low - Large	Low	Low
Subsidising delivery of energy services	Moderate-large	Moderate-large	Small-large	Low - Moderate	Moderate-large
Mandatory audits and adoption	Moderate	Moderate	Moderate	Moderate	Moderate
Energy efficiency targets	Moderate-large	Moderate-large	Small	Moderate-high	Moderate-large

Source: The Allen Consulting Group

In the final analysis, the 'white certificates' policy has many of the hallmarks of a subsidies based approach. As noted, it has the advantage of the retailers having access to data on end users' consumption. On the other hand, the approach has large fixed costs of establishment, and is possibly less flexible than the subsidies based approach.⁶²

4.7 Conclusions

Given the diverse market failures outlined above it may be difficult to rely on a single policy instrument to achieve cost effective uptake of energy efficiency. Rather, a package of policy instruments that selectively targets key market failures is required. The package approach may be further supported by the heterogeneous nature of the markets for energy services (residential, commercial, industry and energy-intensive end users), with differing market failures in each case. Golove and Eto summarise this neatly:

We do not believe the market barriers debate can be settled by ideological fiat; instead, it must be addressed in a highly disaggregate fashion, considering particular markets and a realistic assessment of the limitations of particular institutions and policies. It is unlikely that, even when public policies are appropriate, there will ever be a single best policy solution (e.g., government minimum efficiency standards); instead, multiple approaches to overcoming market failures or reducing high transaction costs tailored to particular circumstances are more likely to be appropriate.⁶³

⁶² The existence of pre-existing model and associated infrastructure — such as that for the Mandatory Renewable Energy Target — does provide scope to reduce the fixed costs of establishing such a scheme to the extent that a new program could 'piggy back' on the old.

⁶³ W.H.Golove and J.H.Eto 1996, *Market Barriers to Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency*, p34, LBL-38059, eed.lbl.gov/ea/EMP/ee-pubs.html.

We have identified the key market failures impeding the uptake of energy efficiency as being:

- distorted relative prices;
- information imperfections; and
- institutional and organisational constraints.

The following package of policies is likely to offer the most cost effective approach to overcome these failures:

- energy market pricing and institutional arrangements that reward cost effective investments in energy efficiency and provide a signal on the need to address the emerging greenhouse externality;
- information disclosure through labelling and cost effective minimum energy performance standards for appliances, equipment and buildings;
- mandatory energy efficiency audits and uptake for larger firms in the mining, manufacturing and services sectors;
- competitive sourcing of energy efficiency products and services that aims to:
 - increase awareness of opportunities and reduce organisation barriers, particularly for smaller end users;
 - transform the market to improve the energy efficiency of appliances, equipment and buildings; and
 - reduce transactions costs of adopting energy efficiency goods and services by developing the energy services industry.

Chapter 5

Costs and benefits of improving energy efficiency

There is a large number of studies examining the costs and benefits of addressing energy efficiency. These range from the thousands of energy efficiency audits that have been conducted through to large scale economic studies. This Chapter provides a brief survey of a small subset of the estimates of the costs and benefits of improving energy efficiency. It is by no means an exhaustive survey, rather, it is intended to give a sense of the magnitude of the savings that are available, and their net benefits.

5.1 NFEE study

In the Australian context, the most recent and comprehensive assessments of opportunities for energy efficiency at current prices are the studies conducted for the National Framework for Energy Efficiency (NFEE), which were summarised in Chapter 2. While the initial NFEE estimates were based on a diverse review of the literature, the second phase of the NFEE assessment (see Table 2.1) were far more robust. First, these estimates involved detailed assessment of current opportunities for energy efficiency in the industrial, commercial and residential sector — undertaken by respected Australian energy efficiency experts familiar with the range of opportunities that are commonly available. Secondly, the phase 2 estimates were extremely conservative, only adopting those opportunities with a payback of less than or equal to 4 years.⁶⁴ As noted in Chapter 2, the resulting average payback of all opportunities — of 2.4 years — is equivalent to an internal rate of return of more than 50 per cent.

To assess the full economy-wide estimates of the costs and benefits of implementing these opportunities, the estimates were then modelled using the computable general equilibrium (CGE) model MMRF–GREEN, operated by the Centre of Policy Studies (CoPS) at Monash University.

The phase 2 modeling utilised revised input data on the direct costs and benefits associated with the adoption of energy–saving technologies in different industries, derived from the phase 2 technical studies. The Sustainable Energy Authority of Victoria integrated the new data into a single dataset, which was then provided to The Allen Consulting Group and CoPS. Importantly, costs were inflated by 7.5 per cent in the industrial and commercial sectors reflect hidden costs and other transactions costs that may not have been accounted for.

A single scenario was modelled: one in which opportunities for energy–saving improvements with up to four–year payback period are taken up economy–wide at a rate of 50 per cent (the 50 per cent – low scenario). With the 50 per cent penetration rate, a further element of conservatism was introduced.

⁶⁴

The Phase 1 work was based on measures with an *average* payback of 4 years.

The adoption of energy-saving improvements under this scenario leads to a range of economic, social and environmental benefits. Over the complete period of the policy simulation (23 years — the effective life of the investments), the net present value (NPV)⁶⁵ of the projected rise in national consumption — or in broad terms, national economic welfare — brought about by improved energy efficiency is around \$5.3 billion. The equivalent figure for gross domestic product (GDP) is around \$6.6 billion. Employment is estimated to increase by around 2,600 persons by year 12, when the full impact of the investments is being realised, than would otherwise have been the case without the improvements. The improvements also lead to substantial reductions in both greenhouse gas emissions from the stationary energy sector and energy consumption in year 12 — around 9.5 Mt of CO₂-e and 75.5 petajoules respectively. Table 5.1 summarises the effects of improved energy efficiency in year 12.

Table 5.1

SUMMARY OF ECONOMIC IMPACTS OF IMPROVED ENERGY EFFICIENCY^a

<i>Macroeconomic variable</i>	<i>Change relative to base case (year 12)</i>
GDP (\$m)	975
Real Private Consumption (\$m)	724
Employment (persons)	2,600
Greenhouse Gas Emissions (Mt of CO ₂ -e)	-9.5
Energy Use (petajoules)	-75.5

^a Relates to the 50 per cent – low scenario.

Source: MMRF-GREEN.

Two features of these results are worth highlighting.

First, the rebound factor in this study was around 28 per cent. This reflects that savings from energy efficiency tend to be expansionary, resulting in second round increases in energy consumption in the economy. While the overall savings from cost effective uptake of energy efficiency are therefore less than the raw sum of the individual savings, this does not mean that the benefits for individuals adopting energy efficiency measures are diminished.

Second, the conservative nature of the estimates, and the addition of transactions costs included in the estimates mean that even if there are hidden costs that have not been accounted for, the overall returns are still likely to remain high compared to other standard internal rates of return in the economy. (Recall that the internal rates of return of the energy efficiency opportunities were in excess of 50 per cent.) As a final point, the returns to the economy from the overall expansionary effects of the measures are estimated to add a further 4.5 per cent to the first round savings. This provides a further buffer against 'hidden costs'.

⁶⁵

Assuming a real discount rate of 4 per cent per annum, and expressed in terms of 1999 dollars.

5.2 Sectoral considerations

Residential sector

The NFEE study suggested that savings approaching 12 per cent are available at current prices in the residential sector with paybacks up to 4 years. However, the analysis in Chapters 3 and 4 suggested that lack of awareness and bounded rationality are likely to be significant barriers to uptake of energy efficiency in the residential sector. In addition, the transactions costs associated with the sector are likely to be large. This suggests care is needed to pick key products and services that have a potential to be amenable to cost effective intervention. Subsequent policy intervention could aim to transform the market for these selected products, by working on the supply side arrangements and importantly, the attitudes and decision-making capacity in the residential sector.

In light of the transactions costs, approaches such as minimum energy performance standards (MEPS) become important, as they sidestep the need to change behaviour. The ability of MEPS to enhance economic welfare has been demonstrated in a wide range of cost benefit analyses conducted for appliance MEPS, and more recently for proposed buildings standards. For example, appliance MEPS were estimated to deliver overall net benefits to consumers of \$4.2 billion in net present value terms over the period 2003 to 2018.⁶⁶ Similarly, the 5 star building standards coming into force in Victoria from 2005 were estimated to have GDP net present value benefits in the range of \$30 to 566 million over the period 2002 to 2012.⁶⁷

Commercial sector

The commercial sector offers significant energy efficiency savings opportunities from energy efficiency. The NFEE commercial sector study estimated savings of around 10 per cent are available at paybacks of up to 4 years or less. The conservative nature of these estimates is highlighted by other studies, which suggest that savings exceeding this magnitude have been achieved in a wide range of buildings. For example, estimates of private returns to energy improvements undertaken as part of the NSW Energy Smart Buildings program have exceeded 24 per cent in office buildings, and 18 per cent in the healthcare sector.⁶⁸

Industrial sector

Numerous studies on potential savings in the industrial sector support the NFEE estimates. For example, ABARE reviewed evidence from opportunities identified as part of the Energy Efficiency Audit Program conducted by the Commonwealth Government during the 1990s. ABARE found that the program unambiguously benefited firms (Box 5.1).

⁶⁶ Commonwealth of Australia 2003, *National Appliance and Equipment Energy Program: Projected Impacts 2000-2020*, www.energyrating.gov.au.

⁶⁷ The Allen Consulting Group 2002, *Cost-Benefit of New Housing Energy Performance Regulations: Impact of Proposed Regulations*, www.seav.gov.au.

⁶⁸ The Allen Consulting Group 2003, *The NSW Government Energy Program: A Triple Bottom Line Analysis*, Report to the Sustainable Energy Development Authority.

Box 5.1

ENERGY EFFICIENCY AUDIT PROGRAM

ABARE conducted a survey of 100 firms that took part in the Commonwealth Government's Enterprise Energy Audit Program (EEAP) — which ran for six years until May 1997 and was monitored by ABARE. The survey included detailed questions about each firm's implementation of audit report recommendations. Implementation rates were found to be high and audits to be cost effective.

Using both the (one-off total) cost and savings (per year) reported by the auditor, the NPV of each investment was calculated assuming a 10 year investment life, and a discount rate of 8 per cent. The average NPV per firm from implementing all recommendations was calculated to be A\$429 000, and the NPV of the recommendations actually implemented was A\$364 000 per firm.

While the estimates did not include all hidden costs, such as risks, ABARE concluded that 'it can probably be concluded that the EEAP audit process was cost effective to firms. This is backed up by the 93 per cent or so of EEAP participants who said that it was worthwhile In addition it is probably safe to say that, given the magnitudes of the results, audits are worthwhile for many firms even without government subsidies'.

Source: J.Harris, J.Anderson, W.Shafron 2000, Investment in energy efficiency: a survey of Australian firms, *Energy Policy* 28 (2000) 867-876.

As noted in Chapter 3, evidence from programs such as the Energy Efficiency Best Practice Programs of the United Kingdom and Australia, and the detailed investigations by the SPRU BARRIERS project, also support the existence of cost effective energy savings in the industrial sector.

5.3 Conclusions

There is a wealth of empirical evidence to suggest that significant savings are available from investments in energy efficiency in the residential, commercial and industrial sectors. Generally, the studies support the contention that savings exceeding 10 per cent of energy use are available in all sectors of the economy, at internal rates of return that exceed 50 per cent.

However, many of these empirical studies are *ex ante* studies that do not follow up to establish the extent to which actual savings are achieved after implementation. Consequently, there is very little insight into the extent of hidden costs that might explain the lack of uptake of these opportunities. This points to the importance of conducting rigorous follow-up evaluation of actual savings achieved in any future policies or programs, and also the value of identifying what market failures were overcome, and how.

A Clean Energy Future for Australia



A Study by
Energy Strategies for the
Clean Energy Future Group

Consisting of:

Australasian Energy Performance Contracting Association

Australian Business Council for Sustainable Energy

Australian Gas Association

Australian Wind Energy Association

Bioenergy Australia

Renewable Energy Generators of Australia

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AEPCA is the **Australasian Energy Performance Contracting Association**. Its members are formed from energy service companies, state government departments and private companies interested in the performance contracting process. Energy performance contracting is a smart, affordable and increasingly common way to make building improvements that save energy and money. Its mission is to act as the Peak Body to support the commercial growth of members and their market through education, industry promotion, self-regulation and industry standards. www.aepca.asn.au



The **Australian Business Council for Sustainable Energy (BCSE)** represents the interests of the broader sustainable energy industry including, renewables energy, cogeneration, gas-fired generation, waste-to-energy and energy efficiency industry. It has more than 250 organisations as members. It formed in September 2002 through the merger of the Australian EcoGeneration Association and the Sustainable Energy Industry Association. www.bcse.org.au



The **Australian Wind Energy Association (AusWEA)**'s vision is for a robust Australian Wind Community that makes a significant contribution to safe, reliable, economically and environmentally sustainable energy supply in Australia. AusWEA's mission is to represent the Australian Wind Energy Community and promote the sensitive and appropriate uptake of wind energy. www.auswea.com.au



Bioenergy Australia was established in 1997 as a government-industry forum to foster and facilitate the development of biomass for energy, liquid fuels, and other value added bio-based products. Bioenergy Australia is concerned with all aspects of biomass and bioenergy, from production through to utilisation, and its work embraces technical, commercial, economic, societal, environmental, policy and market issues. This report does not necessarily reflect the views of all individual Bioenergy Australia members. www.bioenergyaustralia.org



The **Renewable Energy Generators of Australia (REGA)** was formed in 1999 as an industry association with a common purpose of supporting the development of generation of electricity from truly renewable resources. REGA represents all sectors of the renewable energy industry; members represent 95% of the existing renewable energy generation capacity, and include equipment suppliers, developers and industry specialists. www.rega.com.au



WWF Australia is part of the WWF International Network - the world's largest independent conservation organisation. With the help of more than 50,000 supporters across Australia, we're helping to protect and conserve our most biologically outstanding land, freshwater and marine habitats and reduce the causes and impacts of climate change. www.wwf.org.au

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Table of Contents

GLOSSARY	iv
UNITS AND CONVERSION FACTORS	viii
1. INTRODUCTION	1
1.1. Why this study has been done	1
1.2. Structure of this report.....	6
2. METHODOLOGY AND ASSUMPTIONS	
STUDY METHOD	8
2.1. Study method	8
2.2. Future energy costs and prices	18
3. ENERGY IN AUSTRALIA TODAY	22
3.1. How energy systems are described.....	22
3.2. Australia's current pattern of energy use and supply.....	25
4. FUTURE LEVELS OF ECONOMIC ACTIVITY	33
4.1. Introduction.....	33
4.2. Methodology	33
4.3. The contemporary Australian economy	34
4.4. Estimates of future economic activity	39
4.5. Conclusions	41
5. ENERGY AND THE ECONOMY	42
5.1. Economy wide trends in energy intensity over recent years.....	42
5.2. Analysis of individual sectors.....	44
5.3. Baseline energy demand.....	51
6. ENERGY EFFICIENCY TECHNOLOGIES AND POTENTIAL	56
6.1. Concepts and approaches to assessing the potential	56
6.2. Manufacturing.....	58
6.3. Mining, Construction and Agriculture etc.	65
6.4. Commercial and services sectors.....	66
6.5. Residential sector	66
6.6. Transport	68
6.7. Fugitive emissions	69
6.8. The Medium Efficiency demand case.....	70
7. PRESENT AND FUTURE RENEWABLE ENERGY TECHNOLOGIES	76
7.1. Biomass energy	76
7.2. Wind power	85
7.3. Solar heat	90
7.4. Hydro-electricity	91
7.5. Photovoltaics (PVs)	90

7.6.	Solar thermal electricity	95
7.7.	Other renewable energy technologies	97
7.8.	Advanced energy storage	99
7.9.	The 'hydrogen economy'	102
7.10.	Fuel cells	102
7.11.	Transmission and distribution infrastructure	103
7.12.	Projected costs of electricity	103
8.	PRESENT AND FUTURE FOSSIL FUEL TECHNOLOGIES	105
8.1.	Conventional (pulverised fuel) coal-fired power stations	105
8.2.	Combined cycle gas-fired power stations	107
8.3.	Integrated gasification combined cycle (IGCC) coal-fired power stations	108
8.4.	Geosequestration of CO ₂	118
8.5.	Oil substitutes from oil sands, shale and coal	110
8.6.	Cogeneration of heat and electricity	110
8.7.	Phase-out of existing fossil fuelled power stations	113
9.	DECARBONISING ENERGY SUPPLY	116
9.1.	Introduction	116
9.2.	Solar thermal pre-heating	117
9.3.	Substitution of gas for coal and petroleum	118
9.4.	Greater use of cogeneration	119
9.5.	Decarbonising the electricity supply mix	120
9.6.	Decarbonising transport	126
10.	SCENARIOS FOR A CLEAN ENERGY FUTURE IN 2040	127
10.1.	Scenario results: changes in greenhouse gas emissions from stationary energy	127
10.2.	Costs of the various scenarios	132
10.3.	Paying for cleaner energy scenarios	137
11.	INNOVATIVE SCENARIOS FOR BEYOND 2040	139
11.1.	Scenario 5: Geosequestration of CO ₂ from distributed sources	139
11.2.	Scenario 6: Low-cost renewable electricity without additional storage	140
11.3.	Scenario 7: Cheap renewable electricity with cheap storage	141
11.4.	Concluding remarks	142
12.	POLICY OPTIONS AND STRATEGIES	143
12.1.	Axioms and principles	143
12.2.	Policies for all spheres of government	145
12.3.	Specific policies to assist specific technologies and systems	146
12.4.	Costing the recommendations	150
13.	COMPARISON WITH OTHER 'DEEP CUTS' STUDIES	151
13.1.	ABARE's MENSA model, Australia	151
13.2.	'Deep cuts' study by the Australia Institute	152

13.3. Ecofys study on the EU	153
13.4. Royal Commission on Environmental Pollution on the UK	153
13.5. Department of Trade & Industry on the UK	154
13.6. Pew Center study on the USA	154
13.7. US Interlaboratory studies	155
13.8. Study for WWF (USA)	155
13.9. Discussion	156
REFERENCES	157
APPENDIX A: EXTERNAL COSTS OF FOSSIL FUELS.....	161
APPENDIX B: CAN RENEWABLE ENERGY REPLACE COAL WHEN DEMAND IS GROWING RAPIDLY?	163

GLOSSARY

Absorption chiller	A chiller (<i>q.v.</i>) which is operated by heat rather than by mechanical energy as in the more common type of chiller using vapour compression refrigeration. It uses the cyclic separation (by heating) and absorption of a pair of fluids (termed refrigerant and absorbent) having a strong affinity for each other. Heat is absorbed, i.e. “coolth” is produced in the process of absorption.
Anaerobic digestion	A fermentation process for producing gas from biomass in a wet, oxygen-free environment.
Backcast	To develop a scenario by choosing a future state of society or a technology and then working out how to get from the present state to that future state.
Back pressure turbine	A turbine (usually a steam turbine) in which the steam exits the turbine chamber at significant positive pressure and thus with significant remaining energy available to be used in another process.
Bagasse	The fibrous residue of sugar milling that is used as a fuel to raise steam in the mills.
Base-load	Power stations that are designed to run 24 hours per day, 7 days per week. They usually have high capital cost and low running cost.
Biogas	Gas produced from biomass: e.g. from animal manure and garbage tips, by anaerobic digestion (<i>q.v.</i>).
Biomass	Material produced by photosynthesis or an organic by-product from a waste stream. It includes a wide variety of renewable organic materials, including forestry and agricultural wastes and residues, urban tree trimmings, food processing wastes, woody weeds, oil bearing plants, animal manures and sewage, energy crops and the organic fraction of municipal solid waste.
Boiler	A reactor where a fuel is burnt to heat water in order to produce steam or hot water.
Bottoming cycle	A type of cogeneration system in which hot exhaust gases from a kiln or similar high temperature process are used to produce steam which is then passed through a turbine to generate electricity. The steam exits from the turbine at close to atmospheric pressure and cannot be used to provide further useful energy.
Bottom up model (of greenhouse response)	A computer model of all or part of the energy sector that is based directly on data on the cost and performance of specific energy technologies and services.
Brown coal	Sometimes called lignite. The type of coal used to generate electricity in Victoria and South Australia. It has a very high water content and low carbon content and so has among the highest greenhouse intensities of all fossil fuels.
Capacity (of power station)	Rated or peak power, measured in megawatts or similar units.
Capacity credit	The effective capacity of an ‘intermittent’ or ‘unreliable’ power station to meet demand, divided by the capacity of a hypothetically totally reliable power station, often expressed as a percentage. All real power stations are unreliable to some degree and so have capacity credit less than 100%.
Capacity factor	The annual energy generated by a power plant divided by the energy that it would have generated if it had operated continuously at its rated or peak power, often expressed as a percentage.
Chiller	A device for producing “coolth” (as opposed to heat), which can be used to lower the internal temperature of a building.
Coal-bed methane	Methane gas that occurs naturally in black coal seams.
Cofiring	Burning two or more fuels together (e.g. coal and biomass) in the boiler of a power station.
Cogeneration	The production of electricity and useful heat together from the same power plant. Sometimes called ‘combined heat and power’.
Combined cycle	A power station that generates electricity by means of one process (e.g. gas turbine) and then uses the waste heat from that process to generate more electricity from another process (e.g. waste heat boiler plus steam turbine). Combined cycle power stations have higher thermal efficiencies (<i>q.v.</i>) than ordinary ‘single cycle’ power stations.

Coppice	To cut off the above-ground branches of a tree so that they re-grow rapidly.
Dematerialisation	The process whereby advanced economies become relatively less dependent on the production of material commodities and their conversion into physical goods, and more dependent on the production and consumption of services, with the result that the consumption of raw materials per unit of GDP decreases.
Discount rate	An interest rate used to discount (i.e. reduce the value of) income or expenditure in the future (see Net Present Value) due in part to preference for consumption now rather than later. It is often expressed in 'real' terms, i.e. adjusted to exclude the effects of inflation..
Dispatchable power station	A power station that produces power upon demand. Usually refers to either a thermal or a hydro-electric power station based on a dam. Could also be used for an 'intermittent' power plant, such as solar or wind, which has dedicated storage. Concept is an idealisation, since 'dispatchable' power stations may fail to operate unexpectedly at some time or other
Distribution line	Power line for the local distribution of electricity. In Australia, it usually has voltage below 66 kV.
End-use energy	Final energy consumption (<i>q.v.</i>).
Energy intensity (of an economy)	Annual national energy consumption divided by GDP.
Energy service	A service that is provided by a combination of energy supply and a pattern of energy use: e.g. a warm home in winter; clean clothes; access to a school.
Fermentation	One of several methods for converting biomass into a gas or liquid, involving the use of micro-organisms (yeast or bacteria) which change the chemical composition of the biomass by means of enzymatic (biological) reactions that occur in a moist environment with little or no oxygen present.
Final energy consumption	Energy consumed in the 'final' or end-use sector. It equals primary energy consumption less energy consumed or lost in the conversion, transmission and distribution processes.
First Law of Thermodynamics	The conservation of energy, which states that energy cannot be created or destroyed, but only converted from one form to another.
Forecast	To develop a scenario by projecting from the present into the future, based on past trends. (Becomes increasingly unreliable as the future time increases.)
Fossil fuel	A primary fuel (<i>q.v.</i>) consisting of the fossilised organic material derived from plants and animals which lived in the remote geological past; the main fossil fuels are coal, petroleum and natural gas.
Fuel cell	An electrochemical system that converts hydrogen and oxygen into water, producing electricity and heat in the process, thereby providing a high efficiency means for converting the energy in a fuel(hydrogen) directly to electricity.
Fugitive emissions	Greenhouse gas emissions not resulting from the combustion of fossil fuels, but rather from mining, transmission, distribution and storage of fuels.
Gas turbine	An engine that burns a liquid or gaseous fuel to produce an expanding gas that drives a turbine. The turbine can be used to drive a generator (as in a power station), a piece of major mechanical equipment such as a pump or compressor (as in large industrial plants, gas pipelines etc.), or a propeller (as in aircraft engines).
GDP	Gross Domestic Product, a measure of economic activity, formally defined to be the total monetary value of 'final' goods and services produced in a country in a year. 'Final' excludes 'intermediate' goods and services which are used as inputs into the production of other goods and services.
Geosequestration	The capture of CO ₂ gas from a large point source, such as a power station, and its storage deep underground.
Greenhouse (gas) intensity (of power station)	Megatonnes of CO ₂ produced divided by electricity sent out in TWh, which is equivalent to kg of CO ₂ produced divided by electricity sent out in kWh.
Grid	Network of electricity powerlines.
Gross Calorific Value (GCV)	The quantity of heat energy released when a fuel is burned completely with oxygen, and the products of combustion are returned to ambient temperature and pressure. It is normally measured per unit mass or unit volume of a fuel.

	Sometimes termed Higher Heating Value (HHV). GCV is generally used in Australia and the USA, while Net Calorific Value (<i>q.v.</i>) is more often used in other countries.
Higher Heating Value (HHV)	See Gross Calorific Value.
Insolation	Solar energy input as sunshine.
Integrated gasification combined cycle (IGCC)	Combined cycle power station (<i>q.v.</i>) that gasifies solid fuel before burning it.
Intermediate load	A power station whose operation is between that of base-load and peak-load. Output can be varied more rapidly than base-load but more slowly than peak-load. Capital/fuel cost lower/higher than base-load but higher/lower than peak-load. Generally operates for several hours per day during medium to high demand periods.
Inverter	An electronic device that converts direct current (DC) electricity into alternating current (AC) with a specified frequency.
Least-cost planning	A method of planning the future development of an energy supply system that identifies the lowest cost means of meeting the final demand for energy services by assessing both supply-side options (new power stations, power lines etc.) and demand side options (increased energy use efficiency) on an equal basis.
Levelised cost / annuity	An amount of money which, if paid annually over the life of an asset, such as a power station, will fully repay the capital cost plus interest over the life. The term is sometimes used to include also the annual operating costs (fuel, operation and maintenance etc.), and thereby express the full cost of producing electricity from the power station.
Liquefied natural gas (LNG)	Natural gas which is kept in the liquid state at very low temperatures to facilitate storage and transport.
Loss-of-load probability	The average number of hours per year that electricity supply fails to meet demand.
Lower Heating Value (LHV)	See Net Calorific Value.
Mallee	A type of eucalypt which has multiple stems sprouting from a long-lived underground stem, termed a lignotuber (mallee root). Mallees have the ability to re-shoot repeatedly from the lignotuber and so are ideally suited to coppicing (<i>q.v.</i>).
Microturbine	A very small gas turbine that can be used to generate both useful heat and electricity at the point of use in commercial and (possibly in the near future) in residential buildings
MRET	Mandatory Renewable Energy Target
NEM	National Electricity Market
NEMMCO	National Electricity Market Management Company
Net Calorific Value (NCV)	This is equal to GCV (<i>q.v.</i>) minus the latent energy contained in the water vapour (in the exhaust gas) which is produced when hydrogen (from the fuel) is burned. Sometimes termed Lower Heating Value (LHV). Therefore, the difference between GCV and NCV increases as the hydrogen content of the fuel increases. As a result, the thermal efficiency of a coal-fired power station based on NHV is typically 2-3% higher than its thermal efficiency based on GCV; in the case burning natural gas, the NHV thermal efficiency may be 10-15% higher than the GCV thermal efficiency.
Net Present Value (NPV)	The value today of a future stream of revenue (income) and expenses, calculated by discounting future costs and revenues at a chosen discount rate and summing the discounted quantities. The effect of discounting is to make revenue and expenses in the more remote future relatively less important than those in the immediate future.
Off-grid	Not connected to the electricity network.
Peak-load	Power stations that are designed to run for only short periods to meet the peaks in demand. If they are thermal power stations (<i>q.v.</i>) (gas turbines), they have low capital cost and high running cost..
Peak watt	The rated or nameplate power capacity of an energy source, often applied to

	PV modules.
Photovoltaic (PV) cell and module	An electronic device that converts solar energy directly into electricity without any moving parts (apart from the electrons).
Primary energy	The chemical energy stored in a primary fuel (qv).
Primary fuel	Fuel that is extracted directly from the natural environment, such as coal, natural gas, crude oil, uranium, wood, bagasse, wind, solar energy.
Pyrolysis	One of several thermochemical methods for converting biomass or coal into a gas or liquid, involving heating the biomass or coal within a closed chamber in the almost complete absence of oxygen.
Reciprocating engine	An engine whose central elements are a cylinder and piston which moves up and down inside the cylinder, as in a standard car engine.
Remote area power supply	Power plant not connected to a large electricity grid. (However, it may be connected to a small local grid.)
Reformer (in chemistry)	A chemical method of converting alcohols and hydrocarbons into hydrogen, usually for use in a fuel cell.
Scenario	An evolutionary pathway between the present and a future state of society or technology.
Second Law of Thermodynamics	When energy is transformed from one form to another, it tends to flow from a higher grade or more ordered form -- such as mechanical, electrical energy, chemical or high-temperature heat -- to a lower-grade or more disordered form, ultimately low-temperature heat. So energy becomes degraded and less useful to humans. It is possible to reverse this natural flow, pushing low-grade energy 'uphill', but only by expending more high-grade energy at the input than is received at the output.
Secondary fuels	Fuels produced from primary (or other secondary) fuels by conversion processes to produce the fuels commonly consumed: e.g. thermal electricity, coke and refined petroleum products.
Sensitivity analysis	Repetition of a calculation a number of times to investigate the effect of changing an assumption or the data used.
STP	Standard temperature and pressure, comprising 0°C and 1 atmosphere (101.3 kPa)..
Steam turbine	A turbine driven by steam that is produced by burning fuel to boil water.
Supercritical	New kind of boiler used in coal-fired power stations which operates under higher steam pressures and temperatures and so gains higher thermal efficiency. Two new power stations in Queensland are using supercritical boilers.
Thermal efficiency (of power station)	Electrical energy sent out divided by energy input, sometimes expressed as a percentage. In the case of thermal power stations, the energy input is the chemical energy stored in the fuel. There are two ways of calculating the latter, called Higher Heating Value (HHV), which is used in this report and generally in Australia, and Lower Heating Value (LHV), which is sometimes used overseas.
Topping cycle	A type of cogeneration system in which steam direct from the boiler, at high temperature and pressure, is passed through a steam turbine to generate electricity, from which it exits at a lower temperature and pressure to be used for thermal processes.
Transmission line	An electricity power line designed to carry a large quantity of electricity over a long distance. In Australia, a transmission line generally operates at a voltage of at least 132 kV, and most major lines operate at 330 or 500 kV.
Turbine	A motor whose central elements are a series of blades attached to a shaft, which rotates, usually within a chamber. Steam turbines, gas turbines, hydro turbines and wind turbines are used extensively in modern energy systems.
Wind farm	An array of wind turbines located in proximity to one another and generally using the same substation (transformer) and power line to connect to an electricity grid.

Units and Conversion Factors

Powers of 10

Prefix	Symbol	Value	Example
kilo	k	10^3	kilowatt kW
mega	M	10^6	megawatt MW
giga	G	10^9	gigajoule GJ
tera	T	10^{12}	terawatt-hour TWh
peta	P	10^{15}	petajoule PJ

SI units

Basic unit	Name	Symbol
length	metre	m
mass	kilogram	kg
time	second	s
temperature	Kelvin	K

Derived unit	Name	Symbol
energy	joule	J
power	watt	W
potential difference	volt	V
pressure	pascal	Pa
temperature	degree Celsius	°C
time	hour	h

Conversion factors

Type	Name	Symbol	Value
energy	kilowatt-hour	kWh	$3.6 \times 10^6 \text{ J} = 3.6 \text{ MJ}$
energy	terawatt-hour	TWh	$3.6 \times 10^{15} \text{ J} = 3.6 \text{ PJ}$
energy	litre of petrol	L	$3.2 \times 10^7 \text{ J}$
energy	m ³ of natural gas at STP		$3.4 \times 10^7 \text{ J}$
energy	tonne of NSW black coal	t	23 GJ
energy	tonne of Vic. brown coal	t	10 GJ
energy	tonne of green wood	t	10 GJ
energy	tonne of oven-dried wood	t	20 GJ
power	kWh per year	kWh/y	0.114 W
time	year	y	8760 h
pressure	atmosphere		101.325 kPa

1. Introduction

1.1. Why this study has been done

“Energy is vital to a modern economy. We need energy to heat and light our homes, to help us travel and to power our businesses. Our economy has also benefited hugely from our country’s resources of fossil fuels – coal, oil and gas.

“However, our energy system faces new challenges. Energy can no longer be thought of as a short-term domestic issue. Climate change – largely caused by burning fossil fuels – threatens major consequences in the UK and worldwide, most seriously for the poorest countries who are least able to cope ... We need urgent global action to tackle climate change. We are showing leadership by putting the UK on a path to a 60% reduction in its carbon dioxide emissions by 2050...

“Our analysis suggests that, by working with others, the costs of action will be acceptable and the costs of inaction are potentially much greater. And as we move to a new, low carbon economy, there are major opportunities for our businesses to become world leaders in the technologies we will need for the future...”

Tony Blair, Foreword to UK White Paper on Energy (DTI, 2003)

“The world is in the early stages of an inevitable transition to a sustainable energy system that will be largely dependent on renewable resources.”

International Energy Agency (1999)

What this study does

This study explores the potential for deep cuts in emissions of the principal greenhouse gas, carbon dioxide (CO₂), in Australia. It focuses on stationary energy, that is energy that is used in the form of electricity, heat that is not produced from electricity, and mechanical energy. The study does not examine transport, which must be left for a separate study.

The principal goal of the present study is to investigate whether it is possible to achieve a 50% reduction in CO₂ emissions from stationary energy by 2040, by using a mix of existing technologies, with small improvements, in order to produce and use energy more efficiently and more cleanly. So, in our principal scenarios there are no dramatic breakthroughs in technologies: no cheap electricity from solar photovoltaic cells; no cheap capture and sequestration underground of CO₂ emitted by coal-fired power stations; and no cheap methods of producing hydrogen as a means of storing and transporting renewable energy. In practice, however, there will be innovation between now and 2040. In Chapter 11 we offer a glimpse of how, with innovation, we might achieve 80% or more reductions in CO₂ emissions beyond 2050 – but these are not the principal scenarios of this study. If we can reach our 2040 target with small

improvements to existing technologies, then reductions beyond 2050 will be even easier with innovation.

Our method is to take existing technologies and develop a workable and credible stationary energy supply system for 2040 that meets our target and then to identify the key strategies that will allow us to get from the present to that 2040 state. In moving from the present to the future we take account of the main driving forces for increasing energy consumption: economic growth and population growth.

Our study is inspired by several earlier energy and greenhouse scenario studies performed overseas (RCEP, 2000; Interlaboratory Work Group, 1997, 2000; Marsh *et al.*, 2003) and a pilot study published by the Australia Institute (Turton *et al.*, 2002). These and other scenario studies are reviewed briefly in Chapter 13. However, the present study is different from earlier studies because of its focus on existing technologies and because it presents new scenarios on future energy use and greenhouse gas emissions in Australia.

The principal motivation for this study is similar to that expressed in the above quotation from the British Prime Minister: the need to bring human-induced climate change under control. By describing and analysing a feasible long-term future in which energy demand and supply mix are radically different from today's, decision-makers, professionals, environmentalists and the community at large can form a picture of how Australia and the world could have a much cleaner and more efficient energy system while still being prosperous. The present study is a contribution to this longer-term thinking about Australia's response to climate change.

Climate change¹

The world's most authoritative body on climate change, the Intergovernmental Panel on Climate Change (IPCC), has warned that the nations of the world will need to shift to a low-carbon future in order to avoid dangerous changes to the global climate.

The IPCC has developed a number of climate change scenarios to evaluate future impacts. Even the most optimistic scenario, involving rapid change in economic structure and technology, shows CO₂ concentrations doubling by the end of the century, resulting in an increase in average global temperatures of around 2° C and a sea-level rise of 30 cm.² The IPCC notes that the climate system is subject to great inertia so that '[s]tabilization of CO₂ concentrations at any level requires eventual reduction of global CO₂ net emissions to a small fraction of the current emission level' (IPCC, 2001a, p. 16). There are advantages in beginning the task of reducing emissions sooner rather than later: 'The greater the reductions in emissions and the earlier they are introduced, the smaller and slower the projected warming and the rise in sea levels' (IPCC, 2001, p. 19).

Doubling of atmospheric concentrations of CO₂ is expected to be associated with global warming in the range 1.4-2.6°C by the end of the century (IPCC 2001a, Figure 22, p. 209). The United Nations Framework Convention of Climate Change

¹ This subsection reproduces several paragraphs from Turton *et al.* (2002) with permission from the Australia Institute.

² Scenario B1 in IPCC (2001), pp. 10-11.

(UNFCCC) commits nations (including Australia) to taking measures to prevent 'dangerous' levels of climate change. It is widely accepted that concentrations in excess of 550 ppm, or double the pre-industrial levels, would be dangerous, and that even a doubling is likely to be associated with major negative impacts (see IPCCa, 2001). According to the IPCC, stabilising concentrations at double pre-industrial levels will require deep cuts in annual global emissions, eventually by 60 per cent or more (see IPCCa, 2001, Figure 25).³

The need for deep cuts has been formally acknowledged by the Australian Government. The Foreign Minister, Alexander Downer, has stated:

*“If we are going to achieve stability in global temperatures in the years ahead then CO₂ emissions will have to be reduced by between one half and two thirds”.*⁴

Given the wide variation between nations in levels of emissions per capita and income per capita, it would be infeasible and unfair to require all nations to cut their emissions by 60 per cent of current levels. Developing countries might expect to reduce their emissions by less than this amount and wealthy countries with high per capita emissions, such as Australia, should expect to cut their emissions by more than 60 % in the longer term⁵, possibly by 80%. Table 1.1 shows Australia's greenhouse gas emissions in 1990, 1995 and 2001, as reported in the most recent National Greenhouse Gas Inventory (Australian Greenhouse Office, 2003). Emissions are expressed in units of carbon dioxide equivalent (CO₂-e). It can be seen that stationary energy combustion, the main focus of this study, contributed 259.5 Mt, or 47.8% of Australia's total emissions. Moreover, emissions from stationary combustion grew faster and by more than any other sector over the eleven year period. Australia's total net emissions remained effectively constant over the period, mainly because of a large reduction in emissions from Land Use Change and Forestry, which fell by 82 Mt CO₂-e. But growth in total emissions over the period more than offset the decline in Land Use Change and Forestry emissions. By 2001 emissions from Land Use Change had fallen to 37 Mt, partly offset by removals of 23 Mt from managed forestry. Hence, further reductions in emissions from Land Use Change, if achieved, could continue to offset growth in energy related emissions for a few more years. However, unless there is a decisive change in policy, within a few years growth in energy sector emission will start to drive Australia's greenhouse emissions inexorably upward.

³ IPCC 2001a, Figure 25(c) shows that to achieve stabilisation of atmospheric CO₂ concentrations at 550 ppm it is necessary to reduce emissions by 40-60 per cent by the end of the century and 65-85 per cent by 2150. Further reductions will be required beyond 2150.

⁴ ABC Radio News, 28 June 2002.

http://www.abc.net.au/news/politics/2002/06/item20020627170339_1.htm

⁵ This was reaffirmed in the decision adopted by the UNFCCC in Bonn in 2001 '[t]hat the Parties included in Annex I [industrialised countries] shall implement domestic action...with a view to reducing emissions in a manner conducive to narrowing per capita differences between developed and developing country Parties while working towards achievement of the ultimate objective of the Convention' (Decision 5/CP.6).

Table 1.1: Changes in Australia's greenhouse net gas emissions, 1990 to 2001

Sector	Net Emissions (Mt CO ₂ -e)			Increase 1990 to 2001	
	1990	1995	2001	Mt CO ₂ -e	Percent
Stationary energy	195.5	214.0	259.5	64.0	32.7%
Transport	62.0	69.0	77.2	15.2	24.5%
Fugitive energy	28.8	30.4	32.2	3.4	11.8%
Total energy	286.2	313.4	369.0	82.8	28.9%
Land use change and forestry	93.1	42.9	11.4	-81.7	-87.8%
All other sectors	136.5	131.1	147.7	11.3	8.2%
TOTAL NET EMISSIONS	515.8	487.4	528.1	12.3	2.4%

In order to set Australia on the necessary path towards a long-term 80% reduction in total CO₂ emissions, including those from land clearing, we choose in this study a substantial but achievable target for emissions from stationary energy: a 50% reduction compared with 2001.

Lessons for Australia from global responses

In 2000, the UK Royal Commission on Environmental Pollution brought down a report examining the feasibility of achieving a 60 per cent reduction in Britain's emissions by 2050 (RCEP, 2000). The report observed:

Human use of energy has grown enormously, based overwhelmingly on burning fossil fuels. This is causing a significant change in the composition of the atmosphere which, unless halted, is likely to have very serious consequences.

In addition to previously recognised risks from obtaining and using energy, the world is now faced with a radical challenge of a totally new kind, which requires an urgent response. The longer the response is deferred, the more painful the consequences will be. (RCEP 2000, pp. 13, 16)

The Blair Government has responded with detailed study and discussion of how such a reduction might be achieved (DTI, 2003; Marsh *et al.*, 2003). Noting that the UK 'is likely to face increasingly demanding carbon reduction targets', the UK Government concludes:

Credible scenarios for 2050 can deliver a 60% cut in CO₂ emissions, but large changes would be needed both in the energy system and in society. ... Given the strong chance that future, legally binding, international targets will become more stringent beyond 2012, a precautionary approach suggests that the UK should be setting about creating a range of future options by which low carbon futures could be delivered, as, and when, the time comes. (Cabinet Office, 2002, p. 9)

To implement a process for achieving its substantial target for the reduction of CO₂ emissions, namely a 60% reduction by 2050; the UK Government has set a renewable energy obligation of 10.4% of electricity supply by 2010 from eligible technologies that exclude large hydro-electric plants commissioned before April 2002, and have recently extended the obligation to 15.4% by 2015-16. It is providing considerable

financial support⁶ for industry development; research, development and demonstration (where the latter is focused on offshore wind, energy crops and photovoltaics), and the development of scenarios where in some cases coal use is phased out within 20 years.

In 2002 Denmark obtained 18% of its electricity from wind power and a significant fraction of electricity and district heating from crop residues. Denmark plans to reduce its greenhouse gas emissions by 50% by around 2030.

The European Union has committed to introduce emissions trading by 1 January 2005. The scheme will work on a “cap and trade” basis with an emissions target allocated to each country. Coverage will initially be limited to combustion plants in excess of 20 MW capacities. It is estimated that 14,000 industrial as well as power generation facilities will fall under the scheme and be allocated emissions allowances. Each country is to establish its own target and develop a National Allocation Plan that needs to be submitted to the European Commission before the end of March 2004.

In the United States, although the Federal Government has not set a target, there is considerable action at State level (WWF USA, 2003).

- Five States have imposed mandatory limits on CO₂ emissions including three policies directed specifically at electricity sector emissions: In June 2003, Maine became the first US state to enact legislation requiring a statewide reduction in greenhouse gas emissions. In 2002 New Hampshire passed a law to regulate power plant emissions of CO₂ through a multiple pollution reduction program. The program requires a reduction of CO₂ emissions to 1990 levels by 2010 with a lower future cap to be recommended by 2004. In 2001 Massachusetts passed legislation requiring that six of its oldest, dirtiest power plants reduce their emissions of key air pollutants. The law requires the power plants to reduce their CO₂ emissions by 10% below a 1997 -1999 baseline by 2006.
- Thirteen States have passed legislation mandating that a specific portion of their electricity be generated by non-emitting renewable energy resources. These targets range from 2.2% by 2009 in Texas to 18% by 2012 in California.

In Asia there are some substantial actions.

- The Indian Government has strongly supported wind power, with the result that there is a thriving industry with 1700 MW installed by 2002.
- Although developing countries are not required to ratify the Kyoto Protocol, China has done so and has set in place programs to encourage the efficient use of energy and renewable energy. From 1996 to 1999, China reduced its CO₂ emissions⁷, despite one of the highest rates of economic growth in the world (over 7% p.a.).
- Japan is subsidising the conversion of old coal-fired power stations to natural gas; and is funding new energy efficient industrial processes, photovoltaics and other

⁶ See www.dti.gov.uk.

⁷ More recently, emissions have resumed an upward path.

renewable energy sources. It is also extending the application of its Law Concerning the Rational Use of Energy from large factories to large office buildings.

Compared with the responses of the other governments summarised here, the response by federal and state governments in Australia has not been strong. Funding for fossil fuels continues to be increased whilst research and development support for efficient energy use and renewable sources of energy has been substantially decreased.

Specifically:

- Australia is one of only two countries that are signatories to the Kyoto Protocol, yet have said they will not ratify it. Nevertheless, the Government has stated that it intends to work to limit emissions to the level specified for Australia in the Kyoto Protocol⁸.
- The only CRC devoted to renewable energy and efficient energy use has not had its funding renewed, yet there are three federally-funded Cooperative Research Centres devoted to fossil fuels.
- There are large subsidies to the production and use of fossil fuels (Riedy and Diesendorf, 2003; Riedy, 2003) and only small subsidies for renewables, most notably the temporary waiving of excise on ethanol and other bio-fuels produced from crop residues⁹.
- The only industry and market development initiative for renewable energy is the Mandatory Renewable Energy Target (MRET). This has proven highly successful in driving investment but by 2010 it will have delivered less than a 1% increase in renewable energy use in Australia over 1997 levels. Compared with double figure targets in the EU and US states, this is insufficient to create internationally competitive renewable energy industries.

1.2. Structure of this report

Chapter 2 sets out the assumptions and method of this study. Chapter 3 reviews current energy demand and supply in Australia, drawing upon the latest published data (2000-01), and explains the basic concepts and terminology. Chapter 4 presents the economic model that is used to derive the energy demand in 2040. This generates the Baseline scenario which only has a weak implementation of efficient energy use. Its demand in 2040 is 57% above that of 2001. Then in Chapter 6 a medium-strength of efficient energy use is implemented, producing a new, lower level of energy demand for 2040, which we term the Medium Efficiency case. Even in this case, demand in 2040 is 25% higher than in 2001.

In Chapter 7 we turn to the supply side, considering the principal existing renewable energy technologies that could make contributions to our 'clean' energy scenarios. Chapter 8 summarises basic information on the fossil fuelled technologies. Chapter 9 brings this information to bear by specifying ways to increase the efficiency of energy supply and switch to fuels and technologies with lower greenhouse emissions.

⁸ An 8% increase compared with the 1990 level.

⁹ The Government plans to commence phasing out the excise exemption from biofuels and LPG in 2008.

The supply and demand sides are integrated in Chapter 10, where a Baseline – Scenario 1 – is specified with CO₂ emissions 21% higher than in 2001 and contrasted with a Clean Energy – Scenario 2, in which CO₂ emissions are 50% lower than in 2001 and 59% lower than in Scenario 1. Two variants on Scenario 2, Scenarios 3 and 4, are also constructed. The low emission scenarios all have a very large reduction of emissions from electricity generation, and modest increases in emissions from all other stationary energy applications. One of the main problems in comparing the costs of various scenarios is the uncertainty in the prices of fossil fuels in 2040. So the costs of Scenario 2 are compared with those of four different fossil fuel scenarios, each with a large proportion of coal.

Chapter 11 removes the restriction limiting the analysis to small improvements to existing technologies. It finds that, starting from Scenario 2, there are several possible pathways for achieving 80-100% reductions in CO₂ emissions from stationary energy in the period beyond 2040. These pathways are all based on substantial improvement to existing technologies that are currently commercial but only in small markets.

Since the barriers to achieving Scenario 2 is not primarily technological, the proposed policies and strategies for facilitating the transition are set out in Chapter 12. These appear to be inexpensive and achievable, given appropriate policy settings. Finally, Chapter 13 reviews some earlier studies from Australia and overseas that investigated deep cuts in greenhouse gas emissions.

2. Methodology and assumptions

2.1. Study method

Scenario back-casting

This study is concerned with the demand for energy services by Australians and the Australian economy, and the mix of fuels and technologies which could be used to meet that demand. For addressing future energy supply it uses an approach that is commonly termed ‘scenario back-casting’.

The essence of the back-casting approach is that it first leaps a considerable number of years into the future – in our case nearly 40 years – to describe, in some detail, possible patterns of energy demand and supply at that time. The range of possible futures is of course very large, even when constrained by realistic assessments of technological capabilities and available energy resources. However, the objective of this study is to explore whether it is realistically possible to achieve significant reductions in greenhouse gas emissions associated with the supply and use of energy in Australia. We therefore describe an energy future which places strong emphasis on efficiency in energy use and reliance on renewable energy in energy supply.

The choice of the 36 year time horizon is deliberate and important. It is long enough for almost all existing energy supply infrastructure and almost all energy using plant and equipment to be fully amortised, and therefore replaced with higher efficiency and/or lower emission equivalents without costly write-offs. It is also long enough for a large fraction of existing residential and commercial buildings to either be replaced or, if not replaced, to undergo one major refurbishment. Consequently, over the 36 year period, major improvements in energy efficiency can be achieved at minimal economic cost.

However, these efficiency improvements will only occur if, from now on, investments in new energy infrastructure and equipment are made on the basis, not of today’s costs of energy and greenhouse gas emissions, but on the basis of costs that can be expected to apply over the whole economic life of the investment concerned. This will not occur unless governments, and particularly the Commonwealth government, provide the certainty that investors require by establishing the appropriate long term policy framework.

For estimating future demand for energy, this study uses both back-casting and forecasting. The starting point for forecasting, as for any approach to projecting into the future, is the actual pattern of energy use and the actual structure of the economy in the most recent past year for which the necessary data are available. That year for this study is the financial year 2000-01, referred to as 2001 for brevity. Australia’s pattern of energy use and supply in 2001 is described in Chapter 3 and the structure and size of the economy are described in Chapter 4. In Chapter 5 we allow economic growth to drive the growth in energy demand, a forecasting method. However, in Chapter 6 we apply the full economic potential (defined in that Chapter) for efficient energy use to cut back on this demand in 2040, thus drawing upon a method similar to back-casting.

All these steps, and the linkages between them, have been built into a spreadsheet model, especially developed for this study. Figure 2.1 shows the structure of the model, and

readers may find it helpful to refer regularly to this Figure as they read the next few descriptive pages.

Chapter 7 offers an up-to-date account of renewable energy technologies and Chapter 8 does the same concisely for fossil fuel technologies. Chapter 9 is the essence of back-casting, where we choose a much cleaner mix of energy supply technologies than is used in 2001 to meet the energy demand with enhanced energy efficiency.

The Australian economy in the future

The objective of the study is also to describe a future for Australia in which all the major economic activities which make up today's Australian economy are still represented, and in which the overall size of the economy is significantly larger than it is today. This study does not envision a future that is radically disconnected from today's economy and society, because to do so would involve great economic waste and inefficiency and potentially significant social disruption and hardship for many.

Our projected 2040 economy is in effect an extrapolation from today's economy, with changes in the relative size of sectors within the economy, reflecting our "most likely" expectations of the changes that will occur. This is essentially a highly conservative approach to describing the future. For the most part, our projected sizes of the various economic sectors are unaffected by our views about the most likely national and global context so far as energy costs and availability and greenhouse emissions are concerned. The exceptions are those sectors that are particularly exposed to these issues, of which the most important are the productions for export of coal, LNG, alumina and aluminium metal.

Such an approach is explicitly designed to demonstrate that, with good policy and planning, in the future we can still live a life that is remarkably similar to that which we live today. The source of energy will be quite different, but the uses to which it is put need not change radically.

The approach we take to projecting the future economy is described in detail in Chapter 4. It should be noted that there, and throughout this report, the sectoral disaggregation we use to describe the economy has been designed to focus particular attention on those sectors which use the greatest amounts of energy. This involves disaggregating to a fairly low level in some parts of manufacturing industry, and greater aggregation elsewhere in the economy.

We also distinguish those economic sectors which are concerned with the supply of energy to the rest of the economy and whose level of activity therefore depends directly on the demand for energy from the rest of the economy. The most important of these industries is electricity generation and supply, but they also include petroleum refining, natural gas processing and supply and a few others. While the level of economic activity within these sectors, which account for only a small fraction of total GDP, is specified exogenously, as for all other sectors, their demand for energy is determined endogenously within our model of the energy economy in 2040. The analytical logic behind this distinction is described more fully in Chapters 3 and 4. The economic projections are fully consistent with our assumptions about the global energy future, in terms, for example, of international demand for fossil fuels and for metals, but have been prepared independently from (exogenous to)

the main energy system model. The economic projections are shown in the top right hand sector of Figure 2.1.

The scenario approach we use in this study to explore our energy and greenhouse future differs significantly from the modelling approaches that are more familiar to most participants in Australian energy policy debates. We use back-casting for energy supply, together with a combination of forecasting and back-casting for future energy demand. However, traditional approaches are purely forecasting and are based on economic modelling to estimate levels of energy consumption associated with future levels of economic activity. The advantages of these models is that they incorporate feedbacks between energy and greenhouse costs and prices, and the demand for energy from and overall level of economic activity in various sectors and the economy as a whole. In this sense they provide a more realistic way of representing the interaction between the energy and the economy as a whole.

The great drawback of such models is that they usually rely largely (in some cases exclusively) on past relationships between economic activity and the requirements for the various inputs to economic activity – labour, capital, energy, and other material inputs to determine how the economy will respond in the future. Yet these relationships are largely determined by the technology used and the policies in place at the time. If the policy question being asked is “How can changing technology affect the requirement for energy from a given level of economic activity?”, such models are effectively useless, because they define away the topic of interest. All the models can say is what the future may be like if there are no technology changes affecting energy use efficiency. This is not a great problem if projecting a relatively few years into the future. But the longer one projects, the more unrealistic the fixed technology assumptions become.

Economic modellers have attempted to address this concern by adding an additional so-called endogenous energy efficiency improvement factor, again determined by examining past relationships between economic activity and energy use. This factor is commonly set at rates of between 0.5% and 1% per annum. Only in recent years have more sophisticated attempts been made to incorporate processes of technology adoption into the models, and examples of this practice (which is very complex) remain few.

Another weakness of the standard economic modelling approach is that, in its simple form, it assumes that the complex network of policies, institutions, organisational structures and practices that determine the framework within which markets for energy services operate also remains unchanged. Again, more complex models can describe the consequences of particular policy changes, but these have to be individually characterised to do so. Moreover, since the existing market framework is implicit within the relationships between model parameters, not explicitly defined, it is hard to be confident that the exogenous introduction of a few explicit policy changes will accurately capture their full ramifications across the economy.

This kind of economic model is obviously also poorly suited to capturing the consequences of major external events which impose discontinuities on key parameters, such as a change in the world oil price or the emergence of a significant new technology, or, indeed, significant impacts from climate change on the economy or infrastructure.

All in all, the economic modelling approach finds it difficult to describe a future that is anything other than a continuation of the recent past with all relationships unchanged. It is for this reason that studies that seek to look longer into the future almost always use some variant of the scenario back-casting approach we use in this study.

This approach avoids the difficulties associated with the economic modelling approach by asking a different question: not “What *will* or *may* the future system of energy supply and use be like?” but “What *could* it be like?” Assuming the adoption of new or improved technologies is central to this modelling approach. So too is the subsequent question: not “What *will* or *may* be the effect of policies A, B or C?” but “What policies will take us from where we are today to the future described in our scenario?”

These are the questions which this study seeks to address.

Energy demand in the future economy

The next step in our method is to estimate the levels and types of demands for energy services in 2040 which will be generated by our projected levels of economic activity that year. Our starting point is the structure of energy demand in 2001. We first reallocate energy use by sector into two groups: those sectors concerned with producing and processing energy for use by the rest of the economy, and the remainder, making up the great majority of the economy. These are termed respectively Energy production and processing and Final demand. These terms are explained more fully in Section 3.1. The split into these two groups can be seen in the middle of the top of Figure 2.1.

Demand in 2040 is estimated in Chapter 5, by examining each sector in turn to see how its energy intensity has been changing in recent years and consider how it may change in the future. Energy intensity means energy demand per dollar of value added in the sector concerned. If the energy intensity of an economic sector does not change, then any change in value added (the economic size) of a sector will result in a proportionate change in energy consumption.

This is seldom the case, because a number of dynamic factors affect energy intensity. The two most important of these, and the ones which we explicitly model, are structural changes within a sector and long term trends in the technical efficiency of energy use.

Regarding structural change, it is quite clear that in some sectors, such as Food etc. and Chemicals, the dematerialisation¹ trend, which can also be described as a trend towards greater value adding, is significant and long term. Similarly, regarding energy efficiency, it appears that in many of the more energy intensive sectors of manufacturing there is a longstanding gradual trend towards increased energy efficiency. This is to be expected; it is in these sectors that energy purchases account for the highest proportion of the total cost of production and, consequently, in which new, more efficient energy using technologies are likely to be of most effect and therefore most quickly adopted as they become available. However, some energy-intensive industries are heavily subsidised and so do not reach their full potential for implementing energy efficiency.

¹ The term dematerialisation is used to describe the process whereby advanced economies become relatively less dependent on the production of material commodities and their conversion into physical goods, and more dependent on the production and consumption of services, with the result that the consumption of raw materials per unit of GDP decreases.

The study uses a total of 15 final energy consumption sectors, i.e. excluding the endogenous energy supply and processing sectors. Energy use in each sector is distributed between the following six groups or types of fuel:

- coal, including coke
- biomass fuels
- petroleum products, including LPG
- natural gas (including coal seam methane)
- solar heat
- electricity

For each of the sectors used in our modelling we estimate the contribution which internal structural change/value adding and long term energy efficiency increases will make to energy intensity. For each sector, these factors are assumed to be the same for each type of fuel used in the sector. We then combine these factors with the projected growth in economic output for each sector to calculate what we term Baseline energy demand for 2040. This is effectively equivalent to what is commonly called business-as-usual demand, but we find the many connotations of that term unhelpful and potentially confusing, and therefore do not use it in this study.

Increasing efficiency of energy use

It is now almost universally accepted within the energy policy community that all economies contain significant, unrealised opportunities for increasing the efficiency use that are cost effective in technical terms. By this is meant that the annualised capital cost of the new or modified energy using equipment is less than the reduction in energy purchase costs resulting from the new equipment. There is now a voluminous literature on the reasons why markets for energy services fail by not allowing these opportunities to be taken up (see, for example, IPCC 2001b, Chap.5).

In this stage of the analysis we take the baseline demand for energy derived in the previous stage and estimate the economic potential for reducing demand for energy if the full economic potential for use of energy efficient technologies is realised. The precise meaning of these terms is explained at some length in the opening section of Chapter 6. The most important assumptions underlying our analysis are:

- all the technologies used are available and commercially proven today;
- on the basis of the known characteristics of the technologies, they will be cost effective at the level of energy costs expected to prevail in 2040 (see Section 2.2);
- there is no premature retirement of energy using equipment.

The potential for energy efficiency in each sector depends, among other factors, on the purposes or types of equipment for which energy is used in that sector and on the type of fuel used. It was therefore necessary to allocate fuel use to purpose or equipment in each sector. For 13 of the 15 sectors analysed the following equipment types were used:

- boiler systems including cogeneration boilers,
- kilns, furnaces etc.,
- other non-electrical equipment (includes chemical reactor vessels, dryers and others),
- non-electric motors (principally diesel engines and gas turbines) used to provide mechanical power,

- electric motors,
- other electrical equipment (includes electrolysis, lighting etc.).

For the commercial/services sector the following types of energy use were applied:

- air handling,
- cooling,
- heating,
- pumping,
- water heating, cooking etc.,
- lighting,
- other.

For the residential sector the following types of energy use were applied:

- water heating,
- space heating and cooling,
- cooking,
- electrical appliances.

An estimate of the economic potential for increased energy efficiency for each type of fuel used for each type of equipment in each sector was made, based on our extensive reading of the technical literature on energy efficiency technologies and opportunities. In doing so, account was taken of the underlying energy efficiency improvement trend which was identified in some sectors at the previous stage of the analysis. For some of the energy intensive sectors this meant that there was no additional increase in energy efficiency, i.e. the long term trend took up all opportunities for increased energy efficiency, for the reasons given above.

The result of this stage of the analysis is a complete schedule of energy demand by sector, fuel and equipment type, with maximum economic efficient adoption of energy efficient technologies, but no changes in the mix of fuels used, other than those resulting from differential rates of energy efficiency improvement between fuels and equipment types. We term this the Medium Efficiency case.

The reductions in energy demand resulting from more efficient energy use will mean that less energy will need to be supplied, and therefore emissions will be less, to provide the same level of energy services, than if energy were used less efficiently. To achieve further emission reductions, changes will need to be made on the supply side of the energy system.

This study is not directly concerned with energy use in transport. However, transport cannot be ignored, because its demand for energy will affect the endogenous demand in the energy production and processing sectors, and will also have implications for the overall call on energy resources. Accordingly, some relatively simple, default assumptions about demand for transport energy were made. These are described in Section 6.6.

De-carbonising energy supply

In the final stage of the analysis, the focus shifts from demand for energy and energy services to the mix of fuels, energy sources and technologies which can be used to meet the projected demands. The shift is made because opportunities to reduce emissions on the

supply side are less costly than further reductions in demand by means of increased energy use efficiency. The key concept underlying this approach is marginal abatement cost, which is defined as the additional cost of the low emission technology compared with “conventional” technology, divided by the quantity of emissions abated, where both cost and abatement are calculated on a whole of life basis. For example, the marginal abatement cost associated with supplying electricity to a house by building integrated photovoltaics, rather than from a coal fired power station through the grid, is equal to the lifetime incremental cost of the photovoltaic electricity at the house, relative to the grid alternative, divided by the lifetime emission abatement.

In a fully specified and detailed optimisation model such as MARKAL (see Chapter 13), demand and supply side options are all evaluated simultaneously², and the least cost mix of technologies is chosen. However, it is an almost impossibly difficult task to specify such models for 40 years into the future, and it certainly has not been attempted, let alone achieved, for Australia.

In this study we use what might be termed qualitative optimisation. We make estimates of the costs of all relevant technologies, both supply and demand side, which necessarily cover a range of uncertainty. For energy efficiency, and for some individual supply technologies such as wind, the marginal cost of applying the technology begins to increase as adoption or market penetration becomes widespread (the most egregious cases of inefficient energy use and the best wind resource sites are taken up first and after a time the remaining opportunities become less economically attractive). We use the best available data, coupled with our professional judgement, to determine the proportions of the different technologies, for both energy demand and energy supply, at which marginal costs are equal, and the cost of the energy system as a whole is therefore minimised for a given level of demand for energy services. The shift from demand to supply side focus occurs where we judge that this point lies on the combined supply curve for energy efficiency, i.e. at the point where it is more costly to reduce emissions by further energy efficiency than to do so by switching to low emission supply technologies.

Continuing this step by step analytical approach on the supply side, we successively analyse several distinct groups of supply side technologies.

Firstly, fuel substitution was introduced in a number of sectors. These substitutions mainly involved:

- the replacement of coal and petroleum as fuel for boilers by a mix of natural gas and solar thermal energy,
- the replacement of coal and petroleum as fuel for non-metallurgical kilns by natural gas,
- in the commercial/services and residential sectors partial displacement of natural gas and electricity used for water heating by solar heat.

Secondly, extensive uptake of gas-fired cogeneration of heat and electricity (sometimes termed combined heat and power – CHP) was introduced into all sectors of the economy with demands for low temperature heat (boiler systems in industry, space heating and hot water in the commercial/services sector). Installing a cogeneration system has the effect of

² Provided that all relevant technologies are specified in the model, which is often not so in the case of demand side technologies.

increasing the consumption of natural gas in the establishment where the plant is installed, but the increased consumption is much less than the quantity of gas which would be needed to produce the same quantity of electricity in a stand alone power station, with corresponding energy efficiency and greenhouse emission benefits. For modelling purposes, we allocate the estimated additional natural gas consumption required for cogeneration to the electricity generation sector, although in practice this consumption would appear as additional demand in the economic sector where the cogeneration plant is installed.

Thirdly, the electricity supply industry is independently modelled in terms of the mix of fuels and generation types which could be used to meet the demand for electricity at least cost, given the emissions constraint. This constraint is that greenhouse gas emissions from stationary combustion as a whole be reduced to 50% of their level in 2001, while the technical characteristics of the electricity supply mix allows the projected demand for electricity to be met with levels of supply security no less than those provided by Australia's present electricity supply system. Modelling this industry requires the inclusion of three additional types of fuels or energy sources which are important as primary fuels, but not as end use fuels (see Section 3.1 below for a definition of these terms). The additional fuels/energy sources are:

- brown coal,
- hydro,
- wind.

In following this sequence of analytical steps we are in effect allocating the electricity supply sector the role of marginal supplier of abatement. We do this because most of the very low or zero emission technologies, such as hydro, wind and biomass, that are needed to achieve the 50% emission abatement goal, are best suited for the generation of electricity. The result, as will be seen, is that the electricity sector makes a far larger contribution to the overall reduction in emissions, relative to 2001, than does direct use of fuels, such as gas, by end users.

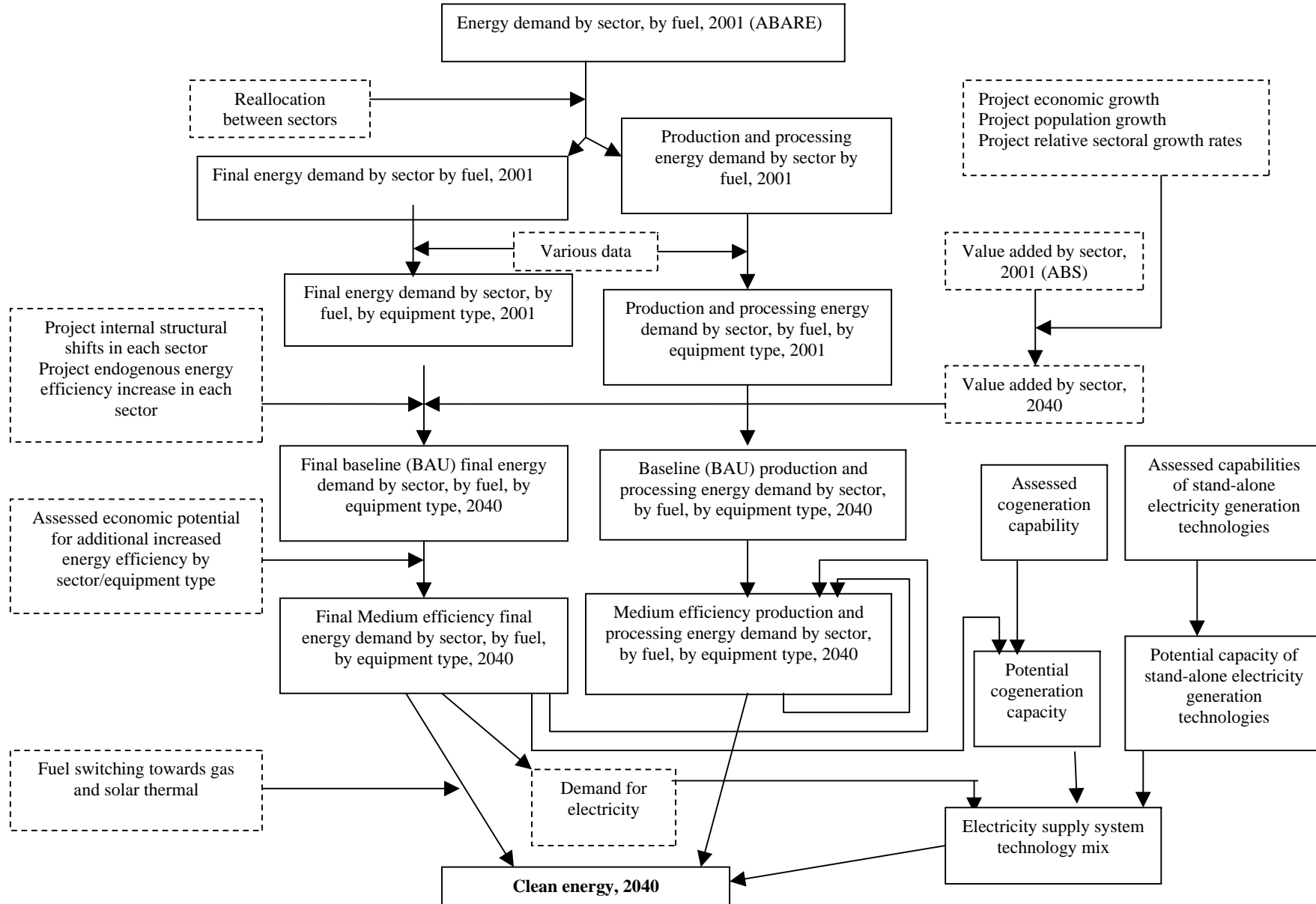
Finally, the demand for energy by the endogenous (energy production and processing) sectors was determined. This was done by using the change in demand for the different types of fuel from 2001 to 2040 to determine the activity level in each of the industries concerned and applying additional improvements in energy efficiency as relevant to the types of activities involved. These calculations involved feedback loops, because each of the industries concerned uses some of the energy it produces itself and/or is produced by the other energy supply industries. This can be seen in the middle towards the bottom of Figure 2.1.

The end point of this modelling is a complete schedule of energy demand by fuel, equipment type and economic sector in 2040, which can be compared directly with the actual pattern of energy demand in 2001. The CO₂ emissions resulting from the mix of primary fuels consumed are calculated, and both energy demand and CO₂ emissions compared with the corresponding figures for 2001. Combustion related emissions of other greenhouse gases are ignored, as these are generally very small (other than in transport) and in any case are roughly proportional to CO₂ emissions, and so do not affect the relativities between fuels.

Readers should note that this is one of a number of detailed methodological differences between this study and the National Greenhouse Gas Inventory (NGGI). Other differences relate to classification/allocation; for example, the NGGI classifies the very considerable CO₂ emissions from iron and steel production as an industrial process rather than an energy sector emission, and allocates these emissions accordingly; the treatment of chemical feedstocks also differs. For these reasons, the emission estimates for 2001 in this study differ from those reported in the NGGI³, but the differences are systematic and the two can be reconciled, albeit with a number of detailed adjustments.

³ Specifically, the NGGI figure for 2001 stationary energy emissions of CO₂ is 257.1 Mt and the figure used in this study is 261.7 Mt. The NGGI figure for emissions of all greenhouse gases is 259.5 Mt CO₂-e.

Figure 2.1: Structure of energy system model



2.2 Future energy costs and prices

The price of energy from different sources is a fundamental element of any study of the energy system today and of how the system may change in the future. Energy prices have the following effects.

- The general or average level of energy prices is one factor determining the level of demand for energy, not because consumers actually want to use more energy *per se* when it is cheaper (though they usually want to use less when it is more expensive), but because more technically efficient energy using equipment is often (though by no means always) more expensive, and cheap energy makes it less cost effective to invest in more efficient equipment. For example, in the early 1980s, demand for energy fell rapidly around the world in response to the much higher level of energy prices, following the second oil shock. When prices fell again from the mid 1980, this trend slowed greatly in most countries and in a few actually reversed, as investment in more efficient equipment slowed.
- Changes in energy prices also affect the relative prices of energy intensive products and services, relative to less energy intensive products and services, and so affect consumers' patterns of spending. For example, when oil prices are low, airline ticket prices fall relative to other goods and more people travel by air, other things being equal, leading to an increase in energy demand, because air travel is a very energy intensive activity.
- The relative level of energy prices is a major influence on choice of fuel and of energy supply technology. Looking back twenty five years or so, the oil price rises of the 1970s resulted in the widescale replacement of petroleum products by natural gas and, to a lesser extent, coal, in most stationary energy applications. Today, in the National Electricity Market, it is the relative prices of electricity supplied by coal fired and natural gas fired generators that determines the mix of fuels used for electricity generation. Without the Mandatory Renewable Energy Target program, the relative price of electricity from renewable sources such as wind would almost totally exclude these sources of generation from the Market.

It should be noted that throughout this discussion we have referred to prices, and not costs. Cost affect prices, but they are not the only factor to do so. The behaviour of market participants will affect how they set prices in relation to their costs. Prices will also be affected by the structure and rules of the particular market concerned, noting that all markets are social constructs, and as such given structure by laws, rules and societal decisions. For example, in the National Electricity Market, market rules specify that transmission costs are averaged across the whole market, rather than being charged to individual generators who use the transmission network to deliver their electricity to consumers (except in the case of new entrant generators, which do have to pay their own costs for accessing the grid). This rule means that in South Australia, electricity from distant coal fired power stations in NSW is cheaper to buy than electricity from local gas fired generators, which would not be the case if the coal fired generator were bearing the cost. The result is that electricity is produced by high emission coal power stations rather than lower emission gas power stations, and that more electricity is transported over longer distances with proportionately greater losses, an outcome which is perverse both for the economy and the environment. In its submission to the National Electricity Code Administrator in April 1998 on the transmission and distribution pricing review, the Commonwealth Government expressed similar concerns:

“Current arrangements, which restrict transmission charging to generators to shallow entry costs, while leaving the bulk of costs to be recovered from customers, provide a substantial subsidy to remote, usually coal fired generation to the competitive disadvantage of more greenhouse friendly natural gas and renewable generation typically located closer to loads. Pursuit of demand management options is also acutely disadvantaged. (p 7)

What energy prices are we projecting for our 2040 scenarios? This is a complex question that confronts everyone who tries to think about energy futures, and requires a fairly complex answer, in several parts.

Firstly, the most important single influence on energy prices everywhere is the world price of crude oil. This directly determines the price of all petroleum products and indirectly affects the price of most other energy sources. As is now well recognised, many factors influence the world oil price. Some relate to the supply/demand balance and the cost of producing crude oil, and can in principle be investigated by quantitative modelling. Many others, however, are political and geopolitical in nature; they may be qualitatively predictable, although there is always wide disagreement between analysts, but they are certainly not susceptible to quantitative modelling. Consequently, all models as well as other energy future studies specify future world crude oil prices exogenously, on the basis of a qualitative consideration of the relevant factors.

Our view is that by 2040 the balance between potential demand for crude oil and available supply will have shifted markedly from what it is today (Hall et al., 2003). We do not adopt the more apocalyptic visions of a world where oil production has collapsed. But we do take the view that the cost of production from the marginal source of crude oil will, as always, set a floor under oil prices over the long run, and that this cost will be substantially higher than it is today.

Secondly, international commodity prices for coal and natural gas (as LNG) will be affected by the higher crude oil prices, as they are both partial substitutes for petroleum products. However, the prices for these other fossil fuels will also be affected by their own supply/demand balance and their own costs of production. Regarding the supply and demand, we expect that coal supply will comfortably exceed potential demand. For natural gas, the supply situation in 2040 will also be fairly comfortable, particularly in the Asia-Pacific region, though it may become much less so later in the century. Regarding cost of production, for coal we do not see much scope for a continuation of the increases in mine productivity, which have enabled the industry to remain profitable despite steady falls in real prices over recent years, reflecting an excess of supply over demand. Indeed, we consider it more likely that costs of production will rise as the industry moves towards mining thinner or deeper seams with more overburden. Regarding LNG, we also expect that costs of production will rise as the industry exploits smaller reserves in deeper or more intractable fields.

Thirdly, we assume that the world of 2040 will be subject to significant constraints on emissions of fossil CO₂ and other anthropogenic greenhouse gas emissions. The costs of this constraint will be internalised into the international traded prices of sources of

these emissions, increasing the price of all fossil fuels. Coal will be the most severely affected fossil fuel and natural gas the least affected.

How will these factors affect prices in the Australian domestic energy markets?

In the case of petroleum, we assume that Australia will be a net importer and will have to pay the going world price, whatever that may be. In the case of natural gas, a more complex situation applies. At present, and for some years to come, the large gas reserves in north west Australia are not accessible to the major domestic markets in southern and eastern Australia. This means that domestic and export markets are not substitutable, and makes it possible for domestic wholesale prices to diverge. We project that by 2040, however, there will be a transcontinental pipeline, carrying gas from west to east and allowing domestic and export prices to converge. Nevertheless, constraints on infrastructure capacity may mean that the two markets are not completely substitutable. The relative levels of export and domestic prices will be determined by the supply/demand balance in each market.

The relationship between domestic and international coal prices is still more complex and less direct. Some black coal currently used for electricity generation could be directly substituted into export markets (given the required transport infrastructure) but other power stations use lower quality coal. Victorian brown coal has no alternative use at all, i.e. its opportunity cost is zero, and thus could continue to be priced, as it is today, at the cost of extraction, which is extremely low. The resultant price of electricity generated from this coal is thus determined by the extraction cost of coal, plus the capital and operating costs of the power station. By similar reasoning, the opportunity cost of most renewable energy resources is zero, and the price of wind or solar thermal electricity will be determined entirely by the cost of building and operating the generation equipment.

If Australia is unconcerned in 2040 about its level of greenhouse gas emissions, it will, in principle, have the option of continuing to price fuels such as brown coal at close to extraction cost and use them to generate low cost electricity. Coal will continue to be the predominant fuel for electricity generation, emissions will continue to grow, in defiance of probable international trends and opinion, but Australia will have “cheap” electricity. It seems much more likely, however, that Australia will seek to place some limits on greenhouse gas emissions. As is now acknowledged by all governments in Australia, this can only be achieved by limiting the emissions from using coal to generate electricity. Several options are available: use “end of pipe” technology, such as CO₂ capture and geosequestration, levy a carbon tax (with or without emissions trading), or limit coal fired generation capacity by regulatory action. We discuss these alternatives in later Chapters. From an economic perspective, however, they will all have the effect of increasing the cost of coal fired electricity. In other words, their effect will be the same as increasing the input price of coal.

To summarise, therefore, we expect that in 2040 the prices of all fossil fuels will be significantly higher than they are today. In the case of coal, we note that this higher price may arise from the cost to the user of technology to make coal “clean”, or from the scarcity value of a regulatory “right” to use coal for electricity generation, rather than the price at which a generator can obtain coal itself. It will be important to recognise this distinction in undertaking subsequent analysis and modelling; for

example, the more that demand can be reduced by energy efficiency, the more scope there will be to use conventional coal fired electricity and the lower the cost will be of the “right” to use coal, all else being equal.

Many greenhouse related energy policy studies use economic models, with feedback between price and demand, in an attempt to estimate the additional cost of achieving defined levels of abatement of energy related greenhouse gas emissions. However, such models require the exogenous specification of energy prices, exclusive of any greenhouse abatement costs, which means that the modeller faces the heroic task of making judgements about the effect on energy prices of all the other highly complex factors described above. In addition, we consider, as explained in Section 2.1, that these models contain deficient descriptions of the mechanisms through which energy prices and demand for energy interact, because they do not contain adequate characterisations of energy efficiency technologies and the processes driving the choice of such technologies. Consequently, we consider that the apparent precision of estimates of the cost of reducing greenhouse emissions from the energy sector, provided by such models, is largely spurious.

The spreadsheet model which we use for this study defines all components of energy prices, including any greenhouse related component, exogenously. Our modelling of both energy efficiency and renewable energy supply technologies is not so detailed as to require precise estimates of prices, which would, in any case, be of little value for the purpose, since the costs, forty years hence, of the various energy technologies on both demand and supply sides are quite uncertain. Approximate costs of technologies and energy systems are discussed in Sections 7.12, 9.5 and 9.6.

Much of the rest of this report is devoted to estimating the economic potential of energy efficiency technologies and determining a least cost mix of low emission energy supply technologies. The price assumption underlying our modelling of the low emission scenarios is that prices of primary fossil fuels across the board will be between 25% and 50% higher than they are today in real terms. The lower end of the range will apply to low grade coals, which have no alternative markets, and the upper end will apply to petroleum (net of taxes), and may well be an understatement. In addition, if the prices of these fuels come to reflect their full external costs, it is likely, as discussed in Chapter 10, that the increase in cost of derived fuels, such as electricity, and of the energy system as a whole, will be somewhat greater.

We also prepare a baseline or business as usual scenario in which prices of coal, and hence coal fired electricity, are assumed to be little different from today.

Finally, we have not linked these assumptions about energy prices to our projections of the economy of 2040, contained in Chapter 4. We do not consider that such energy price increases would have any significant effect on overall economic growth, since the relative prices of energy compared to the rest of the OECD are likely to remain largely unchanged. However, the increases will express themselves as significant cost increases for some of the energy intensive sectors of the economy. We have not attempted to include such effects in our projections for these sectors. For that reason, it is probable that our modelling over-estimates the level of energy demand in 2040.

3. Energy in Australia today

3.1. How energy systems are described

For this study we use the energy balance method of describing Australia's supply and use of energy. This is the internationally accepted method of presenting energy statistics in a standardised format. The energy balance approach is based on a physical understanding of processes for supplying and using energy, but is also consistent with a common sense economic understanding of energy, moving through successive stages of production, supply (or delivery) and use by final consumers.

This representation of the energy system is greatly facilitated by the use of a single common unit for measuring quantities of energy. Australian energy statistics use the petajoule (abbreviation PJ), equal to 10^{15} joules, as the unit. All energy data in this report are expressed in PJ, or smaller multiples such as terajoules (TJ), gigajoules (GJ) or megajoules (MJ). Discussions of electricity alone usually use units of terawatt-hours (TWh), and smaller multiples GWh and MWh. $1 \text{ TWh} = 3.6 \text{ PJ}$. (See also page viii on Units and Conversion Factors.)

Energy balances start with the extraction or harvesting of what are termed primary fuels; these include fossil fuels such as coal, crude oil and natural gas, which are extracted from the earth, and renewable energy sources such as wind, hydro, biomass and solar thermal energy, which are harvested from the atmosphere, from rivers, from the sea or directly from solar radiation.

Some of these sources of energy can be and are used directly by final consumers, but many of them undergo conversion or transformation to end-use fuels, which are more convenient or efficient for final consumers to use. The most important energy conversion processes are thermal electricity generation and oil refining. Each of these processes uses considerable quantities of energy, so the quantity of end-use fuel produced is significantly less than the quantity of primary energy going into the conversion process. Further quantities of final energy are used or lost in the process of delivering to final consumers. As a result, the total quantity of energy available for use by final consumers is significantly less than the quantity of primary energy supplied to the economy.

The third and last stage of the energy balance representation is final consumption by end users of energy, who use energy for all activities other than the production of energy in another form.

For most forms of renewable energy other than biomass, the distinction between primary and final energy has less practical significance. For example, the total quantity of energy contained in a mass of falling water or moving air is of little practical importance for the energy system unless or until it is converted into final energy, usually in the form of electricity. Therefore the quantity of primary energy produced from these sources is defined by the quantity of hydro or wind electricity which can be produced by generators installed to harvest these renewable resources. Engineering improvements which increase the efficiency with which the energy is captured are expressed as increases in the available hydro or wind resource. Similar considerations apply to direct solar thermal energy. Some of the energy generated is

lost in transmission and distribution to the point of final consumption. Therefore, in all these cases, the quantity of final energy is equal to the quantity of primary energy produced less transmission and distribution losses.

Economic descriptions of the energy system usually refer to energy being consumed through these processes. In physical terms, however, energy is not (and cannot be) consumed. Rather, it is converted from a highly concentrated form, notably as the chemical energy contained in fossil fuels, to other forms, such as the chemical energy in an aluminium ingot or the mechanical energy of a rotating pump. Ultimately, most of the energy used by final consumers ends up in the form of low grade heat. The difference between the chemical energy of a fossil fuel and low grade heat is that the former contains far more *useful* energy than low grade heat. (Note that the energy contained in low grade heat has not disappeared, but rather has dispersed into the general environment; it is obvious, for example, in the so-called urban heat island effect, whereby the climate of large cities is typically a few degrees warmer on average than the climate of rural areas surrounding the city.)

The physical concept of useful energy is a key to understanding the potential for improvements in technical energy efficiency. In general terms, efficiency is maximised by maximising the quantity of useful energy which can be obtained from a given quantity of fuel supplied to a process or activity. Most energy efficiency technologies represent ways of applying basic physical principles, such as temperature cascading, to energy using processes, so that extraction of useful energy is increased. The concept of useful energy is also important in understanding many renewable energy technologies. Renewable energy sources occur naturally in a relatively diffuse form, from which it is difficult to extract much useful energy. Most renewable energy technologies aim to extract energy from the environment and deliver it to consumers in a more concentrated form, such as electricity, from which much more useful energy can be extracted.

Electricity obtained from renewable sources, such as hydro and wind, appears in energy balance tables as a form of primary energy, which is supplied directly to final consumers with no intermediate conversion step (but with some proportionate loss in transmission and distribution). The system of energy statistics, which was constructed to suit the centralised, fossil fuel based energy economies of the mid-20th century, has some difficulties in accommodating more extensive use of some forms of decentralised renewable sources of primary energy, because these are often not measured.

Energy statistics have always had difficulty dealing with biomass fuels, such as fuel wood and crop residues, when these are directly collected by final users and do not pass through any market transaction. For this reason, statistics on biomass energy use are subject to a high level of uncertainty. A different sort of uncertainty is associated with figures for the solar contribution to the total energy provided by a solar water heater, which is also not measured, but in this case for reasons of technical practicality, and can only be estimated by indirect methods with a high level of uncertainty. The same usually goes for the electrical energy supplied to a house with a rooftop photovoltaic panel. For yet other ways in which solar energy is used, such as passive solar heating of buildings, it is not even sensible to try to estimate quantities of energy being supplied. It is much better to think of passive solar building design as a type of energy efficiency. Solar water heating and other forms of

active solar heating can be similarly thought of as technologies which greatly multiply the useful energy, or, more accurately, the quantity of energy services that can be extracted from a given quantity of energy supplied by conventional (mainly fossil fuel based) energy systems. Of course these measurement difficulties do not arise with renewable energy sources such as wind, which are converted directly to electricity and fed into the supply system, together with electricity generated from fossil fuels.

In this study we have adopted the following conventions for presenting data on energy.

- Passive use of solar energy to heat buildings (and to provide other services, such as clothes drying) is not shown directly, but is expressed as reduced demand for other energy sources to provide the heating and other energy services concerned.
- Active use of solar energy to produce hot water or steam is shown as an energy source, the quantity of which is defined by the amount of alternative (usually fossil) fuel it displaces. This is important to give some idea of the size of the contribution this source of energy can make to meeting Australia's energy demand and of the investment in active solar thermal systems which will be required. The small quantities of electricity used by these generating systems are ignored.
- Renewable energy sources used to generate electricity, such as hydro, wind and direct solar radiation (whether captured by photovoltaic devices or solar thermal electric systems) are defined by the quantity of electricity they supply. Note that this differs from the approach sometimes adopted in international energy statistics, by which renewable sources of electricity are defined in terms of the quantity of fossil fuel they displace, assuming that the fossil fuel is used to produce electricity in a thermal power station with a typical First Law efficiency (33% is normally used).
- Biomass energy sources are defined, like fossil fuel sources, by the quantity of heat energy they release when they undergo complete combustion, i.e. when they are fully oxidised. Note that Australian energy statistics define the calorific value of fuels in terms of their gross calorific value (sometimes termed higher heating value or HHV). This also differs from common international practice, which is to use net calorific value (sometimes termed lower heating value or LHV)¹.
- In calculating the quantities of fossil or biomass fuels required to provide a given quantity of electricity from a thermal power stations, account is taken of the quantities of electricity used within the power station, which for coal fired power stations in particular are quite large, typically about 7% of electricity generated.

There are several ways, apart from the energy balance, of describing or providing important information about a country's energy system. Two of the most valuable are energy use by economic sector and energy use by equipment type.

Energy use by economic sector breaks the economy down into sectors, defined by the standard classification system used for compiling economic statistics, which for Australia is the Australia and New Zealand Standard Industrial Classification (ANZSIC). This presentation can provide far more detail about how and where energy is used in the economy than the energy balance presentation. However,

¹ See the Glossary for definitions of HHV and LHV

ANZSIC does not recognise the distinction between economic activities which are producing primary energy, processing or transforming primary energy, or using final energy. A good deal of “unravelling” is therefore needed to convert the standard energy use by economic sector statistics into the energy balance format.

Energy use by equipment type is very important for assessing the potential for improving the efficiency of energy use, because many of the technical efficiency improvement opportunities are specific to a particular type of equipment.

The Australian Bureau of Agricultural and Resource Economics (ABARE), the Australian Government body which produces Australia’s energy statistics, provides data in all the formats described here (and in a number of others). The ABARE energy statistics are the main source of data for the modelling work undertaken for this study. The most recent year for which ABARE has published a complete set of Australian energy statistics is 2000-01. We have therefore used that year as the baseline for this study and for the description of Australia’s current pattern of energy use and supply in the next Section of this report.

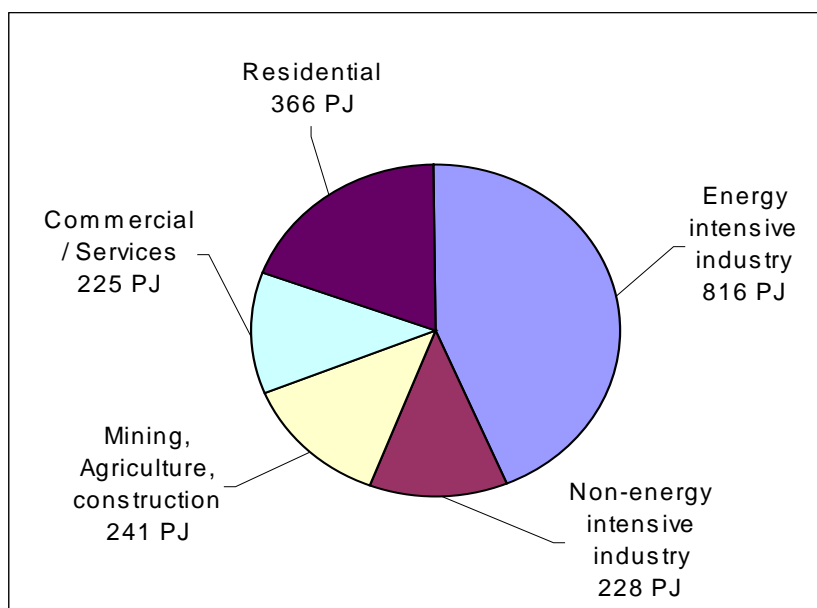
3.2. Australia’s current pattern of energy use and supply

In 2001, total stationary final energy use in Australia was 1,888 PJ. This equals about 97 GJ per head of population. By stationary energy use is meant all energy use other than energy used for transport. This figure has been derived from the energy consumption figures published by ABARE by subtracting fossil fuel (mainly petroleum products) used as solvents, lubricants and bitumen. The estimated quantities of fossil fuels (mainly petroleum products and natural gas) used as chemical feedstocks have also been subtracted. Data on feedstock consumption was in some cases provided on a confidential basis by the chemical companies and in other cases has been estimated, using our knowledge of the industries concerned. Our estimate of the total quantity of fossil fuels used for these non-energy purposes in 2001 is about 5 PJ of coal by-products, 87 PJ of petroleum products and 50 PJ of natural gas and ethane, which is about 3.0% of Australia’s total fossil fuel consumption in that year (measured in energy units).

For the purposes of this study, we have also defined energy use in fuel production and processing to be final energy use, where the fuel produced is exported rather than being used within Australia. Specifically, energy used for mining export coal and energy use for processing and liquefying natural gas that is exported as LNG have been defined as final energy consumption. Australia has a large export trade in crude oil, but this is more than offset by imports of different (mainly heavier) grades of crude oil. We have therefore not included energy used in producing export crude oil in our estimate of final energy consumption.

Figure 3.1 shows how total final energy use was distributed between the various major groups of economic sectors, and Table 3.1 shows a more detailed breakdown of energy consumption by each economic sector modelled in this study. Note that, since the commercial and residential sector are heavy users of electricity, their shares of final energy are significantly smaller than the shares of primary energy required to supply them, as discussed in later Chapters.

Figure 3.1: Total stationary final energy use by major sectoral group, 2001



In preparing these estimates from the original ABARE data, we have subtracted estimates of fossil fuels used for the various purposes described above, and also the estimated incremental consumption attributable to cogeneration of electricity in various sectors. Although this can only be an estimate, given the integrated nature of cogeneration operation, it is a necessary step for the accurate modelling of a major expansion of cogeneration in our future scenarios.

Table 3.1: Final demand for energy, 2001 (PJ)

Economic sector	Energy consumption (PJ)
Mining (incl. LNG and coal exports)	180
Manufacturing	982
Iron and steel	178
Food, beverages, tobacco	164
Basic chemicals	76
Cement, lime, plaster and concrete	42
All other non-metallic mineral products	49
Non-ferrous metals	339
Wood, paper and printing	70
All other manufacturing	64
Construction	51
Commercial/Services	225
Agriculture/Forestry/Fishing	72
Residential	366
TOTAL final stationary energy consumption	1,876

It can be seen that manufacturing accounted for 52% of the total. We have divided manufacturing into two groups, termed energy intensive and non-energy intensive. Energy intensity, as used here, means energy consumption per dollar of value added from the industry. Examination of the data shows a very clear difference between

energy intensive manufacturing sectors and the rest of the economy. The energy intensive sectors of final energy consumption are listed in Table 3.2 below.

Table 3.2: Energy intensive sectors of manufacturing

ANZSIC Subdivision/ Group	Description	Energy intensity 2001 (TJ/\$ million value added)
271	Iron and steel	70
252-53	Basic chemicals	34
263	Cement, lime, plaster and concrete	20
261, 262, 264	All other non-metallic mineral products	32
272	Non-ferrous metals	69
23,	Wood and paper product manufacturing	30

These sectors together accounted for 24% of total final energy use (including transport) in 2001 and 40% of total final energy consumption, but only 2.4% of GDP. The average energy intensity of the whole economy in 2001 was 8 TJ per \$million. It should be noted that this average includes the energy production and processing industries, such as electricity generation and oil refining, which are also very energy intensive. Transport is also relatively energy intensive. By contrast, the other stationary energy final consumption sectors are far less energy intensive. For example, the intensity of construction is 1.5 TJ/\$million value added and the average figure for all service industries is 0.7 TJ/\$million value added.

The energy intensive sectors can be further divided into two groups: those which have a predominant or significant export orientation, and those which supply predominantly domestic markets.

The export focussed groups consist mainly of the non-ferrous metals sector, comprising the production of alumina and aluminium in particular, and also of nickel, copper, zinc, lead and other metals. Production of directly reduced iron (see Chapter 6 for details) is also in this category. While relatively small at present, some analysts expect this to become a major new export industry in the future. Australia also exports significant quantities of steel, but exports have always accounted for less than half of total production. Finally, the production of LNG should be included in this group. However, since there is at present only one LNG producer (the North West Shelf consortium, led by Woodside Petroleum) all relevant economic information about this industry, such as value added, is confidential.

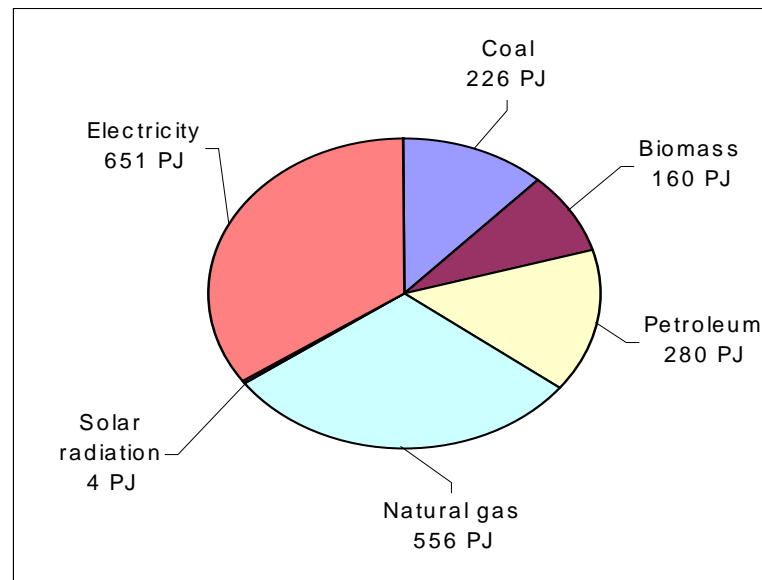
The domestically focussed groups comprise basic chemicals, cement, other non-metallic mineral products, and wood and paper products. At present, none of these sectors has significant exports. There have been sporadic attempts ever since the 1970s to establish some large, export oriented petrochemical manufacturing activities, and several such projects remain under consideration for north west WA. Should one or more such projects be built, the basic chemicals sector would come to resemble the iron and steel sector in having a mix of domestic and export oriented activity.

The energy intensive sectors listed above are all specified and modelled separately in our analysis. The food, beverages and tobacco industry, which is moderately energy intensive, is also modelled as a separate sector. All remaining sectors of

manufacturing, which account for the great bulk of value added, but only a small fraction of energy use, are modelled as a single group.

In 2001, a further 1,267 PJ of energy was used in transport. This study is concerned with stationary energy consumption only, so most of the remaining data presented exclude energy used for transport. The mix of the various fuels contributing to total final stationary energy consumption is shown in Figure 3.2.

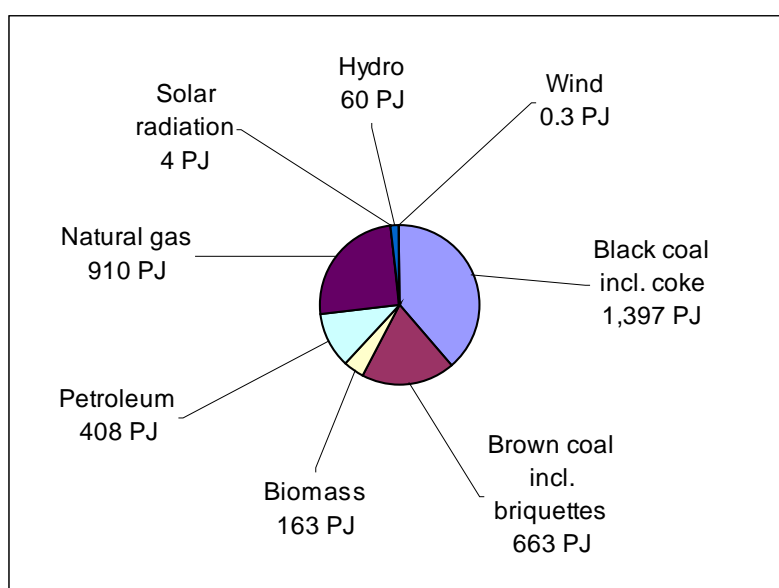
Figure 3.2: Total stationary final energy use by fuel, 2001



It can be seen that electricity and natural gas are the two most important fuels, and relatively small quantities of coal are used in final consumption. When transport is included, petroleum products become the most important fuel used for final energy consumption.

However, as noted in the previous Section, very large quantities of fuel are used to generate electricity and somewhat smaller quantities are used in other energy processing activities, such as oil refining. Total primary energy use in stationary consumption in 2001 was 3,606 PJ. This figure includes all energy use, except final energy consumption of fuels other than electricity for transport, and is equivalent to 186 GJ per head of population. It is this total energy use figure that is the focus of the present study, and the mix of fuels which make up the total is shown in Figure 3.3. It will be noted that it includes energy sources such as hydro and wind that are used directly to produce electricity, following the convention explained in the previous Section. This means that one unit of hydro or wind as primary energy is equivalent to roughly three units of coal or other fossil fuel used for electricity generation. Of the total 3,606 PJ, 2,139 PJ were used in electricity generation and supply, and 229 PJ in other energy processing activities, such as oil refining. It can be seen that coal, most of which is converted to electricity for final use, accounts for well over half of total stationary primary energy consumption. Quantities of petroleum used are relatively modest, as this is predominantly the fuel used for transport.

Figure 3.3: Total stationary primary energy use by fuel, 2001



The modelling of energy demand that we used for this study uses different approaches for final energy demand energy used by the energy supply industries. For the former, the level of economic activity in each sector is exogenously determined, on the basis of projected economic growth, absolute and relative, described in Chapter 4, and anticipated changes in energy intensity of the sector, described in Chapter 5. For the latter, the size of the sector is defined by the quantity of fuel (electricity, petroleum products, coal etc.) which the particular sector produces or processes, and this is determined endogenously by the model. The level of demand for the respective fuels by final energy consumers is the main determinant, but the energy producing and processing sectors themselves also contribute because, for example, some petroleum products are used to generate electricity, and some electricity is used in petroleum refining.

These modelling steps determine the baseline level of demand for each fuel from all stationary combustion sectors. In the subsequent stages of the analysis, enhanced energy efficiency is applied to all sectors. Then active fuel switching towards primary energy sources with inherently lower emissions, such as natural gas, biomass and solar heat, is introduced into the modelling across all sectors.

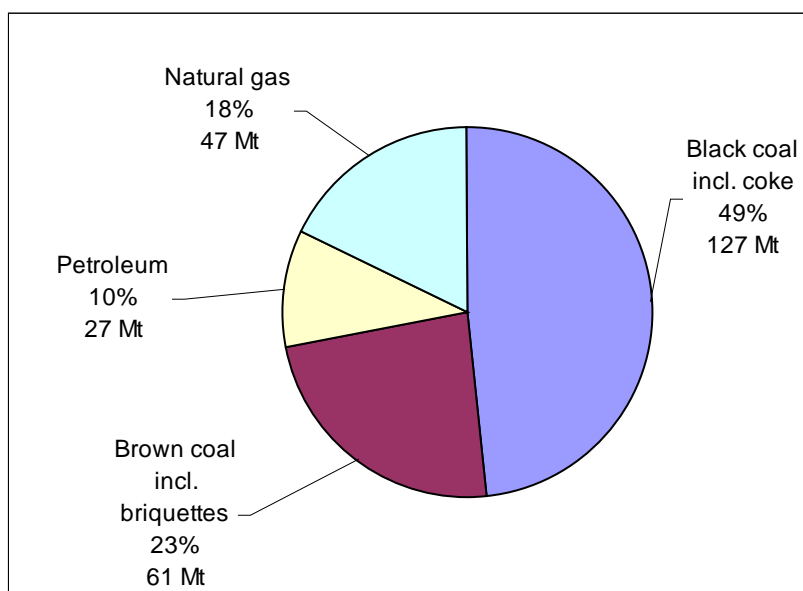
The complete list of energy production and processing sectors used in the model is as follows:

- mining of coal for domestic consumption,
- production and field processing of oil and gas for domestic consumption,
- natural gas transmission and distribution,
- electricity generation, transmission and distribution,
- petroleum refining,
- manufacture of coke,
- manufacture of brown coal briquettes.

We assume that the production of brown coal briquettes will cease within a few years.

The primary fuel mix is the most important determinant of the level of greenhouse gas emissions from the energy sector. Anthropogenic emissions of CO₂ from stationary energy combustion in 2001 totalled 262 Mt, which is equivalent to 13.5 tonnes per head of population. The relative contributions to this total of the various primary fuels are shown in Figure 3.4. It can be seen that coal accounts for over 70% of the total emissions. As explained in Section 2.1, in this study we use CO₂ emission as a proxy for total greenhouse gas emissions from combustion of fossil fuels. We also assume that CO₂ emissions from the combustion of biomass fuels do not contribute to anthropogenic greenhouse gas emissions. In this we follow the international greenhouse emission accounting conventions agreed by the IPCC, which specify that if biomass fuels are not produced on a sustainable basis, the resultant CO₂ emissions should be accounted under the category of land use change. Our scenario for 2040 includes a large consumption of biomass fuel and it is of course axiomatic that this fuel be produced sustainably. Chapter 7 describes how this could be achieved.

Figure 3.4: Total stationary energy CO₂ emissions by fuel, 2001



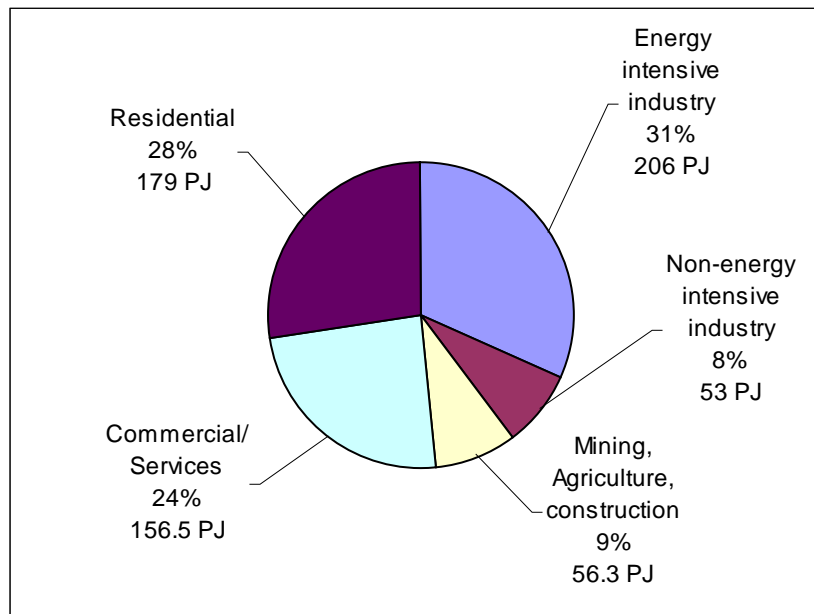
When CO₂ emissions are grouped by sectoral group/activity, it is found that electricity generation accounts for 69% of emissions and all other stationary uses of energy for the remaining 31%. This distribution of emissions of course reflects the fact that most coal is used for electricity generation and most electricity is generated using coal, with over two-thirds of the energy in the coal being lost during generation and delivery. Clearly, if stationary energy emissions are to be halved by 2040, the electricity industry will have to undergo profound changes in the technologies used to generate electricity.

Given the importance of electricity generation, and thus of demand for electricity by final consumers, we conclude this Section with some information about the demand for and the production of electricity.

Figure 3.5 shows demand for electricity by major sectoral group. It can be seen that both the Commercial/Services and the Residential sectors account for much larger shares of demand for electricity than they do of demand for energy in total. This means that measures to limit growth in demand for energy from these sectors, and in

particular measures to stimulate greater energy efficiency, will be much more important for limiting greenhouse gas emissions than their shares of final energy consumption might suggest at first glance.

Figure 3.5: Electricity use by major sectoral group, 2001



Figures 3.6 and 3.7 show respectively the mix of fuels used to generate electricity and the CO₂ emissions produced by each of these fuels. The very great importance of coal in both cases can be clearly seen.

Figure 3.6: Primary energy use in electricity generation by fuel, 2001

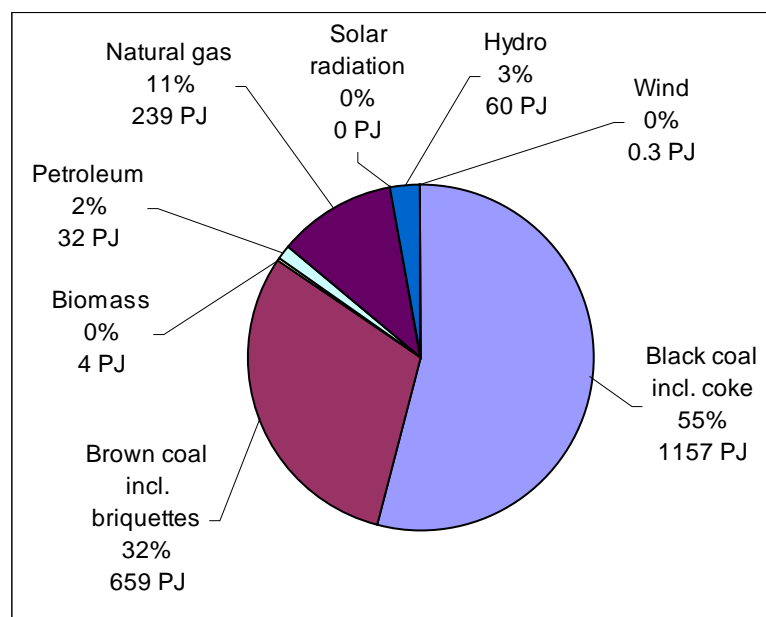
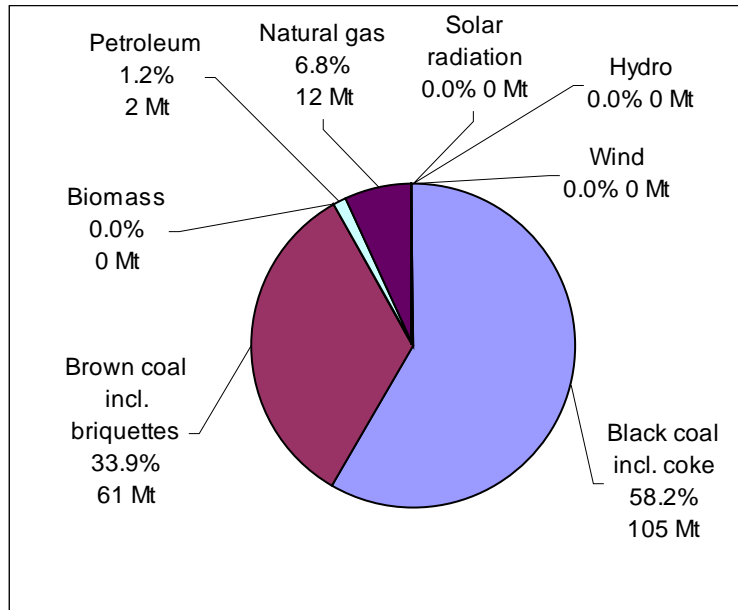


Figure 3.7: CO₂ emissions from electricity generation by fuel, 2001



4. Future levels of economic activity

4.1. Introduction

The level of future economic activity will be a major determinant of the future demand for energy. This section provides an estimate of the amount and composition of economic activity in the years 2013, 2020, 2040 and 2050.

No economic estimates over such a long period of time can be considered to be accurate ‘forecasts’ as the potential for unexpected technological, social and economic transformations to occur is too great. However, using a range of plausible assumptions it is possible to develop future scenarios which provide a sound foundation for current day policy making.

The long lifespan of electricity generation infrastructure makes it necessary to attempt to describe the economy so far into the future. Decisions made today about electricity generation will still have an impact on Australia’s greenhouse gas emissions in 40 years time. The need to scrap electrical generation capacity before it reaches the end of its economic life will significantly increase the cost of greenhouse gas abatement. It is therefore necessary for policy makers to be aware of the future energy needs of the Australian economy, and the capacity to meet those needs from alternative sources, if they are to facilitate a low cost transition to the sustainable emissions of greenhouse gases in Australia.

This chapter is organised as follows. Section 4.2 provides an overview of the methodology used to estimate future economic activity in Australia. Section 4.3 provides a discussion of the contemporary Australian economy and the factors that are likely to shape its development over the next 50 years. Section 4.4 provides the estimates of Australian economic activity for the years 2013, 2020, 2040 and 2050. Section 4.5 offers some conclusions.

4.2. Methodology

The process used to estimate future economic activity is as follows:

- 1) Determine output by sector for the base year (2001).

The sectoral data for the base year was purchased from the Australian Bureau of Statistics (ABS). For most industries data were collected at the two-digit level in the ANZSIC classification system. However, for some highly energy intensive industries such as manufacturing and mining, more disaggregated three-digit ANZSIC data were used.

- 2) Determine the growth rate(s) for individual sectors between the base year, the point estimates and the end point.

While most sectors were assumed to grow in line with the economy overall (see below) a number of sectors were assumed to grow faster or slower than average. A discussion of the more significant assumptions concerning sectoral growth patterns is provided below.

3) Forecast the output of each sector.

The sectoral growth rates were applied to the base year estimates of sectoral output to determine the first estimate of sectoral output. Refinements to these estimates, however, are necessary to ensure that the combined output of each sector does not exceed the forecast potential output for the economy as a whole. Steps 4-6 outline the process for estimating future output for the economy as a whole.

4) Determine the total output of the economy in the base year.

ABS output data were purchased as described above.

5) Estimate the potential growth rate.

Long run economic growth is constrained by the available resources and technology. The two factors that are most important in determining the long run rate of economic growth are labour force growth and labour productivity (which is assumed to capture technological change). The rates of employment growth and labour productivity used in the *Intergenerational Report* (Costello 2002) were used in estimating the overall level of economic activity. These forecasts however, end in 2040. The employment and productivity growth rates used in the *Intergenerational Report* for 2040 were therefore assumed to hold until the end of the current analysis in 2050. The forecasts from the *Intergenerational Report* are provided in Table 4.1.

Table 4.1: Growth in labour productivity, employment and GDP

Decade	Labour productivity growth (% p.a.)	Employment growth (% p.a.)	Real GDP growth (% p.a.)
2000s	1.7	1.5	3.1
2010s	1.75	0.6	2.3
2020s	1.75	0.2	2.0
2030s	1.75	0.1	1.9

Source: Costello (2002) p. 30.

6) Estimate output for the end point.

The sectoral growth and overall growth then need to be reconciled. If all sectors were assumed to grow at the forecast average rate of growth then such reconciliation would not be necessary. However, given that differential sectoral growth rates were assumed to exist the sectors for which differential growth were assumed to occur were estimated first and then the average rate of growth for the remaining sectors was estimated subject to the constraint that the sum of sectoral outputs must equal the estimated size of the economy as a whole.

4.3. The contemporary Australian economy

The Australian economy, like that of all developed economies, has been shaped by a wide range of historical, technological, cultural and political forces. The nature and extent of the impact of individual factors on Australia's economic development has been highly contestable in the past (see for example EPAC 1986; Bureau of Industry Economics 1992, Howe 1993, Dao *et al.* 1993) and will, no doubt, continue to remain that way.

That said, it is possible to identify particular trends that have occurred in recent times and, in turn, to suggest trends which may continue or are likely to emerge. As stated above, however, the following estimates can not be considered as forecasts due to the long length of the period under examination and the inevitability of new technological, social and cultural trends emerging.

Table 4.2 shows the share of GDP by industry for Australia in 2000-01. Manufacturing and property and business services are by far the largest industries accounting for 11.6% and 11.5% of GDP respectively. However, given the length of the time period being analysed in this study it is important to note that relative growth rates, rather than current industry size, will be the major determinants of the composition of economic activity in 2050.

Table 4.2: Australian industry share of GDP, 2000-01

Industry	Share of GDP (%)
Agriculture forestry and fishing	3.0
Mining	4.6
Manufacturing	11.6
Electricity gas and water supply	2.5
Construction	4.6
Wholesale trade	5.0
Retail trade	5.1
Accommodation, cafes and restaurants	2.3
Transport and storage	4.9
Communication services	3.2
Finance and insurance	6.3
Property and business services	11.5
Government administration and defence	3.9
Education	4.3
Health and community services	5.5
Cultural and recreational services	1.9
Personal and other services	2.4

Source: ABS 5204.0

Table 4.3 shows the growth rates of each industry for each of the years between 1993-94 and 2000-01 as well as the simple average growth rate over that period. The highest rate of growth has been in the communication services industry, which averaged 10.37 % growth over the period. The lowest growth rate, on the other hand, was achieved in the education industry, which grew by only 1.73 % over the period, less than half the growth rate for the economy as a whole.

Table 4.3: Australian industry growth rates 1993-94 to 2000-01

	Average (% p.a.)
Agriculture forestry and fishing	3.13
Mining	4.75
Manufacturing	2.67
Electricity gas and water supply	2.28
Construction	2.66
Wholesale trade	5.76
Retail trade	3.89
Accommodation, cafes and restaurants	4.89
Transport and storage	4.07
Communication services	10.37
Finance and insurance	4.62
Property and business services	6.23
Government administration and defence	2.42
Education	1.73
Health and community services	3.46
Cultural and recreational services	4.06
Personal and other services	5.10
Ownership of dwellings	4.01
GDP	3.98

Source: ABS 5204.0

It is important to note that energy intensive industries such as manufacturing, electricity, gas and water and construction all grew at well below average over the period 1993-94 to 2000-01. Similarly, industries with low energy intensity, including property and business services and wholesale trade have expanded much more rapidly than the economy as a whole. In other words, the economy is gradually becoming less energy intensive.

Table 4.4 provides recent ABARE estimates of future economic growth and industry output for highly energy intensive manufacturing industries. It shows that, excluding direct reduced iron production, metal production is expected to grow at a substantially slower rate than the economy as a whole.

Table 4.4: ABARE estimates of growth in selected manufacturing industries

	% change
GDP	
2000-01 to 2005-06	3.7
2000-01 to 2019-20	3.4
Direct reduced iron production	
2000-01 to 2005-06	21.0
2000-01 to 2019-20	11.6
Steel production	
2000-01 to 2005-06	1.7
2000-01 to 2019-20	2.6
Aluminium production	
2000-01 to 2005-06	2.2
2000-01 to 2019-20	1.4
Alumina production	
2000-01 to 2005-06	2.2
2000-01 to 2019-20	1.3

Source: Dickson, Akmal and Thorpe, 2003, p. 11.

In line with reduced shares of activity in the energy intensive manufacturing sectors the coal mining industry is expected to grow at a slower than average rate. Such shifts, combined with policy changes aimed at reducing the subsidies to coal mining relative to the cost of renewable energy, are likely to result in a substantial decline in worldwide demand for coal. The International Energy Agency, for example, forecasts a 17 % decline in coal use in the OECD by 2020 (IEA 2002, p. 336).

Another important recent trend that is likely to continue is the relative growth of the services sector, particularly communications, banking and finance and hospitality (See for example HSBC 1999; National Office for the Information Economy 2003). These sectors have demonstrated strong growth in recent years and can be expected to continue to do so.

A further note is required on the treatment of the more important of the economic sectors which are determined endogenously in our energy model. These are Oil and Gas Production, Petroleum Refining and Electricity. In the case of Oil and Gas, current expectations are for a decline in Australian production of crude oil, as reserves are depleted, but for this to be offset by a large expansion in natural gas production to supply rapidly growing domestic and international demand. The latter will be supplied by LNG, the production of which constitutes a high value added element of the Oil and Gas sector. We assume that the net effect of these changes will be that economic value added of the sector as a whole grows slightly faster than the economy as a whole, and that demand for energy services for LNG production grows at the same rate. The growth in demand for energy services in processing natural gas for domestic markets is determined endogenously within the energy system model.

In our scenario, physical demand for both electricity and petroleum products grows much more slowly than the economy. This implies that the conventional businesses supplying these commodities will also grow more slowly. However, the lower level of physical demand growth is largely brought about by significant growth in expenditure on energy efficiency – *negawatts* displacing megawatts in the terminology coined by Amory Lovins. This implies greatly increased growth in the diverse industries that supply energy efficiency services, some of which may well be undertaken by electricity supply businesses. We have modelled this change by defining growth in the Electricity and Petroleum Refining industries to be equal to the growth in demand (including demand from transport) for these fuels in the Baseline energy demand projections, i.e. energy demand without the implementation of strong energy efficiency measures.

Table 4.5 provides the relative growth rates for industries that have been assumed to grow at above or below average rates of growth. The figures in Table 4.5 are expressed relative to the assumed rate of growth for the economy as a whole (which change over time as shown in Table 4.1). That is, the figure of 0.9 for Metal Ore and Other Mining suggests that these parts of the mining industry will grow at 90% of the average rate of growth for the economy as a whole while a figure of 1.3 for Accommodation, cafes and restaurants suggests that the industry will grow at 30% above the average rate of growth.

Table 4.5: Relative growth rates for selected industries (% p.a.)

Coal Mining	0.5
Oil & Gas	1.1
Metal Ore Mining	0.9
Other Mining	0.9
Petroleum Refining	0.9
Petroleum and Coal Product Manufacturing n.e.c.	0.4
Basic Chemicals	0.4
Ceramic products	1.1
Cement, lime, plaster & concrete products	0.9
Iron & steel	0.4
Basic Non-Ferrous Metal	based on ABARE ¹
Non-Ferrous Basic Metal Products	0.7
Paper & Paper Product	0.4
Accommodation, café's and restaurants	1.3
Road transport	0.9
Rail transport	1.2
Air transport	1.1
Communication services	1.2
Finance and insurance	1.2
Education	1.1
Health and Community services	1.2

¹ The growth rate of aluminium production was assumed to change over time in line with Dickson, Akmal and Thorpe (2003). It is assumed to grow at 2.2% p.a. from 2001-2006 and 1.4% p.a. until 2050.

4.4. Estimates of future economic activity

Estimates of the size of individual sectors and the economy as a whole are derived from the application of the differential growth rates for each sector to the base year estimates of the size of each sector. The results of this process for the years 2013, 2020, 2040 and 2050 are shown in Table 4.6.

Table 4.6: Estimated output by industry 2013, 2020, 2040 and 2050 (\$million)

	2013	2020	2040	2050
Coal mining	6659	7203	8742	9609
Oil & gas	24433	29009	44300	54479
Metal ore mining	12987	14950	21154	25062
Other mining	1205	1387	1963	2326
Petroleum refining	1800	2072	2932	3474
Petroleum and Coal Product Manufacturing n.e.c.	67	71	83	90
Basic chemical	2503	2666	3113	3358
Plastic product	3225	3771	5543	6691
Ceramic product	829	984	1502	1847
Cement, lime, plaster & concrete product	2778	3197	4524	5360
Iron & steel	2947	3138	3665	3953
Basic non-ferrous metal	6338	6985	9225	10601
Non-ferrous basic metal product	660	736	965	1101
Other chemical product	4991	5834	8577	10353
Paper & paper product	2822	3005	3509	3785
Accommodation, café's and rest.	22754	27860	45906	58592
Road	12902	14852	21015	24898
Rail	5491	6621	10503	13159
Air	8402	9976	15234	18734
Water	760	881	1264	1506
Other transport	1222	1417	2034	2423
Communication services	28728	34638	54948	68843
Finance and insurance	67008	80792	128164	160573
Education	43153	51235	78242	96221
Health and Community serv.	57094	68839	109202	136817
Agriculture, forestry and Fishing	29757	34500	49519	58990
Services to Mining	1286	1491	2139	2549
Food, beverage & tobacco	20247	23474	33693	40137
Textile, Clothing, Footwear and Leather]	3556	4123	5918	7049
Log sawmilling & timber dressing	1323	1533	2201	2622
Other wood product	2070	2400	3444	4103
Printing, Publishing and Recorded Media	9084	10532	15116	18008
Rubber product	699	810	1163	1385
Glass and Glass Product	912	1057	1518	1808
Non-Metallic Mineral Product Manufacturing n.e.c.	436	506	726	865
Structural metal product	2603	3018	4331	5160
Sheet metal product	1699	1970	2828	3368
Fabricated metal product	3135	3634	5217	6214
Machinery and Equipment Manufacturing	18565	21524	30895	36804
Other manufacturing	3327	3857	5536	6595

Electricity	13125	15217	21841	26019
Gas	2194	2544	3651	4350
Water	5812	6738	9671	11521
General construction	20515	23784	34139	40668
Construction trade services	27563	31956	45867	54640
Wholesale trade	46125	53477	76758	91438
Retail trade	45220	52427	75250	89643
Services	16310	18910	27142	32333
Storage	1890	2191	3145	3747
Property and bus. Services	101251	117388	168492	200717
Govt. admin and defence	34665	40189	57686	68719
Cultural and Rec. Services	16218	18803	26989	32150
Personal and other services	20253	23480	33702	40148

The data presented in Table 4.6 are summarised in Table 4.7, which shows the proportionate increase in value added between 2001 and 2040 for each sector of the economy that was separately analysed in the model. Note that this sectoral breakdown was adopted in order to focus analytical attention on industries which use large amounts of energy, or have particularly distinctive and important energy use characteristics (such as the sugar industry), rather than basing breakdown solely on economic size.

This summary shows clearly that service industries as a whole (termed Commercial/institutional) grow faster than the total economy, though, within this large grouping, accounting for about half of total GDP, some sectors grow faster than others, as shown in Table 4.6. All other sectors of the economy grow at less than the average rate for GDP as a whole, but they all nevertheless show significant growth. Export coal mining, for example, is 55% larger in 2040 than in 2001, making it larger than today's total coal mining industry that supplies both export and domestic markets. There will, therefore, be no need for substantial job losses in any industries on the basis of limited growth alone.

Table 4.7: GDP and Sectoral value added growth ratios, 2001 to 2040 (%)

Category	Output ratio
GDP	2.40 ^a
Domestic energy supply industries	N/A ^b
Coal mining for export	1.55
LNG production for export	2.62
Mining (non energy)	2.2
Iron and Steel	1.42
Food, beverages, tobacco	2.3
Sugar industry	1.21
Basic chemicals	1.42
Cement, lime, plaster and concrete	2.2
All other non metallic mineral products	2.3
Non-ferrous metals	1.79
Wood, paper and printing	1.42
All other manufacturing	2.3
Construction	2.3
Commercial/ institutional	2.5
Agriculture/ Forestry/ Fishing	2.3

Residential	2.3
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a: *Intergenerational Report* (Costello, 2002)

b: endogenously determined

4.5. Conclusions

The scenario presented above is, by design, highly conservative. That is, the nature and structure of the contemporary economy is used as the starting point for the analysis and the application of differential growth rates is such that no industries are assumed to disappear and no new industries are assumed to emerge.

As discussed above, the objective of this analysis is not to provide a forecast of the likely industry composition of the Australian economy in the future. Rather, the purpose is to highlight the fact that, using plausible increases in energy efficiency and technological change, it would be possible to meet the likely energy demands of an Australian economy which, while broadly similar to the contemporary economy, had experienced long periods of subsequent economic growth.

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

Div B	ANZSIC economic sector	Energy intensity 2001 (TJ/\$M value added)	Average annual intensity change 1994 to 2001 (%)
	Manufacturing		
21	Food, beverages, tobacco	13.89	-1.5%
23	Wood and paper products	27.17	0.1%
25	Petroleum and chemicals incl. oil refining	22.42	-1.6%
26	Non-metallic mineral products	46.86	-1.8%
27	Metal products	1.58	0.7%
22, 24, 28, 29	All other manufacturing	16.24	-1.1%
Div C	All manufacturing	1.46	-1.1%
Div E	Construction	0.64	0.2%
37, Divs F, G, H, J,K, L, M, N, O, P, Q	Commercial/Services		-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,

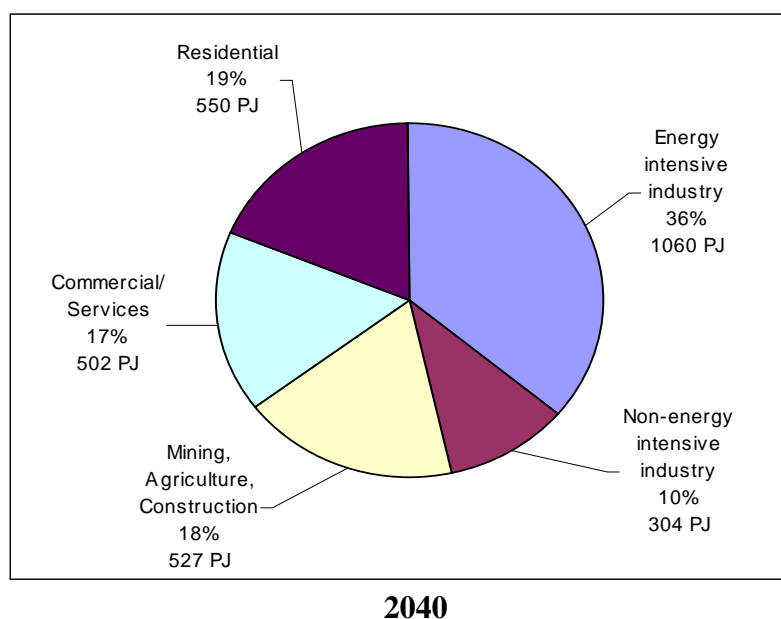
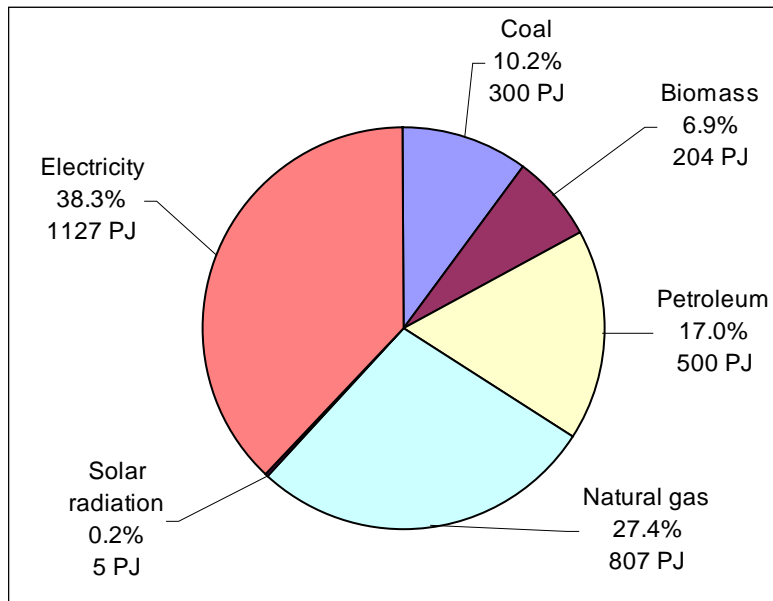


Table 5.4: Baseline (BAU) stationary final demand for energy by sector, 2040 (PJ)

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

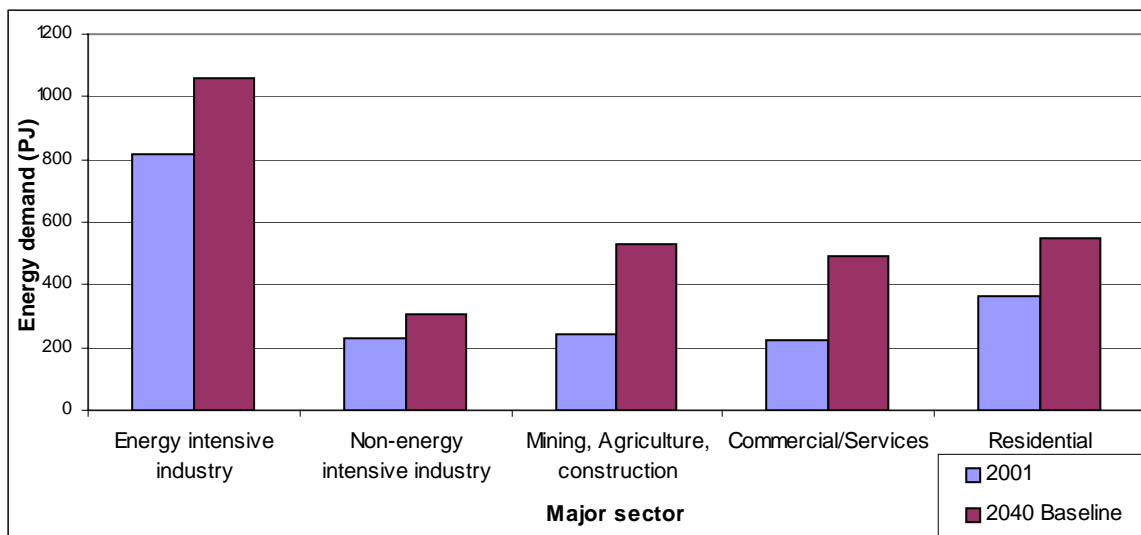
Figure 5.2 shows baseline final energy demand in terms of fuels.

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



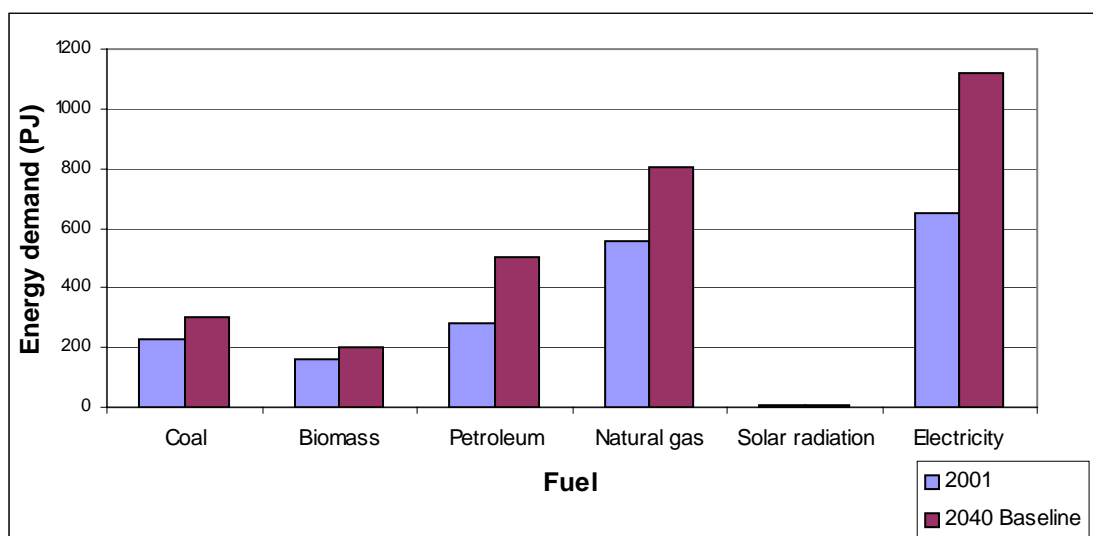
Figures 5.3 and 5.4 compare the projected baseline final demand for stationary energy in 2040 with actual 2001 final demand, by major sectoral group and by fuel.

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 CO₂ 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.

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 CO₂). 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 producer 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
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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/m² 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/m².

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 result 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 CO₂ capture to produce hydrogen.

6.7. Fugitive emissions

The production and supply of energy from fossil fuel sources is associated with emissions of CO₂ 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 CO₂-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 CO₂. Most other mines could similarly oxidise waste methane at an abatement cost of a few dollars per tonne of CO₂-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 CO₂ from gas processing can be almost completely eliminated by reinjecting the extracted CO₂ 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 CO₂ 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

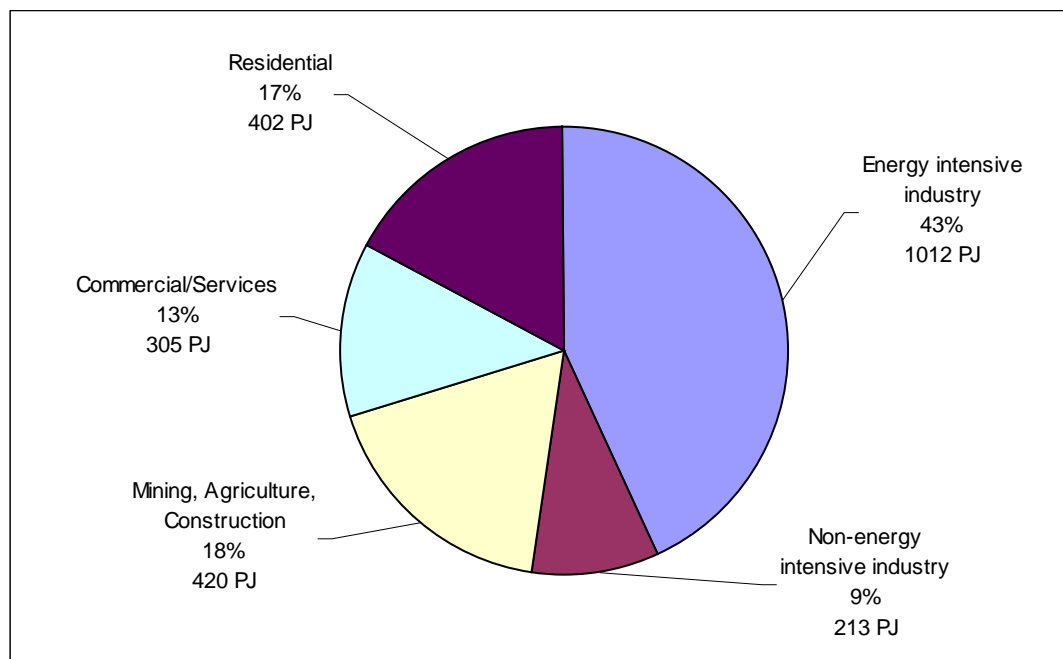
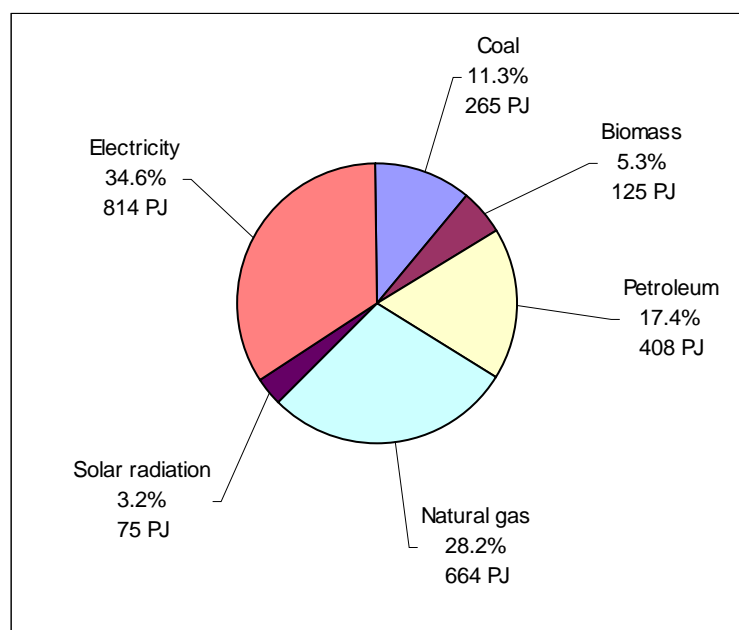


Table 6.1: Medium Efficiency stationary final demand for energy by sector, 2040

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

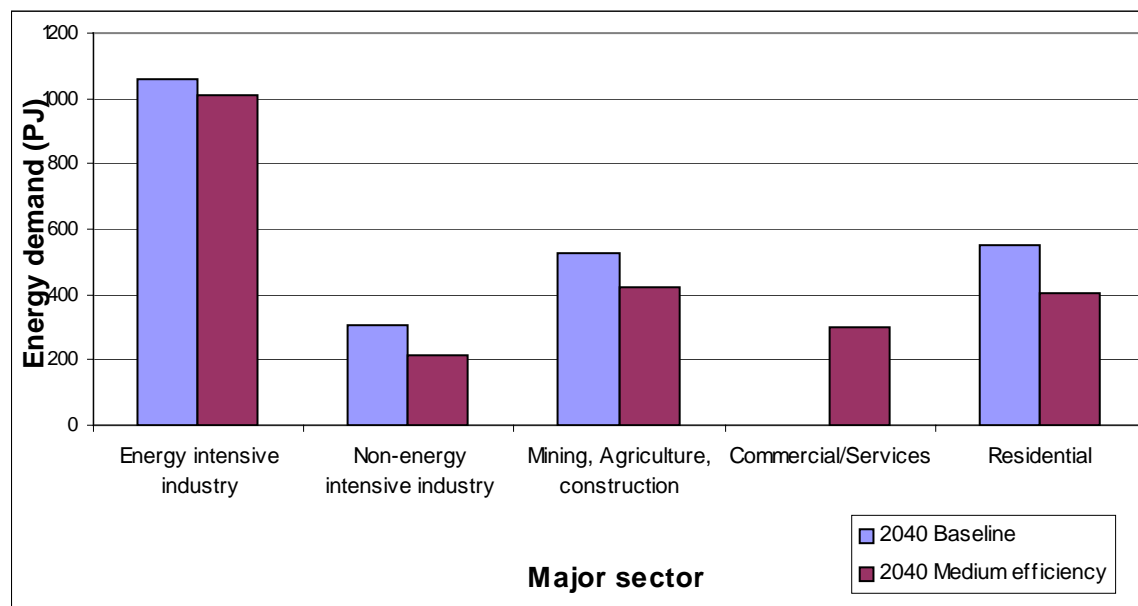
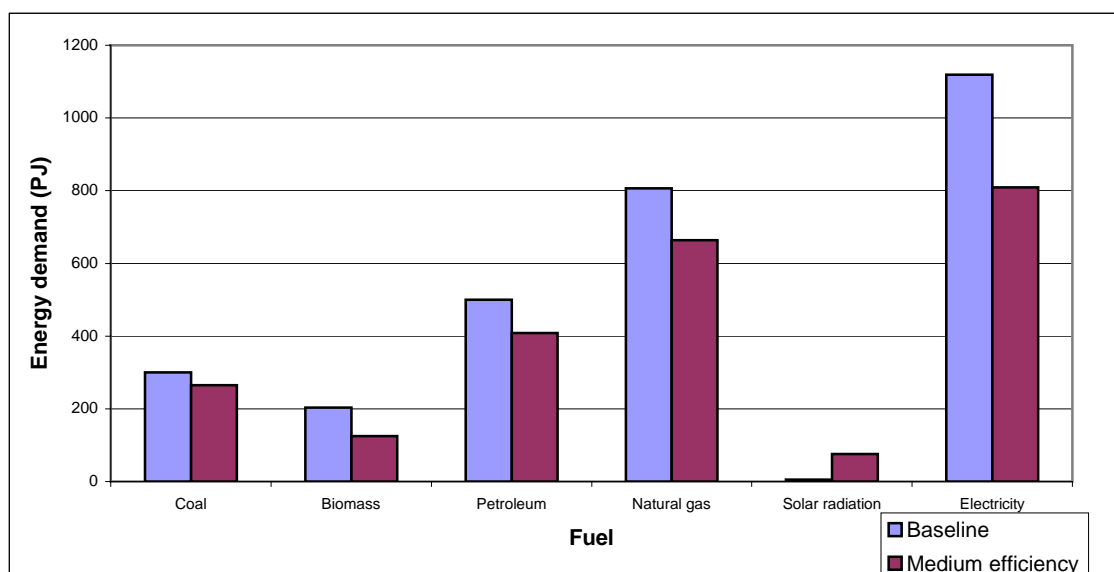


Figure 6.4: Medium Efficiency and Baseline final stationary energy demand by fuel, 2040 (PJ)



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)

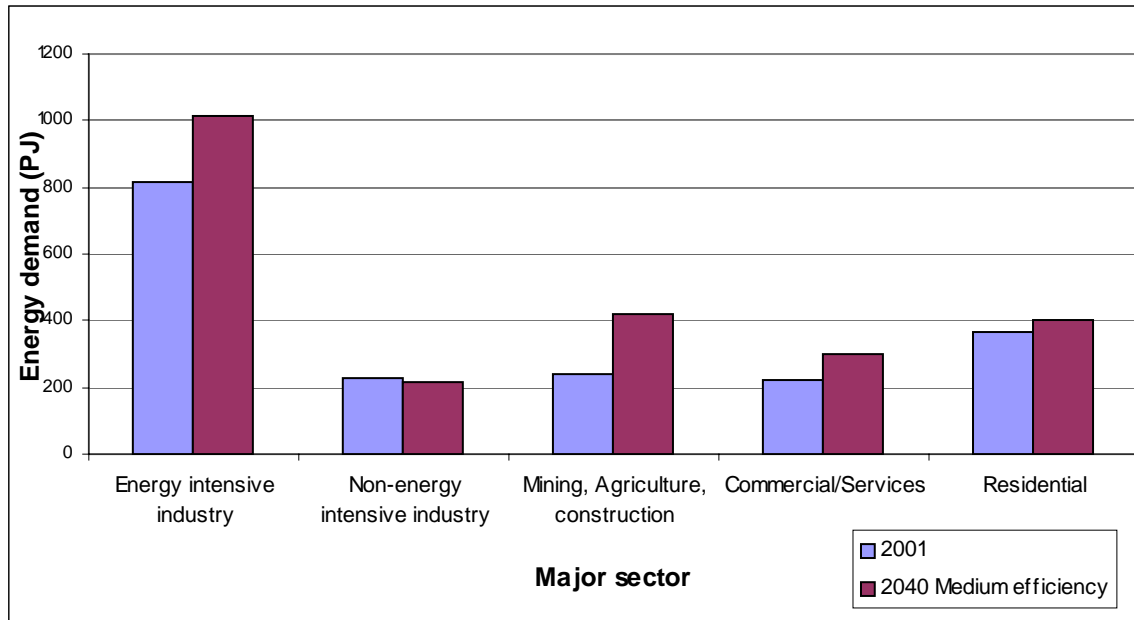
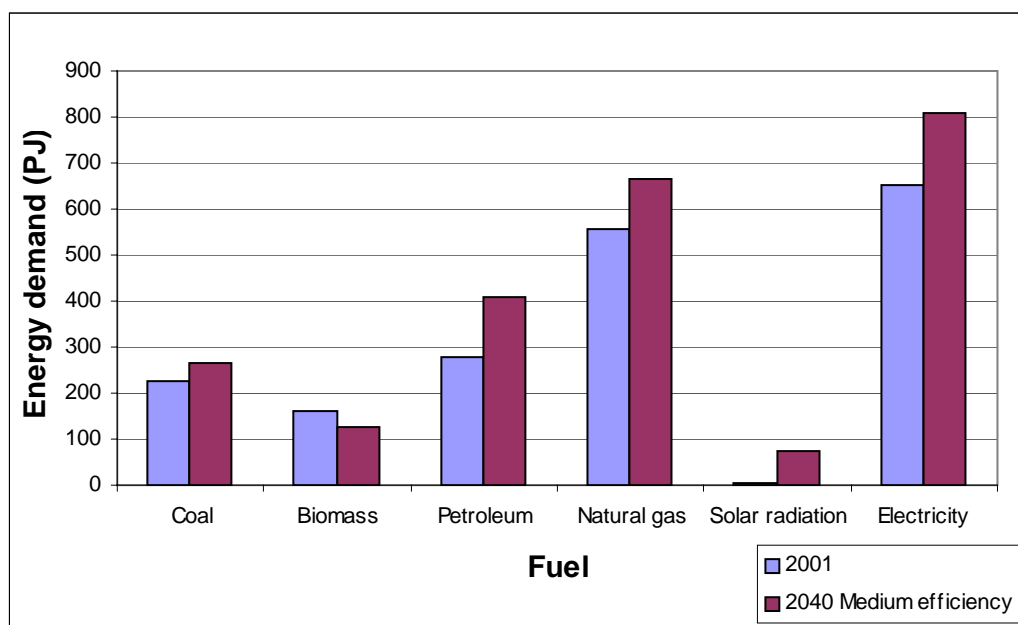


Figure 6.6: Medium efficiency final stationary energy demand by fuel 2040, compared with 2001 (PJ)



7. Present and Future Renewable Energy Technologies

Chapter 6 established a scenario for the demand for energy in 2040 based on a medium level of implementation of efficiency of energy use. At this stage we prepare the ground for the cleaner energy supply mixes presented in Chapters 9 and 10. To this end Chapter 7 reviews the present status and potential future development of several renewable energy technologies and Chapter 8 fulfils a similar role for fossil fuel technologies. The present chapter considers resources, technology development pathways, future costs and alleged limitations on deployment (e.g. land-use, grid integration). It is based on recent review articles, on Web sites and on interviews with several leaders in R & D and business in each of the major technologies being considered.

In our principal Clean Energy Scenarios (see Chapters 9 and 10), the main renewable sources are biomass, wind and solar heat. There are also a significant contributions from hydro-electricity (mostly existing) and, to a lesser degree, direct solar electricity. These are now discussed in approximate order of importance in the 2040 scenarios.

7.1. Biomass energy

Background

Biomass is material produced by photosynthesis or is an organic by-product from a waste stream. It includes a wide variety of renewable organic materials, including forestry and agricultural wastes and residues, urban tree trimmings, food processing wastes, woody weeds, oil bearing plants, animal manures and sewage, energy crops and the organic fraction of municipal solid waste. In photosynthesis, growing plants capture solar energy and carbon dioxide from the atmosphere to form carbohydrates. These may be used either by combustion of the solid fuel, or by converting them into other useful forms of stored energy, namely biogas (which is mainly methane) or liquid fuels such as methanol and ethanol. The energy conversion paths for biomass are diverse and include gasification for heat and power; pyrolysis to produce liquid and gaseous fuels; anaerobic digestion to produce a combustible gas; and fermentation to produce ethanol.

In 2000 combustible renewables and waste provided 11% of the world's total primary energy supply, dwarfing hydro (2.2%) and the other renewables such as geothermal, solar and wind (0.5%) (IEA, 2002). At present Finland derives over 20%, Sweden 17%, Austria 11% and Australia about 3.3% (about 170 PJ) of total primary energy supplies from biomass¹.

In terms of stationary energy consumption, Australia obtains about 9% from biomass. This includes about 120 PJ of process heat, but so far only about 500 MW of installed electricity generating capacity (slightly more than 1% of total capacity). Most of this biomass is bagasse, the fibrous residue of the sugar industry, and some is black liquor, a by-product of wood processing, which is used mainly in paper manufacturing.

¹ ABARE gives 202 PJ of biomass energy, but firewood experts suggest that the residential firewood component of this amount should be about 48 PJ instead of ABARE's 80 PJ.

About 48 PJ biomass is burned as firewood in our homes², often used inefficiently and producing significant air pollution. In addition, a small amount of biomass is co-fired with coal in a few base-load power stations.

In terms of reducing greenhouse gas emissions, biomass energy offers three different types of contribution.

- Solid and gaseous biofuels can substitute for fossil fuels (mainly coal and oil) in the generation of electricity and useful heat.
- Liquid and gaseous biofuels can substitute for oil in transportation.
- Biomass, especially timber, can be used in place of much more greenhouse intensive materials, such as concrete (e.g. in power poles and railway sleepers).

The present report is only concerned with the first of these greenhouse benefits.

For the purpose of generating electricity and heat in Australian sustainable energy scenarios, the key issues are:

- resource assessment and hence land and water availability,
- the choice of energy conversion paths and the allocation of a finite quantity of biomass fuels between heat and electricity on one hand and transport on the other,
- obtaining multiple benefits from bioenergy crops, in order to offset the additional costs compared to fossil fuels.

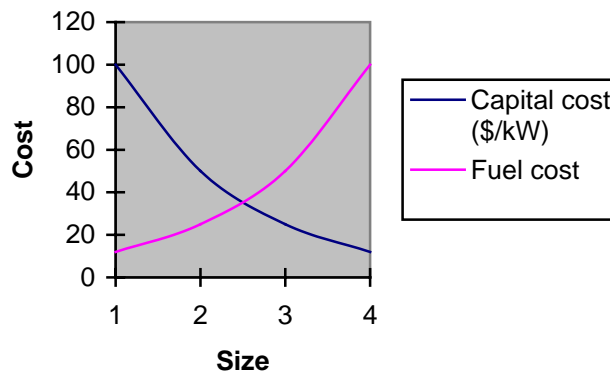
One important additional issue merits highlighting. Biomass energy can create far more jobs per unit of energy generation than fossil fuels and any other renewable source of energy (ERDC, 1994; MacGill, Watt & Passey, 2002). These jobs are diverse, ranging from extensions to existing agricultural and forestry activities through to specialised engineering and electronic functions. Many of them are located in rural areas where there is the greatest need for employment.

Solid biomass

The combustion of solid biomass is well understood, straight-forward, commercially available, readily integrated with existing infrastructure and low in cost, provided the fuel does not have to be transported long distances or stored under cover. As shown schematically in Figure 7.1, as the size or capacity of the power station increases, its capital cost in \$/kW decreases, while its fuel cost increases as fuel has to be transported from further afield. There is an optimal size of power that minimises total cost. The optimum varies with geographic region, however it is usually much smaller than the economic optimal size of a coal-fired power station.

² See previous footnote.

Fig. 7.1. Optimal size of biomass power station in arbitrary units



The cheapest way to convert solid biomass into useful energy is to avoid the capital cost of a dedicated facility by co-firing the biomass in an existing coal-fired power station. In Australia, this is already occurring in a few power stations with typically about 5% biomass (in energy terms) combusted with coal.

There are also several small power stations burning 100% solid biomass, mainly bagasse and forestry residues. In some regions there is a potentially large market for small cogeneration plants fuelled with biomass. Such regions have a large local availability of biomass and large potential demand for both heat and electricity in small industries, horticulture and buildings. A well-designed biomass-burning power station emits similar particulates and much less nitrogen oxides and sulphur dioxide than a coal-fired equivalent.

Solid biomass fuels, in the form of wood and wood chips, and low calorific value biogas are relatively expensive to transport due to their low bulk and energy densities, and so transportation distances rarely exceed 40-80 km³. They may also decay slightly during the time required for transport and storage. On the other hand, wood pellets and liquid and medium to high calorific value gaseous fuels made from biomass are better suited to long-distance transport, as the energy inputs for transport are usually a small fraction of the energy content of the fuel. Domestic heating by burning wood pellets is much more efficient and less polluting than traditional wood-burning. It is expanding rapidly in northern Europe and could play a role in parts of Australia⁴.

Gaseous and liquid biofuels

Compared with solid fuels, there is much less experience with the production and use of gaseous fuels and alcohols derived from biomass in Australia. However, ethanol is a mature industry here, albeit small. There is a need for demonstration projects to assist in choosing the most appropriate technology for a given fuel and circumstances, and estimating its likely future cost. Biomass may be gasified by heating it with steam and air/oxygen, but less oxygen than that required for conventional combustion. The resulting gas is of a low or medium calorific value compared with a higher calorific

³ In northern Europe, 40 km tends to be the limit. However, this depends on the prices of the biomass transported and the transport fuel.

⁴ E.g. in Hobart, Launceston, Canberra, Cooma, Tamworth and Armidale, provided the source of the pellets satisfies environmental requirements.

value for natural gas and can be used in gas turbines and internal combustion engines. Alternatively, the biomass derived gas may be upgraded to a higher quality and may be converted to methanol. Potentially gasification could improve the efficiency of energy conversion, transportability and clean burning of biomass fuels. Of the gaseous fuels, landfill gas is the most widely used at present, with some 100 MW of installed generation in Australia. However, because most sustainable development practitioners consider that it is essential to phase out landfills, this source is not included in the 2040 scenario. It is well accepted that the priorities are to reduce the production of wastes, then to reuse and only after that to recycle or burn as a fuel. In the long run, biogas could play a substantial role in the generation of electricity and heat in 2040. This is likely to be via bioreactor cells and engineered anaerobic digesters.

The liquid fuels, methanol, ethanol and bio-oil⁵, can be produced from biomass. At the present time methanol is exclusively produced from natural gas. With quite high energy densities (but significantly below that of petrol) and ease of handling, methanol, ethanol and bio-oil can be used conveniently for both stationary energy and motor vehicles. In future, these liquid fuels may be more convenient forms of energy storage and transportation than hydrogen in its gaseous, liquid or metal hydrate forms. Methanol burns more cleanly and efficiently than petrol in internal combustion engines⁶. More important from the perspective of the present report, methanol can be fed directly into some types of fuel cell to generate electricity (see Section 7.8).

Environmental and resource constraints

The large-scale production and use of biomass is subject to natural constraints. Bioenergy can have significant beneficial environmental, economic and social advantages. However, as with any development, care needs to be taken to ensure sustainability criteria are met. For instance, this could be achieved through independent certification of biomass sources and setting standards for its conversion and use. The main constraints, both natural and human, on the sustainable production and use of biomass fuels are:

- the land area required to grow biomass and the balance of food, fodder and bioenergy produced on that land; however, even a small reduction in meat eating or meat exports would make a large amount of pasture available for fuel;
- the availability of water, a particular problem in large areas of Australia;
- the environmental constraint to produce biomass crops from plantations on land that was cleared pre-1990;
- avoiding pests and diseases through selection of biomass varieties;
- the need to use biomass at a rate no faster than the rate it regrows;
- the management of any 'wastes', including reuse where possible; in particular, the need to return nutrients to land from which biomass is cropped;
- the cost in relation to the multiple socio-economic and environmental benefits;

⁵ Produced by pyrolysis

⁶ Indeed some racing cars run on methanol.

- the need to avoid further land clearing or conversion of forests into managed plantations (which have reduced biodiversity) for biomass production.

Properly sourced, collected and converted, using biomass energy has lower local air and water pollution and land degradation than coal use, as well as much lower net greenhouse gas emissions than all fossil fuel combustion processes. It can enhance energy security by substituting for imported oil. It also has value for adding to animal habitat and biodiversity.

Using agricultural and forestry residues

The cheapest sources of biomass energy are the limited resources of urban wastes and landfill gas; agricultural residues (including bagasse) and forestry residues. For these sources the cost of the fuel, where it lies on the ground, may be zero or even negative. Provided the processing plant is located near its fuel source and not too distant from consumers of the electricity, heat, or gaseous or liquid fuel produced, electricity generation and especially cogeneration of heat and electricity from residues may not be much more expensive than fossil fuels.

Australia is one of the worlds lowest cost sugar producers. Combustion of a sugar cane residue, known as bagasse, can produce both steam to run the sugar mill and electricity for the grid. Bagasse is available for about 8 months in the year and cannot be stored cheaply, and so supplementation by another fuel is advisable. At Rocky Point power station, sawmill waste plays this role. Dixon and Bullock (2003) find that, given appropriate capital investment in new plant, the total cogeneration potential of sugar mills in Queensland and New South Wales is considerable. They calculate that, based on high-pressure steam boilers that burn both bagasse and 80% of the ‘trash’ recovered from the fields⁷, there is potential for total generating capacity of 1.65 GWe and energy generation of 9.8 TWh (35 PJ)⁸. However, the future potential of bagasse is uncertain, because in the short term it is dependent on possible restructure of the Australian sugar industry and in the long term industry viability depends on the level of sugar prices and alternate use to which the harvested land can be placed. The ability to produce renewable electricity would help to diversify revenue and assist in underpinning the economic viability of the industry.

Kelleher (1997) has estimated that the harvestable stubble residues from Australian grain crops (mostly wheat) and cotton in 1996-97 amounted to 68 Mt. Previously, stubble used to be burned off and this led to the structural degradation of soil, erosion and fertility decline in many areas. Nowadays conservation farming methods are prevalent and so crop residues are retained in many areas to protect the soil surface and conserve nutrients.

Since the area under all agricultural crops (not trees) in 1997 was about 20 million ha (Mha), this is equivalent to 3.4 green t/ha. Kelleher assumes that 1 green t/ha would be retained on the land to maintain sustainability of the soil. This leaves 48 Mt green

⁷ This level of recovery leaves sufficient ‘trash’ in the field for normal agronomic benefit.

⁸ Dixon and Bullock (2003) estimate that a further advance in technology to biomass-fired integrated gasification combined cycle (see Section 8.3 for a discussion of the coal-fired equivalent)) could lift the potential capacity to 5.65 GWe and potential output to 34.5 TWh (124 PJ).

residue, which is approximately equivalent to 24 dry Mt⁹. Given that this has an energy content of about 20 GJ/ dry tonne, we obtain total energy available in the fuel of 480 PJ. Assuming that this is all converted to bioelectricity by direct combustion at 35% efficiency¹⁰, it would generate 47 TWh (169 PJ), which is about 23% of Australia's electricity generation in 2001. This source would be further boosted by adding the residues from the existing plantation forestry. However, it would also be reduced by the lack of proximity of much of our agricultural crops to towns and cities. Some authors are also concerned that returning 1 green t/ha to the land may not be sufficient, so we assume here that 1.4 green tonnes/ha are retained, reducing the stubble contribution to electricity generation to 39 TWh (140 PJ) or 19% of electricity in 2001.

We have not attempted to evaluate the size of the resource from plantation forestry residues and the cost of generating electricity from it. However, we note that the Forest and Wood Products Action Agenda has a target of tripling Australia's plantation estate by 2020, and plantation residues (thinnings and logging residues) are likely to be quite large.

While biomass residues could make a substantial contribution to electricity and heat generation, they may not be enough to supply a zero coal energy mix (our Scenario 3 in Chapter 10), which may require about 330 PJ (92 TWh) of biomass electricity, and so dedicated energy crops may also form part of the future Australian clean energy mix.

Obtaining multiple benefits from biomass crops

Enecon (2002) have estimated the cost of electricity generated in a 30 MWe wood-burning power station to be 9.5 c/kWh. This may be compared with electricity from a new 1000 MWe coal-fired power station at 3.5-4.0 c/kWh. However, biomass electricity plants that are located close to country towns and regional centre may not have to pay transmission costs, which can be large in rural areas. Enecon points out that the remaining large price gap could be closed by assuming that growing and burning biomass has a substantial greenhouse gas reduction benefit and a value in reducing dryland salinity. We support the payment of salinity credits to farmers. However, we suggest that it would be less risky to grow an energy crop which has immediate multiple commercial benefits.

An example is the demonstration integrated wood processing plant that has just been built (but not yet commissioned) at Narrogin W.A., which will produce electricity,

⁹ Green biofuel contains a lot of moisture and typically has an energy content of about 10 GJ/green tonne. If it is oven dried, it loses about half its mass and its energy content becomes 20 GJ/dry tonne. In practice, it dries partially outdoors to the extent that its mass decreases by about 37% and energy content becomes about 16 GJ/tonne. For our 'back of the envelope' calculations of energy content, we reduce mass of fuel to hypothetical oven-dry tonnes by halving the green tonnage.

¹⁰ The thermal energy conversion efficiency is largely a design parameter. If fuel is expensive, it is worth going to higher steam temperatures and pressures to get efficiencies equal to those of coal-fired power plants, i.e. 35-38%. Currently fluidised bed boilers being delivered to Germany at 20 MWe scale have efficiency of 35%. For 5-10 MWe plants, efficiency is typically 20-30% at present, however there is no technical barrier to increasing this to at least 35% too. Therefore we assume that 35% will be the norm for direct combustion of biofuels 2040. However, for integrated gasification combined-cycle power stations, 40% would be readily achieved.

activated carbon and eucalyptus oil from mallee eucalypts grown on farms in the wheatbelt of Western Australia. Mallee is the common name given to a tree that has many stems shooting out from an underground root mass just below the soil surface, known as the lignotuber or 'mallee root' (a prized source of firewood). During fire or harvest, the above-ground mallee stems are lost, but the starch-rich lignotuber remains intact underground. The mallee is able to sprout back from buds on the surface of the lignotuber, enabling the tree to survive. This process is known as coppicing. Benefits associated with planting mallees and other eucalypts on existing agricultural land include:

- decreased waterlogging and therefore increased cropping yields;
- reduction of dryland salinity;
- shelter for stock, and therefore increased lambing rates;
- reduced erosion by wind and water;
- increased biodiversity and aesthetic value.

Once established, mallees have the potential to generate multiple revenue streams. However, at present the sizes of the markets for eucalyptus oil and activated carbon are limited. The first harvest is at age 4 or 5 and then re-harvests are every 2 or 3 years (depending upon the site) in perpetuity. Experience in the eastern States confirms that mallees may be harvested regularly for 100 years or more with no negative effects. This suggests that requirements for fertiliser may be very small¹¹. Moisture supplies mainly determine mallee biomass yield and frequency of harvest. Mallees appear to be a promising option in terms of both economics and environmental benefits. (See www.oilmallee.com.au)

Mallee are arranged in belts along contours where they intercept the downslope movement of the water that is surplus in the annual plant agriculture. This is the unused rainfall that drives groundwater accumulation and hence salinity. Production of mallee on wheat farms will be low, on average about 3 dry tonnes per ha of farmland per harvest, assuming that mallee occupies 15% of the wheat farm. To assess the total resource, it is assumed conservatively that the period between harvests is 3 years and so the average annual yield is 1.0 dry tonnes/ha of farmland which is equivalent to 6.7 dry tonnes/ha of land actually planted with biomass. Given that there is 15.4 million ha of wheatbelt farmland in Western Australia alone and sticking with the 15% planting, the annual yield of mallee biomass in that state could be as much as 15.4 million dry tonnes/year. In one year an integrated wood processing plant would take in 100,000 green tonnes (50,000 dry tonnes) feed and produce 37.5 GWh of electricity, 3,450 tonnes activated carbon and 1,050 tonnes of eucalyptus oil (Western Power et al., c.2002). Therefore, the whole W.A. wheatbelt could produce 308 times as much of each product, including 11.6 TWh of electricity, equivalent to 1.54 GWe of capacity. This is more than W.A.'s baseload electricity generation in 2001/02. However, a more detailed examination may reveal that somewhat less than 15.4 Mha of wheatbelt farmland is suitable for growing mallee. At present about 4.4 Mha (5-year average to 2002) is actually planted with wheat. This suggests that mallee need not displace any food crops.

¹¹ This depends on location and the presence or absence of nitrogen-fixing crops. In Western Australia there is a large reservoir of nutrients under many farms, too deep for annual crops but well within reach of tree roots.

On the basis of wheatbelt land areas, possibly 8-9 TWh of electricity could be generated from mallee grown in NSW, and 2-3 TWh in each of South Australia, Victoria and Queensland. Then total Australian electricity generation from mallee could be 25-30 TWh, still assuming 15% of land planted.

However, if we assume that the area of wheatbelt land that is not planted with wheat could be planted with oil mallee at a much higher density than 15%, so that the average density over 60 Mha of the Australian wheatbelt becomes (say) 40% (see Bartle, 2001), electricity generation would be 67-80 TWh. To confirm this, a detailed investigation of land use would be required.

Dedicated energy crops

If we take the annual electricity generation estimates of 39 TWh from stubble residues and wastes (based on Kelleher, 1997), 8 TWh from bagasse and sugar cane field residues (Dixon, 1997) and about 27 TWh from mallee in the wheatbelt, then, to supply 92 TWh in 2040, there is a shortfall of 18 TWh. (With a 40% planting of the wheatbelt there would be no shortfall.) To cover the shortfall, dedicated energy crops would be required.

Crops dedicated to bioenergy alone in economic terms are going to be less viable than crops with multiple economic benefits. To combat dryland salinity very large biomass plantings are required. Water will not be a problem, since they will draw upon underground water from the high water table which is bringing the salt to the surface. Giving an economic value to combating dryland salinity as well as the reduction of greenhouse gas emissions could improve the economics of dedicated energy crops.

Tree crops may also be planted to clean up waste water and to rehabilitate land that has been polluted with heavy metals, other toxic chemicals and excess nitrogen and other nutrients (Nicholas & McGuire, 2003).

Short rotation crops, with rotation periods typically 2-5 years, offer much higher annual yields of biofuels than long term tree crops (typical harvest periods 20 years or more).

In the UK it has been estimated that short rotation coppice grown on 15% of agricultural land could supply 20% of the country's electricity (DTI, 1999, Annex 3, Fig.2). Although Australia generally has a much drier climate with poorer soils, its trees are not deciduous and grow in a warmer climate. The net result is that Australian yields per hectare are about *twice* those of northern Europe, where there are some thriving biomass energy industries. Furthermore, Australia has a lot more land that is suitable for tree crops, although much of this land is a long distance from potential consumers of the biomass energy. A comprehensive survey of Australia's bioenergy resources has not been performed, although some valuable initial studies have been made, such as ERDC (1994) and the Bioenergy Atlas (accessible from www.brs.gov.au), which provides excellent maps and is currently developing its ability to provide quantitative tabulated data. Estimates of bioenergy potential have been made for particular sources such as grain crops (Kelleher, 1997) and bagasse plus sugar cane field residues (Dixon, 1997).

To obtain a rough estimate of the land area required for tree plantation crops (other than mallee in the wheatbelt) dedicated to bioenergy and grown on short rotation to generate biomass electricity and heat, we assume that on average 10 tonnes of dry matter can be harvested per hectare per year in Australia. Actually there is a wide range of variation, from 10 dry t/ha/yr for densely packed eucalyptus plantations in the dry Murray Darling basin to 35 dry t/ha/yr for eucalypts and other trees in moist south-east Queensland (Enecon, 2003). For average energy content of biomass we take 20 GJ/ dry tonne (20 PJ/ dry Mt). It seems reasonable to assume that in the future biomass from dedicated crops will be converted to electricity in integrated gasification combined cycle (IGCC) power plants with thermal efficiency of 40%. Then, to supply the remaining 18 TWh we require biofuel with energy content 45 TWh thermal or 162 PJ. This corresponds to 8.1 Mt of dry wood which requires 0.81 million ha (Mha) of land, which is about half the area of land currently under tree plantations in Australia.

In addition a much larger plantation area would be required for the production of liquid fuels, methanol and/or ethanol, to substitute for declining oil supplies¹² (Foran & Mardon 1999; Foran & Crane, 2002). These authors modelled the transition to an Australian biofuel economy in which dedicated short-rotation perennial tree plantations provide most of our liquid fuel and large fractions of our electricity demands in 2050. Table 7.1 summarises some aspects of the base case and three scenarios that each involve electricity generation and liquid fuel production together.

Table 7.1: CSIRO scenarios for biofuels for both electricity and transport

Scenario	Australia's CO ₂ emissions in 2050 ^a (Mt)	Land area under biofuel plantation ^b (Mha)	Bioelectricity generated in 2050 ^c (TWh)
Base	1,200	6 (trees only)	negligible
Methanol + bioelectricity	800	31 (trees only)	194
Ethanol + bioelectricity	700	20 (trees + agricultural crops + residues)	no data supplied
'Radical' economy ^d + methanol + bioelectricity	270	16 (trees only)	116

Source: From data provided by Foran & Crane (2002) and Foran & Mardon (1999)

Notes:

- For comparison, in 2001 Australia's total net CO₂ emissions amounted to 362 Mt and total net emissions to 528 Mt CO₂-e, including 38 Mt from Land Use Change.
- This land area serves both liquid fuel and electricity production together.
- The report does not state explicitly how much electricity is generated in each scenario. We have made the estimates in the 4th column by the same assumptions as set out above.
- 'Radical economy' has a lower rate of economic growth than the other scenarios.

Concluding remarks on bioenergy

More detailed work is needed to evaluate the bioenergy potential of all the different climatic regions of Australia and to evaluate its economics, taking into account multiple economic and environmental values and proximity to population centres and powerlines. However, on the basis of the above estimates, it appears that biomass could make a substantial contribution to electricity, heat and transport in Australia and at most only a minor fraction would have to come from dedicated energy crops.

¹² However, this does not have to be all forest. Oil seed crops and high lipid content algae could also play a role.

Specifically for electricity generation it appears that all biomass crops and residues could together supply considerably more than 92 TWh (330 PJ) of Australia's electricity in 2040, without competing with food production. Furthermore, this outcome could be achieved without using residues from native forests. To permit this scenario to develop, it is essential to modify the MRET rules that currently do not allow trees to be grown specifically for bioenergy.

In the coming decades, there will be a need to use increasing amounts of biomass for both electricity generation and liquid fuels for transportation. Some recent studies envisage factories that produce both together in a flexible manner. During peak periods of electricity demand they could produce mainly electricity, thus gaining the best price for that product which is expensive to store, while during off-peak periods the factories can produce mainly methanol, which is itself a storable fuel. (Enecon, 2002)

For further reading, a wealth of general information on biomass energy around the world may be obtained from Bioenergy Australia, website www.bioenergyaustralia.org/. The international bioenergy collaboration within the International Energy Agency may be accessed via www.ieabioenergy.com. A valuable international journal is *Biomass and Bioenergy*.

7.2. Wind power

Background

Over the past decade, wind power has been the fastest growing energy technology in the world, growing at about 25% p.a. on average. At the end of 2002, global installed capacity was nearly 32 GW (32,000 MW); Denmark had the largest percentage contribution to electricity generation from wind power, 18%; Germany had the largest installed wind power capacity, 12 GW; and Australia's installed wind power capacity was 104 MW¹³.

A wind farm, when installed on agricultural land, has one of the lowest environmental impacts of all energy sources.

- It occupies less land area per kilowatt-hour (kWh) of electricity generated than any other energy conversion system¹⁴, apart from rooftop or building-integrated solar energy, and is compatible with grazing and almost all crops.
- It generates the energy used in its construction in just 3 months of operation, yet its operational lifetime is at least 20 years.
- Greenhouse gas emissions and air pollution produced by its construction are very tiny and declining. There are no emissions or pollution produced by its operation.
- In substituting for base-load (mostly coal power) in mainland Australia (see Myth 1, below), wind power produces a net decrease in greenhouse gas emissions and air pollution, and a net increase in biodiversity.

¹³ At the time of writing (November 2003), Australian wind power capacity had reached 196 MW.

¹⁴ Typically less than 2% of land area within the boundaries of a wind farm is actually used for roads and tower bases.

- Modern wind turbines are almost silent and rotate so slowly (in terms of revolutions per minute) that they are rarely a hazard to birds.
- Currently wind farms in Australia have about 40% Australian content and create 2-3 times as many local jobs per kWh generated as coal power (McGill, Watt & Passey, 2003). However, as wind power expands, Australian content is expected to rise to about 80% and so the number of local jobs per kWh will rise to 4-6 times those of coal¹⁵.

The siting issue

Although wind farms are not permitted in national parks, there are some local community concerns about erecting them near other places of wild scenic beauty, such as at some sites along the Great Ocean Road in Victoria. The problem for wind farm developers is that the power in the wind is proportional to the cube of the windspeed. A reduction in annual mean windspeed from 8 to 7 m/s reduces the available wind energy by one-third and therefore entails a corresponding increase in the cost of electricity. Clearly, the planning authorities must weigh up the range of environmental, social and economic impacts of any wind farm project in their decision-making process. Stakeholders must recognise that we need a number of high-wind sites to assist in building up the industry and reducing greenhouse emissions, while protecting some special sites outside national parks.

The cost of electricity from a wind farm decreases as the annual mean wind power and the size of the wind farm increase. Currently land-based wind power has an installed capital cost in some overseas countries of about US \$1000/kW peak. However, a very large order (500-1600 wind turbines) can reduce the price per kW by up to 45% from the list price (Junginger et al., 2003). Capacity factors at 'excellent' on-land sites are about 35% and at 'good' sites are 25-30%. Assuming a real discount rate of 8%, electricity from large (50-100 MW) wind farms at 'excellent' sites currently costs US 4-5 c/kWh. In Australia, corresponding prices, allowing for the cost of imported components, are 7.5-9 Ac/kWh.

By 'excellent' sites, we mean that the annual mean wind speed at hub height is 8 m/s or more. As the scale of installation increases both internationally and within Australia, the capital cost of machines and installation cost will decrease and it will become economically viable to install large wind farms at sites with annual mean wind speeds of 7 m/s. Wind energy prices are currently falling at a rate of around 4% per annum and this suggests that the cost at excellent overseas sites will decline to US 3 c/kWh by some time in 2010-2020. Whether Australian prices reach the corresponding level of A 4.3-5.0 c/kWh (as the A\$ varies from US\$0.7-0.6) will depend partly upon international trends, partly upon the exchange rate and partly upon whether the scale of installation increases to the extent that 80% or more Australian content is reached. A strengthening of the MRET would make today's more marginal sites more attractive, easing development pressure on sensitive parts of the Victorian coast.

¹⁵ Since this was written the world's largest wind turbine manufacturer, Vestas, has opened a factory for manufacturing nacelle components in Wynyard, Tasmania.

At ‘good’ sites with 7 m/s annual mean windspeed the amount of land available increases by a factor of 20 over that available in excellent (8 m/s) sites (Gareth Johnston, WindLab Systems Pty Ltd, personal communication, 2003). Most of this land is inland pasture and is unlikely to be seen as important landscape to be preserved. On this land it should be possible to install at least 20 GW of wind capacity, as proposed in our scenarios. However, detailed published resource assessments still need to be done. The problem is building up the scale of installations in Australia to the extent that such ‘good’ wind sites become economically viable.

In our cleaner energy scenarios, we have assumed conservatively that mainly ‘good’ sites with capacity factor 30% will be occupied by wind farms in 2040 and that the average price of electricity at these sites will be 5.5 c/kWh.

Clarifying myths

In order to justify our scenario with 20% wind energy generation, we respond to three myths about wind power that are being spread by vested interests and some local groups.

Myth 1. Since wind power is an intermittent source, it cannot replace coal-fired power unless it has expensive, dedicated, long-term storage.

This claim was refuted 20 years ago in a series of scientific papers by a team of Australian scientists in CSIRO and ANU, who showed that wind power, like coal power, is a partially reliable source of power. In technical jargon, wind power has ‘capacity credit’ (Martin and Diesendorf, 1980; Haslett and Diesendorf, 1981). This was shown by means of three different methods: Monte Carlo computer simulations, numerical probabilistic models and mathematical probabilistic models of electricity grids containing various amounts of wind power capacity. The numerical probabilistic models used hourly-averaged real data to generate probability distributions for available capacity of thermal power stations, electricity demand and wind speeds. The scientists calculated loss-of-load probability (LOLP) for generating plant in the grid. In this way they addressed intermittency quantitatively. This early work has been confirmed and extended overseas by several different authors (e.g. Michael Grubb from UK and Alkemade and Turkenburg from the Netherlands) using a number of different probabilistic methods.

For relatively small penetrations of wind power into an electricity grid, the capacity credit of wind power is equal to the annual average wind power generated. In generation planning models, wind farms displace the amount of base-load power plant that has approximately the same annual average power output as the wind power plant. For example, in an electricity grid with total generating capacity of 10,000 MW, 2,000 MW of wind power would have an annual average power output of about 660 MW, so this amount of base-load capacity (coal in eastern Australia) could be retired or deferred. At the same time, to maintain the reliability (e.g. as measured by LOLP) of the grid at the pre-wind level, up to about 300 MW of peak-load gas turbines may have to be installed in grids without sufficient hydro plant. Because these gas turbines have low capital cost and rarely have to be operated, they are like reliability insurance with a low premium (Martin & Diesendorf, 1982, 1983).

It may be possible to operate an electricity grid with 40% or more of its energy generated from the wind, without highly expensive long-term storage. The small stand-alone wind-diesel system at Denham W.A. is currently generating 42% of its annual electricity output from the wind, without any storage. This has been achieved by using specially developed 'low-load' diesels, whose output can be varied down to zero or even negative load, together with a boiler into which excess wind electricity is dumped and sophisticated power electronics. Wind farms feeding into state or national grids have the advantage of spatial diversity of wind power, back-up gas turbines, which are cheaper and more convenient to operate than diesels, and the generalised back-up that the whole grid can supply. Nevertheless, as more and more wind power is connected into the grid system, it needs more and more peak-load back-up and some wind energy is wasted during off-peak periods. Therefore costs increase. Computer modelling shows that the average cost of 40% wind power penetration plus gas turbine back-up would be considerably higher than if only 8% of grid energy came from the wind (Martin & Diesendorf, 1982). However, in the real world, this cost increase would be offset to some extent by the reduced cost of wind turbines in large-scale mass production.

In most of the Australian States (though less in Victoria), it is possible to vary the output of coal-fired power stations substantially over a period of an hour or so to help follow variations in demand and in wind power. In this case, these coal power stations are said to be operating as intermediate load. Since the main changes in weather patterns and associated wind conditions tend to occur every 5-8 days or so, intermediate load stations can help handle the slower variations in the output of a large amount of wind power plant.

To be fair, before charging the additional costs of peak-load back-up and intermediate load power variations against wind power, we should also take into account the cost of backing up coal-fired stations. Although the latter break down less frequently than the wind farms suffer calms, the duration of breakdowns of coal stations is generally longer than that of wind calms. Backing up an electricity grid's coal-fired power stations requires additional base-load. In the interconnected eastern Australian grid, the National Electricity Market Management Company (NEMMCO) currently requires a total of 750 MW back-up for existing base-load plants. Whether this back-up is provided by the other coal-fired stations (the usual case) or by gas-fired stations that have to be run for quite long periods, this is expensive. An isolated electricity grid, such as Western Australia's, has to provide a much larger proportion of back-up for its fossil-fuelled base-load stations, possibly 20% or more of total grid capacity.

Thus, large blocks of wind power, with rapid response back-up either from hydro or gas turbines and slow response from intermediate load stations, can provide reliable base-load power and substitute for some coal power. This is not just theory, but is actually happening in countries that have made a major commitment to wind generation. In 2002 Denmark generated 18% of its electricity from wind power and still plans to increase this substantially. There are problems and costs with handling such large wind inputs, but they appear to be manageable. As wind capacity and generation have increased in Denmark, coal capacity and generation have decreased.

The operation of electric generation systems containing large amounts of wind power capacity is being facilitated by improved wind forecasting models, increasing geographic diversity of wind farms and improvements in the control of individual

wind turbines and wind farms. Recognising these advances, the German Government is planning for the generation of 25% of electricity by 2030.

Myth 1a: Because of wind power's intermittency, it has no value in meeting peak demands

This is a variant of Myth 1. It is often presented in a context that assumes incorrectly that peak demands are the only times that loss-of-load events occur due to insufficient generation. In practice, such events occur at other times as well (e.g. when one or more base-load power stations have breakdowns), and the only accurate way to assess their risk with different generation mixes is to perform probabilistic calculations, as done in response to Myth 1. As indicated there, the combination of wind farm and gas turbine or hydro back-up can be just as reliable as a coal fired power station. An aeroderivative gas turbine would be particularly valuable as backup, because it can be brought from cold to full power with 3 minutes. There seems to be no good reason why such a combination should be denied status as dispatchable power.

Myth 2: To maintain a steady state of voltage and frequency requires much additional expense.

In Australia, with its centralised generation and long-distance transmission lines, maintaining voltage and frequency is already an expense, even where there is no wind power plant installed. Until recently, installing a large wind farm increased voltage and frequency fluctuations and required additional equipment at additional cost. However, new types of large wind generators that are already coming on line, with variable speed drives and power electronics, can control voltage and frequency *locally* at no extra cost.

Although local fluctuations in voltage and frequency can be handled, there are still problems for the whole grid if there are big power fluctuations resulting from sudden changes in wind speed, or a sudden shut-down or start up of large amounts of wind power capacity. These can be ameliorated to some extent by installing wind farms separated by large distances in different wind regimes, and by using computer control to stagger start-ups and shut-downs of individual wind turbines in a wind farm. These precautions are already being done with new large wind farms in Europe. Then, it becomes very unlikely that the whole wind input to the grid would be lost simultaneously. Further protection can be obtained by using an aeroderivative gas turbine with a wind farm, or allocating some occasional hydro back-up, if such plant are part of the grid.

This issue is discussed in much more detail by Outhred (2003).

Myth 3. There are necessarily large energy losses in transmitting wind power to end users.

Currently about 10% of electricity sent out from centralised power stations is lost in long-distance transmission and local distribution. The transmission component of this loss is about 3% in NSW and Victoria, and is somewhat higher in the other mainland states. Distribution loss varies with locality. In some localities where there are regional population centres, the electricity from local wind farms has less transmission losses than electricity from more distant coal-fired generators. However,

electricity generated by the majority of wind farms in 2040 will have to be transmitted to the major population centres. Although losses can be significant where wind power feeds into weak transmission systems, for large wind power generation connected by extra high voltage transmission lines, losses are small.

Rather it is the capital cost of transmission lines that constrains locating such wind farms a long distance from the grid. The capital cost means that decisions on the locations of wind farms involve some degree of trade-off between high wind speed and distance from the existing grid. Wind farm proponents argue that, if State governments are serious about renewable energy and decentralised development, they will fund grid extensions to tap our best wind resources.

There is precedent for this. In the 1940s and 1950s small battery-charging wind generators were widely used on farms. This domestic wind power industry was wiped out by the spread of the (then) heavily subsidised transmission and distribution lines into rural areas, carrying electricity from centralised coal-fired power stations. More recently Victorians funded an expensive transmission line from the power stations of the Latrobe Valley right across the state to the ALCOA aluminium smelter at Portland¹⁶. The Murraylink (Vic – SA) interconnector, which provides increased access for NEM generators into the SA market, has been given regulated status and will be paid for by Victorian and South Australian electricity customers. The Business Council for Sustainable Energy argues that network access principles should be applied in a consistent manner to both incumbent and new generators. All generators should receive distribution and transmission augmentation up to a pre-determined level that reflects the benefits that customers receive. This should form part of the regulated cost recovered from customers

Further information on wind power is available from the websites of Australian, US, British and Danish Wind Energy Associations: see www.auswea.com.au, www.awea.org, www.bwea.com, www.windpower.dk.

7.3. Solar heat

Solar energy, collected with either flat-plate or evacuated tube collectors, is an established commercial energy technology for heating water to temperatures below 100°C. When solar energy is collected with concentrators, which are more expensive than flat-plate collectors, it can be used for producing low-temperature commercial and industrial heat for a variety of purposes. In this case there are several pilot plants in Australia and a niche market is opening up. With more intense concentration of sunlight, still higher temperatures can be achieved and electricity can be generated, as discussed in Section 7.6.

Solar hot water

Domestic sales of solar water heaters (SWH) have been growing by more than 30% over the last two years due principally to MRET. Sales of SWH are currently running at 36,000 units per annum which is 5% of total water heater sales in Australia.

¹⁶ This is a separate subsidy to the ongoing subsidy paid by Victorian electricity consumers on electricity purchased by the Portland aluminium smelter – see Turton (2002).

Hot water accounts for 27% of residential energy use. Our principal scenario for 2040 assumes that essentially all residential hot water in mainland Australia is provided either by solar or, if the roof is shaded or building is high-rise, by electric heat pump. Where natural gas is available, it is assumed that gas-boosted solar systems are used on half the rooftops and solar electric or heat pump systems on the other half¹⁷.

According to SEDA's hot water cost calculator on the Energy Smart Website, www.energysmart.com.au/les/, for an additional investment of \$800-\$2,100 above the price of a conventional electric hot water system, a solar hot water system installed in NSW can pay for itself in approximately 5-10 years, depending on a household's water consumption and the strategy chosen for boosting. The solar hot water system boosted by electricity and the electric heat pump system pay for their additional up-front costs the fastest. Although it is more expensive, the solar gas system reduces greenhouse gas emissions to a much greater degree than solar-electric or heat pump (although this is not shown in the calculator) and its total capital plus operating cost is still less than that of conventional electric after 10 years.

At present the main disadvantages of solar hot water are its high up-front cost, the very low cost of off-peak electricity used by standard electric water heaters, the lower price of standard water heaters and the situation that some Councils require planning permission to install solar hot water, but not its competitors.

As in the case of photovoltaics (see below), there are two approaches to address the up-front cost of solar hot water. First is to produce low-cost solar hot water systems by moulding them from plastic and combining the collector and tank into a single unit. A commercial example is the Solco Industries system, for which the compact manufacturing plants have been exported to tropical developing countries for decades. The Solco system is now being sold in Australia. Another plastic system, based on similar principles, is under development by Gough Industries.

Solar heat at temperatures above 100°C

The second approach is to produce more efficient but more expensive systems than the traditional flat plate solar collector. Since 2001 Solahart has been manufacturing such a system based on evacuated tubes originally developed at the University of Sydney. It works in both hot and cold climates and can generate heat at 150°C or more. Therefore, it is not limited to producing residential hot water, but can also be used in space heating and in industrial applications such as food processing, desalination and brewing, which require large volumes of very hot water, and solar air conditioning and refrigeration that require the production of temperatures above 150°C.

CSIRO has developed a hybrid energy system, that uses solar heat collected with a paraboloidal dish developed by Solar Systems Pty Ltd, to convert natural gas into a fuel with higher energy content and higher economic value. The process is known as 'reforming' natural gas. The gas is combined with steam to form a 'synthesis gas' which is a mixture of carbon monoxide and hydrogen. This gas can either be used as it is, or further upgraded into hydrogen and CO₂, followed by recovery of CO₂ in a

¹⁷ Gas-boosted solar hot water systems are much more efficient in terms of greenhouse gas emissions, but are considerably dearer than electricity-boosted or heat pumps systems.

concentrated form, as required for a subsequent CO₂ disposal process such as geosequestration. For further information see <http://www.energy.csiro.au/factsheets/solarthermal.htm>.

7.4. Hydro-electricity

Hydro generation currently represents over 90% of Australia's existing renewable electricity generation capacity with total energy production of 16 TWh (60.4 PJ) per annum, about 8% of Australia's total electricity generation. Most is generated from large dams in the Snowy Mountains Scheme near the NSW/Victoria border, from Southern Hydro's power stations in Victoria, and in various schemes in Tasmania. The International Hydropower Association (2003) estimates that for Australia only 49% of technically feasible hydropower has been developed. However, strong and consistent public opposition has made it unlikely that any more large dams will ever be built. Nevertheless, there is potential for increasing the TWh contribution from hydro-electricity through maintaining and refurbishing existing assets.

Existing hydro generation assets are old, on average 45 years old. The hydro-electricity industry states that, in a competitive electricity market, there are significant pressures on maintaining the existing output and that with ageing assets this task is a big challenge. Hence, the industry seeks incentives under MRET to maintain the existing output and deliver the expected amount in 2040.

This would stimulate the hydro power industry in a number of ways:

- changing water storage management practices so that output is increased;
- improving the efficiency of the way stored water is used to increase output and also plant capacities (i.e. ability to meet peak demands);
- upgrading and refurbishing turbines, generators and other plant to increase output; and
- constructing new hydro plants, such as micro and mini hydro, and adding generators to existing dams and structures.

The industry estimates that as a result of such stimulus the efficiency of existing plants could be increased by 6% on average and capacities by up to 30%. To enable MRET to assist existing hydro as well as new renewable electricity sources and solar heat, we recommend in Chapter 11 a large increase in MRET.

Australian Governments are investigating the potential for water trading schemes in a number of Australian states. Such schemes will put a true value on water at different locations, thus encouraging users of this precious resource to optimise water releases for both irrigation and energy production.

In the electricity supply mix of our principal scenario for 2040, we assume that Australia's hydro-electric generation has increased by 10% over that of 2001.

7.5. Photovoltaics (PVs)

At the end of 2002 the total capacity of PV installed in IEA countries was 1334 MW and its rate of growth about 30% p.a. over the past 5 years. Australian installed

capacity at the end of 2002 was 39 MW. PVs are one of the most promising renewable sources of electricity, but also currently by far the most expensive.

They are promising because:

- there has been rapid progress made over the past two decades in R & D, improving manufacturing processes, reducing costs and establishing small but rapidly growing niche markets;
- PVs can be readily installed in a modular fashion on rooftops and integrated with building envelopes near electrical loads. The total potential capacity far exceeds Australia's current electricity demand;
- PVs require very little maintenance, apart from occasional cleaning and replacement of the inverter once in their lifetimes, and so are highly suitable for ordinary households.

They are expensive because of the costs of PV modules, balance of system (inverter to produce AC from DC electricity, mounting, meter, cabling and accessories) and installation, and because of their low capacity factors (see below).

They can be used in three principal ways:

- installed on rooftops at the points of use where they have to compete with retail electricity prices;
- installed as small grid-connected power stations more distant from consumers, where they must compete with the generation costs of conventional power stations. In this case their land requirements and maintenance costs (for tracking systems) are larger than for fixed household systems, but still relatively small.
- installed as stand-alone power supplies with battery storage, or in hybrid systems with diesel or petrol generators as back-up, for homes and farms in more remote areas, and industries and infrastructure in niche markets in many locations (e.g. telecommunications, telemetry, beacons, public lighting, portable signs, water pumps).

The potential for the third category of use is very small in terms of its potential contribution to Australia's greenhouse gas reductions, because the vast majority of Australians are connected to the grid. However, in terms of industry development, the off-grid market offers about 500 MW of peak and billions of dollars of value and is therefore an excellent means of building up the industry (Blakers and Diesendorf, 1996). At present excise exemptions for rural diesel users and cross-subsidies on the price of rural grid electricity are undermining PV's potential in rural and remote areas.

The future of PVs in the first two categories of use depends critically upon whether the price reductions of the past 20 years can be continued into the future. Currently, PV modules in bulk cost about US\$2.7 per peak watt, having declined from about US\$20 per peak watt in 1981, using fixed year 2000 currency. Whole PV systems connected to the grid (i.e. no batteries) cost US\$6.5-8.1 per peak watt if less than 10 kW and US\$5.4-7.1 if greater than 10 kW. A major international study (Music FM, 1997) suggests that, if global production could be increased to 500 MW peak per annum, the cost of PV modules would decline to below 1 ECU per peak watt (or approximately US\$1 per peak watt). The study focuses on conventional crystalline silicon PV modules. Strong targets established for PV in Japan, Germany and the US, that are supported by domestic policy measures, are underpinning the rapid growth

that has been observed over recent years (over 35% per annum) with prices falling by 18% in real terms with every doubling of installed capacity.

Two Australian PV experts from different R & D groups have reservations about this decrease in price continuing at the current rate. Martin Green (2003) from the University of New South Wales, supported by Peter Lawley from Pacific Solar (personal communication, 2003), argue that current bulk wafer and ribbon approaches are too material-intensive for this to occur. They expect the rate of cost decline to slow, as indeed it has for wind power. Green (2003) suggests that shifting to 'rugged' thin films will be required to achieve the US\$1/watt target. He points out that thin films are cheaper than bulk silicon for a given production volume and that this suggests a greater potential for low costs in the long term as production volume increases. Andrew Blakers from the Australian National University also believes that technological innovation, possibly Sliver[®] Solar Cells¹⁸, will be required to achieve the target. This means that the timescale for achieving the target and the risk of not succeeding may both be greater than expected in the Music-FM study.

Even if this target is achieved, PV systems are likely to be still one of the most expensive sources of electricity. This is because the module cost is only one component of the total system cost, and because the capacity factor¹⁹ is quite small, taken to be equal to 15.8% in the MRET Zone 3 which includes Sydney, Brisbane, Perth, Adelaide and Canberra. Although the MRET value is a little below optimum values that are technically possible (0.17 for Sydney), Lawley argues that it takes into account non-optimal installations and gradual reductions in output with PV module age.

Other significant cost components are the inverter, which will have to be replaced once or twice during the expected 25 year lifetime of the system, installation cost, quite significant on rooftops, and mark-up between wholesale and retail prices. Accepting the US\$1/watt target for PV modules, assuming that inverter prices will decline to A\$1/W under mass production, that two inverters will be required over the system lifetime, that installation price is about A\$1/W, and using levelised annuity over 25 years at 5% real discount rate²⁰, gives a projected economic price in 2003 Australian currency of about 19 c/kWh for rooftop systems. In the case of PV power stations we use 8% discount rate and obtain a price of 18 c/kWh.²¹

The rooftop price of 19 c/kWh is only a few c/kWh above current retail prices of electricity for small business consumers in several capital cities (15-17 c/kWh) and (cross-subsidised) rural electricity prices in several states (15-19 c/kWh), and so we consider in our scenarios that a large fraction of this market will have PVs in 2040.

¹⁸ The Sliver[®] Solar Cell uses one tenth of the silicon used in conventional solar panels while still matching power, performance and efficiency. Origin Energy has announced December 2003 that construction of a manufacturing plant for these cells is under way in Adelaide and that the cells will be on the market in early 2005.

¹⁹ Average annual electrical power output from the inverter divided by peak or rated power, usually expressed as a percentage.

²⁰ We have used a 5% discount rate for residential PVs, because it is close to a home mortgage rate and therefore seems more appropriate for this case. If we had used 8% (as we have done for all grid-connected power stations) the price of residential PV electricity would become 25 c/kWh.

²¹ Installation and maintenance are cheaper than in the residential case.

However, 19c/kWh is far above current residential electricity prices (typically around 11-13 c/kWh) in capital cities other than Darwin (16 c/kWh). (ESAA, 2003).

One way that PVs could possibly come close to competing in the residential electricity market of most cities is for energy retailers to supply consumers with time-of-day meters and introduce peak-load pricing²². There is also potential for further reduction in installation, retail and distribution costs, beyond the levels assumed above. Retail outlets could expand as grid-connected PV becomes more like other mass marketed white goods (including air conditioners). Our scenarios assume that these changes have occurred by 2040 and as a result the gap between conventional grid electricity and PV electricity has been reduced to the extent that a small but significant fraction of urban residential consumers install PVs on their roofs.

Since PV power stations, located at a distance from consumers, must compete with conventional power stations and much cheaper renewable energy sources such as biomass and wind power, their prospects do not appear to be promising in economic terms. Their main hope is to be high-value providers of peak power. To do this, they would have to be granted value for meeting the summer peaks with a high degree of probability. Some utility engineers may argue that PV power stations would need the equivalent of overnight electrical storage, which is currently expensive. However, we assume conservatively that cheap electrical storage will *not* be available by 2040, that in future the height of summer peaks will be controlled by a price mechanism and therefore that PV power stations will make a small but significant contribution to summer peaks without overnight storage.

7.6. Solar thermal electricity

While PV has growing commercial niche markets, solar thermal electricity (STE) exists as a few experimental and demonstration power plants of various types scattered around the world. While PV currently seems most suitable for rooftop supply in competition with retail prices for small business and rural areas, STE is more suitable for power stations. Nevertheless, STE has a potential advantage: to become a high value source of peak-load electricity, since in that role it only needs thermal storage, which is generally less expensive than electrical storage. A new STE plant to be built in Spain will use molten salt storage at a low cost (see below). So, there is the possibility of complementary roles being played by STE and PV.

Several different types of solar collector are used in STE and indeed can also be used by PV:

²² The growth in air conditioner sales across most states in Australia is significantly increasing peak power demands. This not only requires considerable investment in additional peak-load generation but also considerable network investment. As an example, network businesses in NSW expect to spend \$5 billion over the next five years to meet growing power demands. Power produced from a PV system has a good correlation with peak summer power needs. Unfortunately consumers do not pay for the full costs that they impose on the electricity system. The Charles River Associates report for Integral Energy, dealing with the impact of air conditioning on Integral Energy's network, identified that customers without air conditioners were subsidising customers with them by some \$80 to \$100 million per annum. The cost to add network related to peak demand was found to be \$91 per kW per annum (page 26 of the report). The contribution of customers with air conditioners was about \$1 per annum.

- parabolic trough;
- paraboloidal dish;
- an array of flat mirrors focusing on a 'power tower';
- others, such as Fresnel focusing.

The largest collection of STE power stations in the world is rated at 354 MWe, is based on parabolic trough collectors, with sections of these stations having operated for up to 15 years in southern California. After a long period of neglect by governments world-wide, there are now improved prospects of an increase in demonstration STE plants, because it is being included under solar feed laws and renewable energy portfolios in several places overseas. Spain is paying Euro 0.12/kWh plus about Euro 0.04/kWh wholesale electricity price for this source of electricity. In Germany STE is to be included under the Solar Feed Law in 2004; in the USA, Nevada and probably New Mexico and California will include STE in mandatory renewable energy portfolios.

The University of Sydney's approach

Much of the following is based on an interview in September 2003 with Dr David Mills of Sydney University, where a new company, Solar Heat & Power, has been established. For Australia, Mills proposes a two-step process for industry development of STE:

Step 1: Further experience and acceptance of the technology are gained by installing it to preheat feed-water going into coal-fired power stations. Feed-water is the water that is heated by burning coal to produce steam to turn the turbines. Preheating by solar energy will save a little coal. Mills estimates that the maximum contribution per power station is about 7% of energy generation, provided land is available. Because there is no need for storage and because the land, owned by the generator, is free, the cost of electricity is quite low, estimated to be 5-6 c/kWh. Taking into account the area of suitable land available close to power stations, Mills estimates that there is a niche market in Australia equivalent to about 1000 MWe.

The first of these plants is currently (October 2003) being installed by Macquarie Generation at Liddell Power station, which has an installed capacity of 2000 MW of coal power. The land area and funding are limited, and so the solar contribution has capacity 35 MW, with capacity factor 14%. The solar collectors are mirrors that are almost flat, are set up close to the ground in 300 m lines, and are lower in cost than collectors used overseas in STE plants. These collectors cost only \$65/m², compared with solar hot water collectors at \$200/m². In general, this system covers one-third the land of ordinary trough collectors, because of less shading between lines of collectors.

Step 2: If thermal storage can be achieved at low cost, Mills proposes that large STE systems could be established in high-insolation regions where there are large flat inexpensive land areas and rural load centres near the end of transmission lines. Possibly suitable sites are near Moree and Cobar, NSW, each town being at the end of a 132 kV transmission line. With a big array, a steam turbine designed for pressurized water reactors could be purchased relatively cheaply. The potential size of the total Australian STE resource near the electricity grid has not been estimated. The costs of

storage in molten salt are currently about US\$25 of capital cost per daily kWh stored²³.

Because this is new technology, we only include Step 1 in our principal sustainable energy scenarios to 2040. However, it is clearly one of the potential big resources for the new technology scenarios.

The Australian National University's approach

Another STE technology, based on paraboloidal dish collectors, has been developed at the Australian National University. The collector produces steam which generates electricity by means of a steam engine/generator. The largest version of this system, the 'big dish', has an area of 400 m² and generates peak electric power of about 50 kW (Lovegrove et al., 2003a).

Another team at ANU has developed a thermochemical storage system based on the dissociation of ammonia. This storage could be used either with a paraboloidal dish or a parabolic trough collector to produce 24 hour power.

Cost estimates for both the steam version and the ammonia storage version under future mass production are both about 15-16 c/kWh (Lovegrove et al., 2003b). If this could really be achieved with storage, the system would be competitive with the real cost of rural electricity both on-grid and off-grid, and with peak-load residential and small business electricity in urban areas, provided time-of-day pricing is introduced.

7.7. Other renewable energy technologies

The following renewable energy technologies are either limited in terms of siting, or are not sufficiently developed to permit good estimates of future costs. Therefore they are not part of our principal sustainable energy scenario, which is based on small improvements to existing technologies. Nevertheless, some could possibly become major contenders in a future energy mix.

7.7.1. Hot dry rock geothermal

Heat is generated by the decay of radioactive isotopes in granites located 3km or more below the Earth's surface. The heat inside these granites is trapped by overlying rocks which act as an insulating blanket. The heat is extracted from these granites by circulating water through them in an engineered, artificial reservoir or underground heat exchanger, bringing steam to the surface. Standard geothermal power stations (e.g. as located in New Zealand and California) convert the extracted heat into baseload electricity by using steam turbines.

Hot dry rock (HDR) geothermal energy relies on existing technologies and engineering processes such as drilling and hydraulic fracturing, techniques established by the oil and gas industry. HDR is 'firm' base-load power and is relatively

²³ This rather confusing method of measuring storage cost means that, if the lifetime of the system is 20 years, the actual energy stored 'per daily kWh' is 20 x 365 = 7300 kWh, and so the cost of storage in more familiar units becomes US\$25/7300 = US 0.34 c/kWh.

environmentally benign, as it does not produce greenhouse gases. However there are concerns relating to handling of contamination built up in circulated water.

Australia's potential HDR resource is very large, but at this stage it is uncertain whether a large resource is located near the electricity grid. The cost of proving the potential by drilling is significant and the cost of a demonstration HDR plant is likely to be higher than most direct solar and biomass power demonstrations.

An Australian public company, Geodynamics Ltd, has secured two HDR geothermal tenements in the Hunter Valley in New South Wales and two in the Cooper Basin in South Australia. The company's business plan is based on three stages, (i) development of an underground heat exchanger (currently in progress); (ii) development of a demonstration HDR geothermal power plant (10-15MWe) and (iii) a commercial scale HDR geothermal power plant capable of generating hundreds of megawatts. (For further information see www.geodynamics.com.au)

7.7.2. Conventional tidal power

This source usually involves the construction of a large dam across an estuary and the generation of electricity from both incoming and outgoing tides. The power output is predictable, although it is not constant in time. Tidal power can have huge impacts on biodiversity in estuaries, similar to the impacts of large dams across rivers. Sites with sufficiently high tides and low potential environmental impact are scarce globally. A 240 MW tidal power station has been operating since 1967 at La Rance, France. Several other tidal power stations are being considered, including the Severn project in England.

In Australia the main potential site is in the north-west, very remote from the main centres of electricity demand. However, if a pipeline is eventually built to bring natural gas from the North-West Shelf to the eastern States, it could make sense to design it to a standard where it can carry a large percentage of hydrogen produced from tidal power. A proposed tidal project at Derby is understood to have more recently run into problems with environmental impacts on mangrove habitats and there has been some discussion about a new project involving offshore islands.

7.7.3. Ocean currents

This is an entirely different approach from the 'large dam' approach of conventional tidal power. It involves immersing turbines under water in powerful ocean currents that may or may not be tidal. So, the energy conversion system has more in common with wind power than conventional tidal and its environmental impact is very low. Although the speeds of ocean currents are generally less than those of wind, the density of water is much greater than that of air, and so the net effect is that ocean currents can provide the same power output with smaller turbines than wind power. Ocean currents are a predictable source of power, but not always constant in time. An experimental 300 kW tidal current turbine is being installed about 1 km off the coast of Devon, UK.

To the best of our knowledge, there has been no survey of the potential resource in Australian waters. As in the case of wind power, proximity to the main centres of electricity demand would be an advantage.

7.7.4. Wave power

There are several different technologies proposed for the conversion of wave energy into electricity, including:

- oscillating air columns that drive air turbines;
- tapered channels that focus incoming waves into a reservoir on cliffs. Electricity is then generated by running falling water through a standard hydro-electric turbine. Appropriate sites are rare;
- floating vanes or ‘ducks’ that oscillate in the waves, driving turbines directly.

Energetech Australia Pty Ltd (www.energetech.com.au) received a grant from the Australian Greenhouse Office to construct a 300 kW wave power generator on the breakwater at Port Kembla. The system uses a parabolic wall to focus wave energy into the column. It then uses an air turbine and so has features of both the first two types of wave power converter.

Ocean Power Technologies (Australasia) Pty Ltd has built a 20 kW pilot scale prototype PowerBuoy™, to be moored to the sea-bed several km off the Victorian coast near Portland. The buoy floats underwater and its up-and-down motion drives a hydraulic cylinder and thus generates power. A ‘farm’ of many such buoys would be required to generate sufficient electricity to meet the cost of transmission and the buoys themselves.

Because the best wave power potential lies in the deep ocean, the transmission of energy from such sites to the user could be quite expensive. If an underwater transmission line is used, there is a trade-off between wave energy available and the cost of transmission.

Other problems encountered in wave power include survival in extreme wave conditions, operation of equipment in salt water environment and impact on navigation.

7.7.5. Solar chimney/tower

Enviromission Ltd has proposed a 200 MWe system to be built near Mildura, Vic. (see www.enviromission.com.au). A pilot 50 kW system operated successfully in Spain for 7 years in the 1980s. The full-sized system would comprise a circular greenhouse of diameter 5 km which warms air that then rises through a hollow cylindrical tower 1 km high located at the centre of the greenhouse. As the air is drawn into the tower, it passes through air turbines that generate electricity. Under the greenhouse is thermal storage in the form of rocks or water in tanks, and so the tower can operate for 24 hours. According to different press reports, its expected energy generation is either 500 GWh or 650 GWh per year, corresponding to capacity factors of 29% and 37%, respectively. The first capacity factor is about the same as that of a wind farm at a good site. But it is unclear whether the output and the estimated cost of \$700 million assumes thermal storage. The electricity generated by solar tower will be much dearer than from wind power located at a good site, but possibly cheaper than electricity from PV or conventional STE.

The greenhouse will occupy quite a large area of land for the amount of electricity generated and the tower could be intensive in its use of materials. Nevertheless, the solar tower could be an option in areas that are not windy if the cost reductions envisaged for PV and STE do not eventuate.

7.8. Advanced energy storage

In our principal scenario, which achieves a 50% reduction in greenhouse gas emissions from stationary energy by 2040, natural gas and biomass energy are the main energy sources and the ‘intermittent’ renewable energy sources, wind and direct solar, together contribute almost 30% of electricity. Under these circumstances, we find that additional energy storage is unnecessary, since the fluctuations in renewable power are compensated for by backup from gas turbines and hydro electricity and from intermediate load natural gas and biomass-fuelled power plants.

However, to obtain much larger greenhouse gas reductions than envisaged in our 2040 scenario, it may be necessary to develop energy supply systems in which the major contributions come from direct solar energy and wind power. Then low-cost electrical and thermal storage become essential. At present electricity storage is either commercially available at high prices, or still under development, and cheap commercial storage of solar heat is limited to water storage at temperatures below 100°C. This Section reviews some existing and potential storage technologies for the future.

To store effectively high-quality energy forms, such as electrical and mechanical energy, requires low losses while in the store (called ‘standing losses’) and low losses in transfer to and from the store. The latter is generally measured as ‘cycle efficiency’ on a scale of 0 to 1, where cycle efficiency = 0 means that all the energy transferred to store is lost, while cycle efficiency = 1 is the ideal but unachievable case when no energy is lost in transfer. Cycle efficiencies are less important when storing low-quality energy (i.e. heat at low temperatures). The other important parameters are the energy stored per kg and per cubic metre of the store. Several different forms of energy storage, their status and properties are summarised in Table 7.2.

Table 7.2: Properties of different forms of energy storage

Storage form	Properties and comments
<i>Conventional fuels</i>	
Coal	Long-term storage of black coal; no standing loss; energy density of NSW black steaming coal 23,000 kJ/kg & 22 GJ/m ³ ; Vic. brown coal 10,000 kJ/kg not stored after mining.
Crude oil	Long-term storage; no standing loss; energy density 42,000 kJ/kg, 37 GJ/ m ³ .
Natural gas	Long-term storage, no standing loss, but significant energy use in compression for liquefaction or for transportation in pipelines. Energy density is 51,000 kJ/kg and at standard atmospheric pressure (STP) is 38 GJ/m ³ . However, can be compressed to hundreds of atmospheres or liquefied at -162C at STP to increase the energy stored/m ³ .
Dry wood	Long-term storage; low standing loss; energy density 20,000 kJ/kg, 10 GJ/ m ³ .
<i>Electrical & mechanical energy</i>	
Lead-acid battery	In commercial mass production for decades. Significant standing loss; energy density 40-140 kJ/kg & 100-900 MJ/ m ³ ; cycle efficiency 0.7-0.8; short cycle life.
Nickel-cadmium battery	Energy density about 350 kJ/kg & 350 MJ/ m ³
Vanadium redox battery	Developed at University of New South Wales and now in small-scale commercial production. No standing loss; long cycle life; energy density 72-108 kJ/kg & 90-144 MJ/m ³ ; cycle efficiency 0.8-0.85. Very expensive at present, but there are prospects for reduction.
Flywheel	Storage period of several minutes; cycle efficiency 0.95 for advanced carbon-fibre flywheels under development overseas, which have energy density >200 kJ/kg & >100MJ/m ³ .
Storage dams and pumped hydro, 100 m head	Large dams provide long-term storage (seasonal or longer) with low energy density 1 kJ/kg & 1 MJ/m ³ ; and cycle efficiency 0.65-0.8. Further large dams unlikely in Australia because of environmental constraints.
Compressed air	Long-term storage; energy density about 15 MJ/m ³ ; cycle efficiency low at 0.4-0.5
Methanol	Long-term; no standing loss; energy density 21,000 kJ/kg, 17 GJ/m ³ .
Ethanol	Long-term; no standing loss; energy density 28,000 kJ/kg, 22 GJ/m ³ .
Hydrogen, compressed gas	Long-term storage; energy density 120,000 kJ/kg & 1.9-2.7 GJ/m ³ at pressures of 20-30 MPa; cycle efficiency 0.4-0.6
Hydrogen, liquid	Long-term storage; energy density 120,000 kJ/kg & 8.7 GJ/m ³
Hydrogen, metal hydride	Long-term storage; energy density 2,000-9,000 kJ/kg & 5-15 GJ/m ³
<i>Heat</i>	
Thermo-chemical	E.g. closed loop thermochemical energy storage system using ammonia, being developed at Australian National University, see http://solar.anu.edu.au/ . Long-term; high energy density in terms of both mass and volume and high cycle efficiency.

Table 7.2, continued

Phase change materials	Commercially available products include those based on paraffins and waxes (see www.rubitherm.com) and those based on hydrated salts (see www.teappcm.com). They can be used to store heat at many different temperatures, from below 0°C to above 100°C. The best products are environmentally harmless, stable (i.e. have no standing losses) and have low transfer losses.
Water, 100°C → 40°C	In commercial mass production for solar hot water. Overnight storage; energy density 250 kJ/kg & 250 MJ/m ³ ;
Rocks, 400°C → 200°C	Overnight storage; energy density about 160 kJ/kg & 430 MJ/m ³
Molten sodium	Overnight storage for high-temperature solar heat. Standing loss overnight from well-insulated tank about 1%; energy density about 900 MJ/m ³

Sources: Partly Sørensen (2000), who gives a detailed scientific discussion in his Chap. 5, partly personal communications from Australian technical experts, and partly Web searches.

The conventional fuels, coal and oil, have very high energy densities, both in terms of mass and volume occupied. Methanol and ethanol are nearly as high. They can both be produced from biomass. Compared with coal, dry wood has one-third the energy density per kg and one-quarter the energy density per m³. Hydrogen in liquid and metal hydride forms is next. Commercial gaseous hydrogen containers at present use pressures of 20-30 million Pa, corresponding to energy densities of 1900-2700 MJ/m³, which is less than 7% of oil's. Recent research suggests that it may be possible to increase the pressure to 70 MPa by using high-strength composite materials such as Kevlar fibres. All the other forms of energy storage have much lower energy densities per cubic metre and so are unsuitable for small vehicles (i.e. cars and motor bikes) unless they are much more fuel efficient than those of today. However they may be used in large vehicles, such as trucks and buses, and stationary sources of energy.

Lead-acid batteries have low energy density, medium cycle efficiency, significant standing losses and short lifetimes. Vanadium redox batteries have low energy density, high cycle efficiency and are potentially cheap in mass production, with cost per kWh declining as the storage capacity increases. At present they are in the early, small-scale stages of commercial production and are very expensive. Zinc bromine batteries are similar in some ways to vanadium redox and seem to be progressing through commercialisation a little more quickly. A load-levelling Zn-Br plant is under trial in Nunawading now.

Ideally, flywheel storage would be used to back up wind farms over periods of up to an hour. This would significantly reduce the output variability of wind farms, and provide time for conventional intermediate-load power plant to be brought on line in the event of unexpected drop-outs. But, because of costs, flywheel storage is mainly limited to smoothing short-term fluctuations (over several minutes) in the output of wind turbines in order to improve power quality. It was planned to install flywheel storage with the existing wind-diesel systems at Denham W.A. and the Australian Antarctic base at Mawson, but at the time of writing (October 2003) they are not installed because of technical problems. Flywheels may be unnecessary for short-term storage anyway, because having a diversity of sites within and between wind farms will smooth fluctuations on the timescale of a few minutes, while gas turbines and

hydro-electricity can provide fast response back-up on timescales from minutes to an hour.

7.9. The 'hydrogen economy'

Hydrogen is potentially a means of storing and transporting renewable energy on a large scale. It is of interest to both fossil fuel and renewable energy proponents, because when it is burned in a turbine or converted into electricity by means of a fuel cell, its only 'waste' product is water. So, it is a clean fuel at the point of use. However, hydrogen can be produced from coal, natural gas or biomass by chemical means, or from the electrolysis of water using electricity generated from fossil fuels or renewable energy. If it is produced from fossil fuels, it is not low in greenhouse gas emissions or local pollution at the place of production.

Hydrogen has a very low energy density in terms of volume. This means that, in order to store and transport hydrogen, it has to be compressed at high pressures. This could take up to 10% of its internal energy. Hydrogen can only be liquefied at very low temperature and this could take up to 30% of its internal energy, and so liquefaction does not look promising.

Hydrogen pipelines exist in Europe and the USA. These generally have a larger diameter than a natural gas pipeline and have to hold higher pressures. Therefore the cost of transporting hydrogen in pipelines is higher than that of natural gas. However, in the transition to a hydrogen economy, some hydrogen can be mixed with natural gas and transported through natural gas pipelines. As the fraction of hydrogen in a pipeline is increased, it may be possible to contain it by putting liners within existing natural gas pipelines. For transporting 100% hydrogen, special hydrogen pipelines are required. The existing natural gas infrastructure is useful for this transition, even if the pipes themselves cannot be used, because it already has established easements and access points, making up a significant part of the cost of the pipeline.

Hydrogen's low energy density, and the high energy inputs required for its use, have led some authors to propose that methanol may be a better means of storing and transporting renewable energy. Ethanol, bio-oils and ammonia may also have significant roles.

7.10. Fuel cells

A fuel cell is an electrochemical system that converts hydrogen and oxygen into water, producing electricity and heat in the process. This is the reverse of a battery process. In a sustainable energy system the hydrogen has been previously produced by renewable sources of energy and the oxygen comes from the air. By using a fuel cell the hydrogen can be converted into electricity, when and where the power is required. Because hydrogen is difficult to handle, it may actually be transported and stored in the form of biogas (mostly methane) or methanol. Then, by means of a reformer, these fuels can be converted into hydrogen and fed into the fuel cell. This is not entirely satisfactory, because the reforming processes uses energy and produces impurities and CO₂, as well as hydrogen. Fortunately several types of fuel cell can take methanol directly as the feedstock, without reforming it first into hydrogen.

Most fuel cells operating today use natural gas as the fuel and pass it through a reformer at the point of use. In terms of greenhouse gas emissions and local pollution, this is cleaner than using coal-fired electricity. But, in the long run, producing the feed by means of renewable sources of energy is essential for a sustainable energy system.

Fuel cells may be used as stationary sources of energy, to power a home or an office or even a laptop computer, or in vehicles. Fuel cells that are currently available are either prototypes or in very small-scale commercial production.

7.11. Transmission and distribution infrastructure

An electricity supply system, comprising one third natural gas and more than one-half biomass and wind energy, in the form of many distributed power stations, will require a somewhat different transmission and distribution system than one comprising a few large centralised power stations based on coal.

The sheer quantity of natural gas used will entail new natural gas pipelines, such as the proposed Papua New Guinea to south-east Queensland pipeline and North-West Shelf to Cooper Basin and hence to the eastern States, which would be a major undertaking costing billions of dollars. Such infrastructure will be required under almost any long-term energy scenario. Another energy source to be transported by pipeline is coal seam methane. Combined cycle natural gas power stations are generally smaller than coal-fired power stations (typically hundreds of megawatts rather than 1-2 thousand megawatts) and cogeneration by natural gas involves a huge range of sizes from hundreds of megawatts down to kilowatts. Therefore, much greater flexibility in siting natural gas power stations is possible, but this requires investment in pipelines.

Biomass power stations of up to 20 MWe, scattered through Australia's wheatbelt and elsewhere, may require additional distribution lines, with voltages in the range 11-33 kV, to feed the electricity to transmission lines and hence to the cities where most Australians live. Large wind farms located at excellent sites that are remote from cities, such as Eyre Peninsula in South Australia, north-west Tasmania and parts of the Victorian coastline, may require dedicated transmission lines.

As indicated in Section 7.2 there is a case for customers funding the additional electricity transmission and distribution so as to be consistent with the treatment for existing coal fired generators. It must also be considered that the reduction in energy demand resulting from efficient energy use (see Chapter 6) will avoid substantial investment in new transmission and distribution lines.

7.12. Projected costs of electricity

For some of the principal renewable energy technologies, the average costs of electricity projected by ABARE for 2020 and the Clean Energy Scenario project for 2040 are compared in Table 7.3. For new renewable energy sources our 2040 estimated prices are mostly greater or equal to those projected by ABARE. However, we are being deliberately cautious, and present average prices for much larger capacities than those conceived of by ABARE. This entails that the average site is less favourable than that of ABARE.

Table 7.3: Projected average costs^a of generating electricity from various technologies

Technology	ABARE ^b 2020 (c/kWh)	This study 2040 (c/kWh)
Biomass co-fired with coal	2.3	3
Bagasse, new	4.2	5 ^c
Other crop residues (e.g. wheat stubble)	N/A	5.0
Forest residue and wood waste	5.9	N/A
Wind (Tasmania)	2.8	N/A
Wind (other states)	3.5	5.5 ^d
Energy crops ^e	9.2	9.0
Hydro, small	4.8	5.0
Hydro, large	7.8-8.2	Not costed ^f
Solar thermal electric	9.7	19.0 ^g
Photovoltaics, residential	22.0	19.0
Photovoltaics, grid connected	20.6	18.0
Black coal ^h , IGCC (NSW & Qld) with geosequestration	N/A	10.0

Notes.

- a. Includes capital, fuel, operation and maintenance costs
- b. Short and Dickson (2003)
- c. This allows for the economic benefit of cogenerated heat to run the sugar mills.
- d. Australian average with 20% penetration into grids
- e. Does not include environmental credits (e.g. for reducing salinity and erosion) and economic credits (from sale of co-products) which we envisage will reduce the price to 6 c/kWh or less.
- f. Costs of large hydro vary greatly, depending upon site.
- g. Grid connected with dedicated thermal storage
- h. Included for comparison. Price based on IEA estimates reported in Section 8.4.

8. Present and Future Fossil Fuel Technologies

This Chapter reviews the current status and likely future development of fossil fuel technologies. It considers resources, technology development pathways, present and future costs, and limitations on deployment and operation. It is based on recent review articles, data both new and old, and interviews with several leaders in R & D and business in each of the technologies.

First, existing coal-fired power stations and possible improvements to coal burning technologies are considered. An important indicator of performance of power stations is the thermal efficiency, which is the electrical energy sent out from the power station divided by the chemical energy stored in the fuel, expressed as a percentage. The best thermal efficiencies obtained by Australian conventional black coal-fired power stations up to 2001 were about 36% (HHV).

Another important power station operating parameter is the capacity factor, which is total annual generation divided by total annual generation that it would have achieved if it had operated at its nameplate capacity for the full year, usually expressed as a percentage. Capacity factor of thermal power stations measures both performance and operating strategy. For instance, base-load power stations are operated as much as possible at full power because of high capital costs and low fuel costs. Gas turbine peak-load stations have low capital costs, are operated as little as possible because of high fuel costs, and so have low capacity factors, typically 2-10%. In the case of hydro-electric peak-load stations, there are also constraints on operation because the amount of stored water is limited. Intermediate-load stations are operated just as the name suggests and so have capacity factors falling between those of base-load and peak-load.

At current rates of consumption and export, Australia has 200-300 years of steaming coal, probably 50-100 years of natural gas (depending on the quantity to be exported) and probably only two decades of cheap oil.

8.1. Conventional (pulverised fuel) coal-fired power stations

The combustion of coal is by far the largest contributor to Australia's greenhouse gas emissions, producing 186 million tonnes of CO₂ in 2000. The vast majority of this, about 170 Mt, was emitted by coal-fired power stations. Coal is also the fuel with the highest greenhouse intensity.

With the restructuring of the electricity industry in the mid-1990s, it has become much more difficult to obtain data on the performance and costs of power stations. The following data have been collected from public sources, some extrapolated from before restructuring, and current expert opinion. Different sources use different methods and obtain different results, even disagreeing on whether electricity from black coal is dearer than from brown -- e.g. compare ACIL Tasman (2003) with SKM (2003).

A typical modern black coal-fired power station, rated at (say) 2000 MW (2 GW) and put into operation in the 1990s, has a thermal efficiency of about 36%, a capacity

factor of 75-85%, sends out about 14,000 GWh p.a. of electricity and consumes about 6 million tonnes of black coal in the process. Its greenhouse gas intensity is typically 0.85-1.0 Mt CO₂ emitted per TWh of electricity sent out. Its capital cost in 2001 Australian dollars was about \$1400/kW installed, including interest during construction. Its fuel cost is about \$1/GJ¹ or 1 c/kWh and its other operation and maintenance costs amount to about 0.39 c/kWh. With refurbishment, its operational life may be extended to about 40 years. However, since refurbishment is not included in the above costings, an economic lifetime of 30 years has been assumed. With a discount rate of 8% and 10% real and using the levelised annuity formula, the cost of electricity including all fixed and variable costs becomes 3.6 and 4.0 c/kWh, respectively.

The typical modern brown coal-fired power station, rated at (say) 2000 MW (2 GW) and put into operation in the 1990s, has a thermal efficiency of about 28%, a capacity factor of about 85%, sends out about 15,000 GWh p.a. and consumes about 19 million tonnes of brown coal in the process. Its greenhouse gas intensity is typically 1.2-1.45 Mt CO₂ emitted per TWh of electricity sent out. Its capital cost in 2001 Australian dollars was about \$1800/kW installed, including interest during construction. Its fuel cost is about 0.4 c/kWh and its other operation and maintenance costs amount to about 0.37 c/kWh. With refurbishment, its operational life may be extended to about 45 years. However, since refurbishment is not included in the above costings, an economic lifetime of 30 years has been assumed. With a discount rates of 8% and 10% real and using the levelised annuity formula, the costs of electricity including all fixed and variable costs become 3.6 and 4.1 c/kWh, respectively.

The lower capacity factors of black coal power stations compared with brown reflect the situation that the output of the former can be varied within bounds, allowing the stations to follow variations in demand on timescales of an hour or two. Thus black coal stations can be operated as both base-load and intermediate load. In Victoria, the brown coal stations are strictly base-load and natural gas stations fill the role of intermediate load.

The greatest uncertainties seem to be the magnitudes of capital costs of coal-fired power stations. There is also uncertainty about whether the usually quoted capacity factors are typical of 'normal' operating conditions or whether they reflect lifetime averages in which there may be occasionally long breakdowns in 'abnormal' years. In practice, there also will be variations in the costs depending upon how the power stations are financed – e.g. how much debt and how much equity.

Within the category of pulverised fuel coal-fired power stations, the main pathway to improvements in thermal efficiency and hence reductions in greenhouse gas emissions is to increase the steam temperature and pressure in the boilers. The first power stations with *supercritical* boilers, having steam temperature around 538°C and pressure around 24 MPa, were installed in Queensland in 2002-2003. The generators expect thermal efficiency of around 40% and greenhouse intensity of about 0.8 Mt CO₂/TWh sent out. *Ultra-supercritical* boilers, with temperatures around 600°C and pressure around 36 MPa, are beginning to be installed overseas. These have thermal

¹ One of the new coal-fired power stations commissioned recently in Queensland, Millmerran, is located inland and has considerably cheaper coal. However, because it is air-cooled rather than water-cooled, its capital cost is higher.

efficiencies of 42-45% and manufacturers claim that they will soon be able to reach 50% in the foreseeable future. However, none of these new coal-fired power stations can reduce greenhouse gas emissions to anywhere near that of today's combined cycle natural gas-fired power stations.

8.2. Combined cycle gas-fired power stations

Combined cycle power stations use a gas turbine, fuelled by liquid or gaseous fuels, to generate electricity and take the waste heat from that process to generate steam to drive a steam turbine to generate additional electricity. Because they waste less heat than conventional steam or turbine power stations, combined cycle power stations have one of the highest thermal efficiencies of all non-renewable generating plant currently available. (Cogeneration is currently the most efficient way of generating electricity and usable heat together -- see Section 8.6.) Pelican Point in South Australia is the largest Australian combined cycle power station fuelled by natural gas. Such power stations currently have thermal efficiencies around 50 – 55% -- new models are just coming onto the market with thermal efficiencies of 60% and these will become state-of-the-art by 2010. Greenhouse intensities are currently around 0.4 Mt CO₂/TWh of electricity sent out and declining. In base-load operation capacity factors should be 85-90%, i.e. slightly better than those of base-load coal. It is possible to fuel combined cycle power stations with biogas or coal bed methane.

According to Geoscience Australia (2002), natural gas reserves on 1 January 2001 amounted to 157,343 PJ, of which about 20% is economically recoverable in today's market. The gas industry is confident that the major gas fields of the North-West Shelf and in other remote locations have the capacity to supply both very large export contracts of liquefied natural gas and, as required by our clean energy scenarios, greatly expanded domestic supplies of natural gas. To utilise these fields, pipelines would have to be built to connect remote gas supplies to the existing transmission pipeline networks of the eastern States.

In addition, most black coal seams contain methane gas, naturally held within pores and tiny fractures of the coal. In Queensland and NSW there are substantial reserves of this coal-bed methane in coal seams which are too deep or otherwise considered to be uneconomic or unsuitable for mining. These gas reserves could become a substantial source of gas supply in each of these states. However, only a small fraction of the reserves is actually recoverable and most of this at a higher price than conventional natural gas. In Queensland coal-bed methane is already being produced commercially at several separate fields and is connected to the state-wide pipeline network. In NSW there is active exploration but as yet no commercial production. In both States there are plans to expand the production of this gas.

Coal seam methane must be distinguished from waste coal mine methane, which is methane extracted from coal seams during or just prior to mining. Mine safety and productivity are usually the main drivers for waste coal mine methane collection, but this methane, if not collected, is also a significant source of fugitive energy greenhouse emissions (see Section 6.7). There are projects in both NSW and Queensland which collect waste coal mine methane and use it to produce useful energy in various ways, including one that has been operating since the early 1990s in NSW, generating about 100 MW of electricity.

8.3. Integrated gasification combined cycle (IGCC) coal-fired power stations

IGCC is a combined cycle process fuelled by gasified coal. Coal is gasified by heating it in a gasifier in the presence of steam and oxygen. This produces a fuel gas made up mainly of hydrogen and carbon monoxide. The fuel gas is cleaned of impurities and burnt in a gas turbine, producing electricity, carbon dioxide and water vapour. The waste heat from the gasification process is partially recovered and used to generate steam to drive a steam turbine, thus providing a second 'cycle' to generate electricity. There are currently no coal-fired combined cycle power stations in Australia, although there are several demonstration plants overseas².

In our future energy scenarios, we consider that any black coal-fired power stations existing in 2040 will use IGCC with thermal efficiency of about 43% HHV. However, even these stations are expected to have a greenhouse intensity of about 0.7 Mt CO₂/TWh of electricity sent out. Since the gasification of coal is a low efficiency process that produces CO₂, the reduction of greenhouse intensity achieved by burning coal gas is partially offset by the emissions from gasification. The net result is that building an IGCC power station makes little sense unless it is combined with the capture of CO₂.

8.4. Geosequestration of CO₂

One technically possible way of substantially reducing greenhouse gas emissions from coal-fired power stations would be to capture the CO₂, compress it and transport it by pipeline and/or ship to a secure storage location. Capture of the CO₂ can in principle be done in two different ways:

- after the gas turbine 'cycle' in an IGCC power station; or
- after fuel combustion in a conventional (pulverised coal or natural gas) power station, by extraction of CO₂ from flue (exhaust) gas as it passes up the chimneys.

The CO₂ produced in the gasification process is more concentrated than in the flue gas and so is easier to extract.

The main option for storage of CO₂ from a large point source such as a power station is deep underground, either in depleted oil and gas fields, or in un-minable coal mines or in saline aquifers located in sedimentary rocks. In Australia, oil and gas fields will not be sufficiently depleted to be used before about 2030 and deep un-minable coal mines would not absorb the CO₂ fast enough to be effective. Therefore, the principal option for the period up to 2030 or 2040 is saline aquifers (Bradshaw et al., 2002). For secure storage suitable saline aquifers have to have caps composed of rock that is impervious to CO₂ and have no exit holes. Saline aquifers are not well mapped and the science of storing CO₂ in them is not fully understood.

The main concerns about geosequestration are:

- the amount of CO₂ that could be stored annually;
- ensuring secure storage of CO₂;

² The first full-size IGCC (253 MWe) based on coal is in trial operation in Buggenum (the Netherlands) with a thermal efficiency of about 43 %.

- the environmental and health impacts of an escape of CO₂;
- the cost.

According to a preliminary study by the GEODISC group of the Australian Cooperative Research Centre for Greenhouse Gas Technologies, the largest storage potential is in Western Australia but almost all of the biggest point sources emitters are in eastern Australia. As a result Australia only has the potential to store 100-115 Mt per year of CO₂, corresponding to 27%-31% of total annual CO₂ emissions (Bradshaw et al., 2002). Therefore geosequestration is at best a partial solution and Australia would do well to continue with and expand the development of efficient energy use and renewable sources of energy.

The risks of escape comprise the hazards of global climate change; the danger of CO₂ (which is heavier than air) filling a valley near the escape point and asphyxiating every person who is submerged in it³; and local environmental impacts on soil and waterway ecosystems. These risks can be reduced at a price.

The cost of capture and geosequestration of CO₂ from fossil fuelled power stations has been calculated by the International Energy Agency (Davison, Freund & Smith, 2001; Freund & Davison, 2002). At the rate of exchange of 1 AUD = 0.67 USD and fuel costs of 1.0 AUD per GJ of black coal and 3.1 AUD per GJ of natural gas, the estimated cost of avoiding CO₂ emissions through geosequestration is US\$45/t CO₂ (A\$67.5/t) for IGCC, US\$55/t CO₂ (A\$82.5/t) for conventional (pulverised) coal power stations and US\$45/t CO₂ (A\$67.5/t) for natural gas combined cycle. Other international studies, such as US Department of Energy, give higher costs. Therefore, it is surprising that the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) is claiming costs of only A\$10/t CO₂, without providing any published study to support this extraordinary result. Recent presentations of this claim indicate that it may only represent the geosequestration part of the costs, but not the gasification, combustion or collection of the CO₂ parts. It is unclear whether the cost of transporting CO₂ is included. However, it should be noted that these recent presentations compare the partial cost of so-called 'clean coal' electricity with the full costs of gas fired and renewable sources of electricity.

Continuing with the IEA calculations, the above costs of geosequestration translate into electricity costs in Australian currency of about 10 c/kWh for IGCC and conventional coal-fired power stations and about 7 c/kWh for combined cycle natural gas. Since the projected coal electricity plus geosequestration costs are well above current biomass and wind electricity prices, we do not consider this option as part of our principal scenarios to 2040. However, natural gas combined cycle generation plus geosequestration seems to be a real option for Victoria and Western Australia. We also consider that all new natural gas production at the North-West Shelf, such as the proposed Gorgon field, must capture and store securely the CO₂ that comes up with the gas.

A more detailed discussion of CO₂ emissions from Australia's coal-fired power stations and the limitations of geosequestration is given by Diesendorf (2003).

³ In 1986 a large amount of CO₂ that had been produced by volcanic action escaped from Lake Nyos in the Cameroons. It filled neighboring valleys out to a distance of nearly 30 km and killed 1700 people.

8.5. Oil substitutes from oil sands, shale and coal

The vast majority of liquid fuels from petroleum – such as petrol, diesel and LPG -- are used for transport. A small fraction is used to supply stationary energy in mines, farms, factories and remote homes, and a somewhat larger fraction to power mobile machinery, such as tractors and earth moving equipment, in the Mining, Construction and Agriculture, etc. sectors. Liquid fuels can also be used to generate electricity in power stations with boilers or gas turbines and are widely used for that purpose in many countries, but in Australia, where coal and natural gas are readily available and much cheaper, use of petroleum for electricity generation is limited to small power plants such as diesel and petrol generators.

As oil becomes scarcer and more expensive over the next few decades, non-renewable substitutes in the form of liquid fuels could be obtained from oil sands, shale oil and oil from coal processes, as is currently happening in some other countries, such as Canada (oil sands) and South Africa (oil from coal). In addition, a product called Ultra-Clean Coal, which is a solid fuel with very low ash content made from coal, has been developed in Australia for direct firing, as a very fine powder, in gas turbines.

The production and combustion of each of these potential oil substitutes emits much greater total amounts of CO₂ than the equivalent quantity of oil. Therefore, we do not consider that they will ever be used in significant quantities in Australia. Rather, we envisage liquid fuels from biomass – methanol, ethanol and bio-oils – being used increasingly as oil prices increase (see Chapter 7).

8.6. Cogeneration of heat and electricity

Cogeneration, also termed combined heat and power or CHP in many countries, is the simultaneous production of electricity and useful heat from the same energy source. The energy source is normally combustion of a fossil or biomass fuel. Cogeneration is a means of maximising the useful energy extracted from the combustion process and thereby maximising the efficiency of energy use in terms of both the First and Second Laws of Thermodynamics (see Glossary).

For this reason, cogeneration has long been recognised as a most important and effective means of increasing overall energy efficiency, and thereby reducing the level of greenhouse gas emissions per unit of fossil fuel consumed and of useful energy services delivered. Indeed, like distributed generation in general, cogeneration is a technology which was once much more widespread, and over the last 50 or 60 years has been driven out of the electricity supply mix by the shift to very large centralised power stations and long distance electricity transmission. One way of looking at the long historical trend is to regard the cost of cogeneration as broadly constant over the long term, having been displaced by large, low-cost coal fired power stations, and coming into its own again in the future as environmental considerations and other factors force up the costs of coal-fired generation.

Cogeneration can be used where there is a combined need for both electricity and process heat, the latter normally being supplied as steam, though not necessarily so. The combined need may either be at a single site or simultaneously at several

neighbouring sites which are sufficiently close to allow economic and efficient transportation of the steam generated. If electricity can be sold into the wholesale market at a high enough price, a large heat load alone can suffice to support a cogeneration installation. Typical sites for large cogeneration projects include chemical plants, oil refineries, pulp mills, sugar mills and mineral processing plants which use aqueous phase digestion processes, such as alumina and nickel refineries. Smaller cogeneration projects are suitable for hospitals, larger educational institutions, leisure facilities and office buildings. In the case of office buildings, widespread adoption of absorption chillers (instead of compression cycle chillers, which are the norm today) would combine well with gas engine cogeneration. At present, most cogeneration capacity in Australia is at large industrial sites.

There are a number of different types of cogeneration technology. For many years, all cogeneration installations were based on the use of conventional fuel fired boilers, with steam turbines as the prime mover used for electricity generation. Two alternative configurations are possible: the so-called topping cycle⁴, in which steam is passed first through a back pressure turbine⁵ before going to the thermal load, and the so-called bottoming cycle, in which the sequence of the two components is reversed. The topping cycle is far more common than the bottoming cycle. The latter may be associated with either a boiler installation or a high temperature thermal process, such as a kiln or furnace, where the high temperature exhaust gases are passed through a heat exchanger to generate steam. There are currently a number of these projects associated with furnaces or kilns in Australia.

In recent decades a diversity of new technologies have emerged, as summarized in Table 8.1, and today gas turbine technology has largely superseded steam turbine technology for medium size installations.

Typical or representative characteristics of these various configurations are shown in Table 8.2, taken from a Canadian report (Strickland, 2002). It should be noted that ‘high thermal quality’ refers to high temperature/pressure steam, ‘medium’ thermal quality’ to low temperature/pressure steam, and ‘low thermal quality’ refers to hot water.

Table 8.1: Types of cogeneration

⁴ This terminology derives from thermodynamics; the passage of energy through a total process from high temperature/high quality to low temperature/low quality. It is described as moving from the “top” to the “bottom” in thermodynamic terms, so “topping” means taking energy out at the high temperature end and “bottoming” to taking energy out at the low temperature end.

⁵ A back pressure turbine is one in which steam exits from the turbine at a significant positive pressure, and thus still contains considerable energy, to be used in thermal processes.

Generation prime mover	Thermal energy carrier	Thermal energy source	Typical size range (indicative only)	Typical host industry or sector
Back pressure steam turbine	Steam	Steam turbine exhaust	5-50 MWe	Manufacturing (various)
Condensing steam turbine	Steam or high temperature combustion gases	Boiler or kiln/furnace	5-50 MWe	Manufacturing (various)
Open cycle gas turbine	Steam	Exhaust gas heat exchanger	5-100 MWe	Manufacturing, large commercial
Reciprocating engine	Hot water or steam	Engine cooling water or exhaust gas heat exchanger	< 2 MWe	Commercial/buildings, small industrial
Combined cycle gas turbine	Steam	Exhaust gas heat exchanger and/or Steam turbine exhaust	> 100 MWe	Large industrial/manufacturing
Microturbine	Steam	Exhaust gas heat exchanger	< 100 kWe	Commercial/buildings
Fuel cell	Steam or hot water	Cooling water	< 500 kWe	Demonstration stage only

Table 8.2: Typical performance characteristics of various types of cogeneration configuration

Cogeneration System	Electrical energy output (% of fuel input)	Overall efficiency (%)	Heat-to-power ratio	Thermal qualities
Back-pressure steam turbine	14-28	84-92	4.0-14.3	High
Condensing steam turbine	22-40	60-80	2.0-10.0	High
Gas turbines	24-42	70-85	1.3-2.0	High
Reciprocating engine	33-53	75-85	0.5-2.5	Low
Combined cycle gas turbine	34-55	69-83	1.0-1.7	Medium
Fuel Cells	40-70	75-85	0.33-1	Low to High
Microturbines	15-33	60-75	1.3-2.0	High

Source: Strickland (2002)

It is important to appreciate “that inherently, different types of configurations provide different natural quantities of steam and electricity” (Cogeneration Ready Reckoner Manual, p. 14), as Table 8.2 implies. They are also inherently suited, or most economically efficient, in different size ranges. Broadly speaking, reciprocating engines are the current optimal technology for installations of up to about 2 MWe capacity where relatively low grade heat is typically required. In coming years they will probably be superseded in that role by microturbines (which are very small gas turbines) and fuel cells. Fuel cells in particular may also become economic at sizes smaller than any current cogeneration installations (suitable for an individual house). However, since they are as yet not a fully commercially proven technology, we have not included fuel cells in our 2040 scenario.

At larger sizes, steam turbines and/or gas turbines come to the fore. The choice between the two will depend on a number of factors, including the balance of steam, the pressure and temperature of the heat/steam required, and electrical output desired. In general, a CHP system is designed to meet the heat needs of the host. Then, if a relatively small electrical output is required, as for example an establishment wishing to become partially self sufficient in electricity, but not a significant exporter, steam turbines would be the technology of choice. Otherwise, reciprocating engines would be used in small to medium installations and combined cycle gas turbines (CCGT) would be used in very large installations, where the objective is to maximize electrical production for export, relative to a large on-site steam load.

Looking at cogeneration as a whole, the mix of the different types of fully commercial technology, i.e. not including fuel cells and microturbines, across the whole potential size range for cogeneration installations is still a cost curve which declines with size. For example, a report by Sinclair Knight Merz (2001, pp. 56-7) estimates that the cost of cogenerated electricity for plants of 5 MW capacity or smaller is above \$60 per MWh, falling to around \$50 per MWh at sizes around 50 MW and flattening out at about \$40 per MWh above 200 MW capacity. As fuel cells become fully commercially mature technologies, their costs will fall, but it seems probable that the foreseeable future they will be more costly than large steam and gas turbine plant in terms of \$ per MW of capacity or per MWh of electricity generated. However, being much closer to the electrical loads, small plants can compete on a more equal basis when transmission and distribution costs are taken into account.

As the cost data above demonstrates, medium and larger cogeneration is currently more costly than coal-fired base-load electricity, but not greatly so, and full consideration of avoided transmission, distribution and greenhouse costs could tip the balance in favour of cogeneration. Technology improvements can be expected to reduce the cost of smaller cogeneration installations. Accordingly, our scenario includes widespread use of cogeneration in industries with a requirement for thermal energy in the form of steam (including both manufacturing and also hospitals, educational institutions etc. in the Commercial/Services sector). We also assume widespread use of absorption chillers and small cogeneration in commercial buildings, but do not include use of topping cycle installations in industries that make extensive use of kilns, such as cement and glass. It is assumed that all these installations will be fuelled by natural gas, except in the sugar and pulp and paper industries, which produce large quantities of biomass waste. It is assumed that all sugar mills will be associated with new, technologically optimised cogeneration plants, which can meet the in-house requirements of the mills for steam and electricity from only half the available quantity of biomass, leaving the remaining bagasse available to fuel additional electricity generation. The total electrical energy produced from this group of plants will of course depend on the total size of the sugar industry.

8.7. Phase-out of existing fossil fuelled power stations

One of the constraints on transforming the electricity industry into a much cleaner industry, both in terms of greenhouse gas emissions and other forms of pollution and land degradation, is the long lifetimes of existing power stations. Without a major refurbishment, power stations can be expected to run for 30-35 years. We assume that

henceforth any proposal for a major refurbishment or for a new power station would have to meet very stringent conditions on greenhouse intensity: specifically that such stations would be required to have greenhouse intensities less than or equal to those of the best combined-cycle natural gas power stations in 2003. In practice this is likely to entail that all existing coal-fired power stations, with the possible exception of those commissioned on or after 2000, would have been closed down by 2040.

Table 8.3 lists all Australia's large power stations in order of decreasing total CO₂ emissions, giving their dates of commissioning. The data suggest that, on the basis of our assumed greenhouse constraint, only three existing coal-fired power stations may be still operating in 2040: Millmerran, Tarong North and Callide C. All are located in Queensland and together have a total generating capacity of 2130 MW. At the time of writing, a full year's energy generation data is not available for these stations. Nevertheless, an approximation can be obtained by assuming an average capacity factor of 86%, giving total annual electricity generation of about 16 TWh, which is about 8% of total Australian generation in 2001. Our principal scenario considered in Chapter 10 retains these three power stations.

Table 8.3: Dates of commissioning and greenhouse gas emissions of major existing power stations (Year 2000 or Financial Year 2000-01)

Power station	State	Type of power station ^a	Year of commission	Capacity (MW)	Generating units (no. x MW)	Approx. CO ₂ emissions ^b (Mt)	Approx. greenhouse intensity ^c (Mt CO ₂ /TWh sent out)
Loy Yang A	Vic	brown	1984/87	2,000	4x500	17.3*	1.28
Hazelwood	Vic	brown	1964/71	1,600	8x200	16.3*	1.46
Bayswater	NSW	black	1982/84	2,640	4x660	15.8*	0.93
Yallourn W	Vic	brown	1973/75	1,450	2x350 + 2x375	13.4*	1.43
Eraring	NSW	black	1982/84	2,640	4x660	12.4	0.9
Stanwell	Qld	black	1993/96	1,400	4x350	10.1	1.0
Gladstone	Qld	black	1976/82	1,680	6x280	9.8	1.0
Loy Yang B	Vic	brown	1993/96	1,000	2x500	9.7	1.15
Tarong	Qld	black	1984/86	1,400	4x350	9.4*	0.84
Mt Piper	NSW	black	1992/93	1,320	2x660	9.4	0.9
Liddell	NSW	black	1971/73	2,000	4x500	8.8*	0.98
Vales Point	NSW	black	1978	1,320	2x660	6.8	1.03
Muja	WA	black	1965,81,85/86	1,040	4x60+4x200	6.0	
Callide B	Qld	black	1988/89	700	2x350	5.6	1.0
Northern	SA	brown	1985	520	2x260	4.8	1.1
Wallerawang C	NSW	black	1976/80	1,000	2x500	4.3	1.0
Callide C	Qld	black	2001 2001	840	1x420 1x420	3.0 N/A	0.95
Swanbank A & B	Qld	black	1970/73 1966/69	908	4x125 + 6x68	2.8	1.06
Collie	WA	black	1999	330	1x330	2.5	
Torrens Island ^e	SA	gas		1280		1.9 (e)	0.56 (e)
Kwinana ^d A & C	WA	black	1970, 76	880	4x200 + 4x120	1.8	
Munmorah	NSW	black	1969	600	2x300	1.6	1.1
Pelican Point	SA	gas CC	2000	478	2x160+1x158	1.1	
Kwinana ^d B	WA	gas	1970	240		0.3	
Millmerran	Qld	black	2003	840	2x420	N/A	N/A
Tarong North	Qld	black	2003	450	1x450	N/A	N/A

Sources: ESAA (2003), websites of generators where they exist, and personal communications from some generators

Notes:

- 'Brown' and 'black' denote boiler-type base-load power stations burning brown and black coal respectively; 'gas' denotes boiler-type natural gas-fired; 'gas CC' denotes combined-cycle natural gas.
- CO₂ emissions with asterisk are obtained from company's published reports. The others are our estimates.
- CO₂ intensity is given here in terms of Mt CO₂ produced divided by TWh of electricity sent out from the power station. Electricity generated is typically 6-8% higher than electricity *sent out*. The difference is used to operate the power station.
- Here we assume that Kwinana units A & C burn coal, and unit B burns mainly gas.
- Year 2000 data. CO₂ emissions from personal communication from TXU.

9. Decarbonising energy supply

9.1. Introduction

In Chapter 6 we describe a Medium Efficiency pattern of demand for energy in 2040 in which total demand for stationary energy is 25% higher than it was in 2001. As population is projected by the Australian Bureau of Statistics to grow by over 29% to 25 million, this represents a slight reduction in per capita energy demand. To achieve this result, we have modelled an extensive, but quite achievable uptake of energy efficiency technologies and practices across all sectors of the economy. In the absence of policies to support the wide adoption of cost effective energy efficiency, we project an increase in energy demand from 2001 of 57%. Our modelling of demand by itself assumes no change in the mix of fuels within each individual economic sector modelled; the only source of fuel mix change is the shift in relative sizes of the various economic sectors. The consequence is that the fuel mix does not differ greatly from that in 2001; coal and natural gas take slightly smaller shares of the total and petroleum products a slightly larger share. The analysis of demand makes no assumptions about the mix of generation technologies and fuels used to supply electricity.

The overall effect is that an increase in demand for energy of 25%, with no change in fuel mix in electricity generation, will cause greenhouse gas emissions also to increase by about 25%. As discussed in Chapter 2, at the assumed level of fossil fuel prices in 2040, we estimate, on the basis of marginal abatement costs, that it is more cost effective to achieve further emission reductions by adopting alternative low emission sources of energy supply, than by further reducing demand through increased energy efficiency.

Four distinct measures have been modelled and are discussed in the remaining sections of this Chapter:

- 1) introduction of solar thermal pre-heating into the supply of steam and hot water in industrial and commercial applications (widespread use of solar thermal technology is already factored into the Residential sector);
- 2) substitution of natural gas for coal in almost all non-metallurgical applications;
- 3) widespread adoption of cogeneration, as described in Section 7.6; and
- 4) a change in the mix of electricity generation technologies, away from coal and towards natural gas and renewable energy.

Changing the electricity generation mix is by far the most important of these and is discussed at greatest length. Consideration was given to using biomass as an additional substitute energy source in Steps (1) and (2) above, but it was judged that it would be more cost effective to use limited biomass resources for electricity generation and, if further resources were available, for the production of transport fuels.

It is important to appreciate that all the technologies deployed in Steps (1) to (4) are already commercially well established and in most cases are widely used throughout the energy system today. In most cases, their current market share is limited by relative costs and prices, as ultimately determined by the current underlying prices of coal and natural gas. It can be expected that, with no change in policy settings, all will continue to gain market share, as fossil fuel prices move gradually upward. Hence the full

Baseline scenario, where demand for energy is at the Baseline level described in Chapter 5, will also include a higher penetration than in 2001 of all the technologies considered in this Chapter.

We have therefore modelled two different levels of energy demand and associated levels of uptake of fuel substitution Steps (1), (2) and (3): one based on the Baseline energy demand of Chapter 5 and one based on the Medium Efficiency demand of Chapter 6. In addition, four different electricity supply system technology mixes were modelled, two for each energy demand/direct fuel substitution set. A complete definition of the four scenarios and of their associated energy use and emissions are given in the next Chapter. In this Chapter we describe the modelling assumptions lying behind each combination.

9.2. Solar thermal pre-heating

Solar thermal devices available today are capable of delivering energy, carried in the form of steam or other working fluids, at temperatures well in excess of 100°C. Technically, they would be able to meet much of the industrial and commercial demand for steam and hot water. However, to achieve the higher temperatures more sophisticated equipment, such as evacuated tube collectors, is needed. The technology is most cost effective when used as a pre-heater, to raise the temperature of water from the environmental ambient to a temperature somewhat below 100°C, as commercial solar water heaters do. Moreover, as explained in Chapter 8, establishments with a substantial demand for steam and hot water are ideally suited to host cogeneration plants, but this requires the use of combustion fuels, such as natural gas, which can achieve much higher temperatures than even the most sophisticated solar collector. Hence there is a partial trade-off between use of solar thermal heat and use of cogeneration.

With detailed information about an individual industrial site, it would be possible to determine a mix of solar thermal and cogeneration which minimizes total greenhouse gas emissions. Such optimisation is of course impossible in a high level national study. We have therefore used our professional judgment to estimate the substitution of solar thermal energy, in the form of pre-heaters in boiler systems in all end use sectors of the economy except Iron and Steel, where excess quantities of coal by-product gases are used to produce steam and generate electricity at integrated steel works, and sugar, where there is an excess of biomass fuel. We assume greater use of solar thermal in the Food, Beverages and Tobacco, and All Other Manufacturing sectors, because it is better suited to the smaller scale and lower steam temperature requirements that typify these sectors. A modest substitution of solar water heating for natural gas in the Commercial/Services sector is also assumed.

In the Medium Efficiency demand case a total of 51 PJ of boiler fuel is displaced in manufacturing and mining and a further 3 PJ in the Commercial/Services sector. In the Baseline demand case the quantity of boiler fuel displaced is 27 PJ in total.

Not included here is the extensive adoption of solar water heating in the Residential sector, which, for reasons of methodological simplicity, was modelled jointly with energy efficiency in the Residential sector, as described in Chapter 6. In the Medium Efficiency case residential solar hot water displaces 35 PJ of electricity, 32 PJ of natural gas and 3 PJ of LPG, a total of 70 PJ, while in the Baseline case 35 PJ are displaced.

9.3. Substitution of gas for coal and petroleum

Most sectors of the economy currently use limited quantities of coal as a boiler and kiln fuel. Ever since natural gas first became available in Australia, nearly thirty five years ago in some States, it has steadily been replacing both coal and petroleum products as the direct combustion fuel of choice in all areas of stationary energy use. It could readily substitute for all remaining non-metallurgical uses of coal, except the few without access to gas supplies. Gas is generally a technically superior alternative, but costs more. We expect that this substitution trend will continue, even in the absence of new policies to encourage reduced greenhouse gas emissions.

In the Medium Efficiency demand case, coal is almost completely displaced by natural gas in these applications. The greatest effect is in the Non-ferrous Metals sector, where currently two alumina plants and one nickel plant, among others, use very large quantities of coal as boiler fuel, and cement, where three of the four major plants currently use coal. We assume that where coal is used, in the form of coke, in metallurgical applications, there will be no fuel substitution. Coal by-products continue to be used as boiler fuel in the Iron and Steel sector, for the reason given above.¹

In total, 130 PJ of coal demand in the Medium Efficiency demand case are displaced. The use of natural gas instead of coal will lead to increased energy efficiency, because of the superior technical characteristics of gas. However, we have made no explicit allowance for this effect, which is a conservative element in our assumptions.

Petroleum products, mainly in the form of LPG and fuel oil, are also used in boilers, kilns and space heating installations. By far the largest user is the alumina plant at Gove, which will almost certainly switch from fuel oil to natural gas within the next few years. We assume some modest additional substitution in other sectors. However, much current use of LPG occurs where a gaseous fuel is required for technical reasons and natural gas is not available. While it is certain that by 2040 the natural gas distribution network will be more extensive than it is today, it is also certain that some locations will remain without a piped gas supply, and will continue to rely on LPG. We also assume continued use in the Basic Chemicals sector of petroleum in the form of “waste” by-products from the various chemical processes that use petroleum product feedstocks. Petroleum products continue to be the main source of energy in the Mining, Construction and Agriculture, Forestry and Fishing sectors. Outside these sectors, the assumed substitutions reduce demand for petroleum products by 48 PJ, from 115 to 67 PJ (of which 24 PJ are in Chemicals).

In the Baseline case there is also significant displacement of coal and petroleum by natural gas, totalling 96 PJ of coal and 32 PJ of petroleum products, but this is from a somewhat higher base consumption of coal and petroleum, since all fuels are used less efficiently in this case than in the Medium Efficiency case. In total, 61 PJ more coal and 36 PJ more petroleum are used in boiler and kiln processes in the Baseline case than in the Medium Efficiency demand case.

¹ However, there is potential to use charcoal from biomass as an alternative to coke (see Section 11.2).

9.4. Greater use of cogeneration

ABARE reports that cogeneration plants supplied a total of 25 PJ (about 7 TWh) of electricity in 2001. This represents nearly 4% of total final demand for electricity. It excludes electricity generated at several new, large CCGT based cogeneration plants located at alumina, chemical and paper plants in several States, which both ABARE and the ESAA report as part of the electricity generation sector.

As explained in Section 2.1, in our model we subtract an estimate of the additional energy consumption associated with the 25 PJ of cogenerated electricity and re-allocate it to the electricity sector. This means that projected demand for thermal energy in the various host sectors represents the demand directly associated with the industrial process, and does not include any forward projection of demand from existing cogeneration plants.

In very broad terms, the capacity to support cogeneration at a site is proportional to the host steam load at the site. Consequently, reducing steam loads by increasing energy efficiency reduces potential cogeneration capacity. Substituting use of natural gas or other fuel with solar thermal collectors has a similar effect, as explained above. The logic of our energy system model therefore calls for cogeneration to be introduced into the supply mix following these fuel substitution steps.

In the Medium Efficiency case we introduce cogeneration into all sectors where there is a significant demand for energy in boiler systems. We assume that the following proportions of boiler fuel demand in each sector are suitable to host cogeneration:

Sugar	100%
Iron and Steel, Non-ferrous Metals	90%
Pulp and Paper	80%
All other industry sectors	50%

There is also significant potential for cogeneration in the Commercial/Services sector, in association with both heating and cooling loads in buildings. With heating, a gas engine or small gas turbine is used to generate electricity and the waste heat supplies the space heating demand. With cooling, the waste heat is instead used to drive an absorption chiller, which would replace an electric motor driven compressor chiller, with associated savings in electricity demand. Both types of installation were modelled, assuming that cogeneration installations could supply 50% of the heating and 50% of the cooling demand from the sector.

The results showed that while cogeneration supplying space heating reduced total greenhouse gas emissions, cogeneration with absorption chillers supplying cooling increased emissions. This is because, on the assumptions in our model, the additional gas consumption required for the absorption chillers exceeds the quantity of gas needed to generate the displaced electricity (previously driving a compressor chiller) in a stand-alone gas fired power station. Accordingly, we have not included gas cogeneration with space cooling in our Clean Energy scenario².

² However, other gas-based solutions show potential for lower emissions. For example, Hornsby Library is a site for CSIRO's trial micro-cogeneration system with its waste heat being used to regenerate a desiccant wheel which is then used for cooling.

The result of the analysis is that total cogenerated electricity in 2040 is 132 PJ (37 TWh), as shown, by fuel source, in Table 9.1 below.

In the Baseline case we make the simplifying assumption that uptake of cogeneration in the energy intensive manufacturing sectors (including sugar milling) where the economics are most favourable, is the same as in the Medium Efficiency case, but there is no additional cogeneration in other economic sectors. However, with a lower level of energy efficiency, host thermal loads are larger than in the Medium Efficiency case, so that for a given level of uptake of cogeneration, in terms of share of potential host thermal loads, there is actually more cogeneration capacity and more cogenerated electricity. Hence total cogeneration in the Baseline is only 19% less than in the Medium Efficiency case.

Table 9.1: Quantities of cogenerated electricity under the two demand scenarios

Fuel source	Cogenerated electricity (PJ)	
	Medium Efficiency	Baseline
Coal (including blast furnace gas)	2	19
Biomass	21	22
Petroleum (including petrochemical “waste” gases)	3	7
Natural gas	106	61
Totals	133	108

The final step in the analysis is to introduce cogenerated electricity into the total electricity system supply mix, that is described below. This we do by assuming that biomass cogeneration displaces electricity that would otherwise be generated at stand alone biomass power plants, on the basis of our modelled supply mix, while natural gas, coal and petroleum fuelled cogeneration displaces electricity from gas power plants.

9.5. Decarbonising the electricity supply mix

In 2001 energy which users obtained by direct combustion of fuels and collection of solar heat provided 69% of the energy supplied to users (including use in the production and processing of fuels other than electricity), but accounted for only 31% of greenhouse gas emissions from stationary energy. Electricity generation accounted for the other 69% of emissions.

In our Baseline demand case for 2040, the requirement for energy supplied by combustion and solar heat rises 42% to 2,069 PJ, while emissions increase by 37%. In the Medium Efficiency case, with additional substitution of low emission fuels as described above, the increase in energy supplied is limited to 22%, relative to 2001, and the increase in emissions to 12%.

Electricity requirements increase faster than requirements for other fuels in the Baseline case, but not in the Medium Efficiency case. In 2040 they are 69% higher than in 2001 in the Baseline case and 24% higher in the Medium Efficiency case. In Chapters 7 and 8 we described and reviewed the different technologies which might be used to meet these

requirements. In this Section we describe how the electricity supply system has been modelled in the different scenarios constructed for this study.

In each case the system consists of a mix of different types of generating plant. The types of generation fuel and technology included are shown in Table 9.2, which also shows the key technical characteristics of each type.

For the coal and biomass technologies, thermal efficiency has been assumed to improve significantly, relative to current generating plant using those fuels. The effect will be an appreciable reduction in fuel use and, in the case of coal, greenhouse gas emissions, to generate a given quantity of electricity. For combined cycle gas turbine (CCGT) natural gas plant, a lesser improvement has been assumed, for two reasons: firstly, in order to err on the side of conservatism, so far as the characteristics of “cleaner” technologies are concerned and, secondly, because much of the CCGT plant will be required to operate in load following mode (or be substituted by less efficient open cycle plant), with consequently reduced thermal efficiency.

Table 9.2: Characteristics of different types of electricity generation

Generation fuel/technology	Generation efficiency (fuel to electricity)^a	Own use of electricity (% of generated)	Transmission and distribution losses (% of sent out)
Black coal (conventional)	45%	5%	8%
Brown coal (conventional)	35%	8%	8%
Biomass	40%	5%	8%
Petroleum	45%	1%	8%
Natural gas (CCGT)	50%	1%	8%
Photovoltaics	<i>na</i>	<i>na</i>	2%
Hydro	<i>na</i>	<i>na</i>	8%
Wind	<i>na</i>	<i>na</i>	8%
Cogeneration	77% ^b	<i>na</i>	2%

Notes:

a. Thermal efficiency calculated according to Gross Calorific Value (see Glossary).

b. Except sugar, 140%, because of assumed concurrent improvements in overall efficiency of bagasse utilisation.

Own use of electricity is much the same as in current plant of the same technology type.

Transmission and distribution losses for the centralised generation technologies, including wind and biomass, are much the same as in the present transmission and distribution systems. Only cogeneration and photovoltaics are assumed to be distributed generation technologies in this sense, and allocated much lower losses. It may be argued that biomass and wind should also be treated as distributed technologies, with lower transmission and distribution losses. This would be true with low rates of penetration of these technologies, but, at higher rates of penetration, the electricity supplied by these technologies would exceed demand in the immediate locality. Much of it would require

transmission to major urban centres of demand, thus taking on the characteristics of centralised generation.

It will be noted that the list of technologies includes neither coal with CO₂ capture and geosequestration, nor coal based IGCC; the coal technologies included are conventional thermal generation, with improved efficiency performance. These “low emission” coal technologies do not form part of our various low emission electricity supply system scenarios because, as described in Chapters 7 and 8, both are more costly incremental sources of electricity supply system greenhouse abatement than wind or biomass, up to the level that the latter are included in the various electricity supply system plant mixes modelled for this study (see below). (Incremental abatement is measured in terms of marginal dollars per tonne of marginal abatement relative to conventional coal, the lowest cost source of electricity.)

Baseline scenario (Scenario 1)

Our Baseline scenario consists of energy demand at the Baseline level, which includes 1,129 PJ (314 TWh) of electricity, direct fuel substitution at the level described earlier in this Chapter, and 108 PJ of electricity supplied by cogeneration. The mix of generating plant that supplies the remainder of the electricity demand is our estimate of that which will occur in the absence of further policy measures to limit greenhouse gas emissions from stationary energy.

The last few years have seen the beginning of a shift away from coal and towards natural gas for electricity generation. In common with most other observers, we expect this trend to continue, with current policy settings (including anticipated further changes to energy markets). For example, ABARE’s projection for 2019-20 has coal’s share of electricity generation falling from the current level of over 80% to about 71%. Natural gas makes up most of the difference, but there are also increases in biomass, hydro and wind. Our 2040 Baseline scenario is very similar, with coal having a share of 67%, natural gas (including cogeneration) 16%, and biomass 8%.

Table 9.3 shows the energy generation and corresponding approximate capacity for Scenario 1, and also Scenario 2 (see below) and compares them with actual figures for 2001. All these figures are in terms of electricity generated, rather than electricity supplied, and include electricity lost in transmission and distribution and electricity used at power stations. Note that the available data do not allow capacity corresponding to the 25 PJ of cogenerated electricity reported by ABARE for 2001 to be estimated. For 2040, cogeneration is calculated in relation to host thermal loads, without any assumptions about hours of operation, so calculating capacity has little meaning.

Clean Energy scenario (Scenario 2)

Our principal Clean Energy scenario is one in which greenhouse emissions from stationary energy in 2040 are 50% of their level in 2001. Significant reductions in emissions below the level of Scenario 1 are achieved by increased energy use efficiency, as specified by the Medium Efficiency demand case, and associated adoption of solar thermal pre-heating, increased substitution of natural gas for coal in direct combustion, and widespread uptake of cogeneration, as described in Sections 9.2, 9.3 and 9.4. In our model of the Australian energy system, further reductions in emissions are achieved by

replacing coal as a fuel for electricity generation, using what we have termed a qualitative optimisation approach. The electricity supply system includes 133 PJ (37 TWh) from cogeneration. To construct the remainder of the supply mix, the following steps were taken.

Firstly, wind energy, a relatively low cost, zero emission technology, was adopted up to the point where it starts to require significant back-up generation (from gas turbine plant) in order to achieve acceptable levels of availability, having regards to the diversity available through differences in prevailing wind conditions at any given time across the extensive areas covered by the two major Australian grids (eastern and south west). As described in Chapter 7, we estimate this level to be 20% of total generation and we assess that there are sufficient suitable sites in Australia to be able to supply this level of wind generation (182 PJ or 51 TWh per year) at the costs given in Chapter 7.

Secondly, hydro generation was increased to about 10% above its current level (all four scenarios have the same level of hydro) and a small quantity of petroleum fuelled generation was retained (again, as in all four scenarios), for use in remote and off-grid locations.

Thirdly, photovoltaic generation was adopted to a level of 4.5% of grid generation (38 PJ or 11 TWh per year). Although more expensive on a purely energy basis than the other generation technologies, photovoltaic generation has the great advantage of producing all its electricity during the day and producing maximum output on bright sunny days. Consequently, almost all the output from photovoltaic installation occurs at times of intermediate and peak load, when wholesale electricity prices are considerably above their average level. Added to the fact that most of the output of building integrated photovoltaics can be used in the immediate vicinity of the installations, with consequent large savings in transmission and distribution costs, these conditions make a modest level of photovoltaic generation cost competitive with the other low emission generation technologies.

Finally, the remaining demand for electricity was supplied by a mix of biomass, natural gas and coal. The mix was adjusted to achieve the overall result of a 50% emission reduction. A significant proportion of gas fired generation was required because of its superior technical ability to follow variations in load so as to supply intermediate and peak demand. It was found that this requirement had the effect of constraining coal fired capacity to a relatively small proportion of total generation. Increasing coal (high emission) would have meant increasing biomass (zero emission) also, leaving insufficient capacity of medium emission natural gas generation.

The supply mix adopted for Scenario 2, shown in Figure 9.1, has 73 PJ (20 TWh) supplied by coal fired power stations, which is equivalent to retiring the vast majority of coal-fired power stations, retaining in 2040 only the three Queensland coal-fired power stations that were commissioned in 2000-2003, and adding no new stations from now on.

More details of this Scenario are shown in Table 9.3 and also Figure 9.1.

Other low emission scenarios

For illustrative purposes, two other low emission scenarios were also constructed.

Scenario 3 is identical with Scenario 2, except that coal fired generation is reduced to zero, with the extra generation coming from natural gas and biomass. This results in a further reduction in emissions. Scenario 4 is a low emission scenario with the higher, Baseline level of energy demand, as in Scenario 1. Meeting the higher demand for electricity requires significantly more generating capacity, and is much harder to achieve, in terms of both available energy resources, such as natural gas, biomass and wind, and in terms of cost.

Figure 9.2 compares all four Scenarios with each other and with 2001.

Table 9.3: Electricity generation^g and approximate capacity by fuel source, 2001 and 2040 Scenarios 1 and 2

Generation technology/fuel	Generation (PJ ^c)			Approximate capacity (GW)		
	2001	2040		2001 ^a	2040 ^b	
		Scenario 1	Scenario 2		Scenario 1	Scenario 2
Black coal	414.9	625	84	22.0 ^e	25	3.3
Brown coal	190.6	220	0	7.2	0	0
Natural gas (excl. cogeneration)	76.0 ^f	124	154	6.6 ^{d, f}	8	10
Petroleum	6.4	12	9	1.1	1.3	1
Hydro	60.4	68	68	7.7	9	9
Biomass (excl. cogeneration)	2.5	78	245	0.55	5.4	17
Wind	1	25	182	<0.1	2.6	19
Direct solar	<0.1	6	38	<0.01	1.2	7.5
Cogeneration (gas + biomass)	24.6 ^f	110	135	<i>na</i>	<i>na</i>	<i>na</i>
TOTAL	776.4	1,267	916	<i>na</i>	<i>na</i>	<i>na</i>

Notes:

- Approximate capacities for 2001 based mainly on ESAA (2003), Tables 2.1, 2.3 and 2.4.
- Approximate capacities for 2040 calculated by assuming the following average capacity factors. black coal 0.8; natural gas combined cycle 0.75, natural gas peak-load turbines 0.1; biomass 0.7, wind 0.3, direct solar 0.6. Excludes additional peak-load backup for wind.
- 1 TWh = 3.6 PJ
- Natural gas capacity in 2001 was about 2 GW steam, 1.5 GW combined cycle, 2.5 GW gas turbines (gas fuel) and 0.6 GW gas turbines (dual fuel, gas & oil).
- Includes 1.9 GW dual fuel (black coal + gas).
- Large CCGT cogeneration plants are included under gas fired generation, not under cogeneration, in 2001 data.
- This table gives the final energy actually generated as electricity, not the primary energy input to electricity generation.

Fig. 9.1: Electricity generated by fuel/source, 2040, Clean Energy – Scenario 2

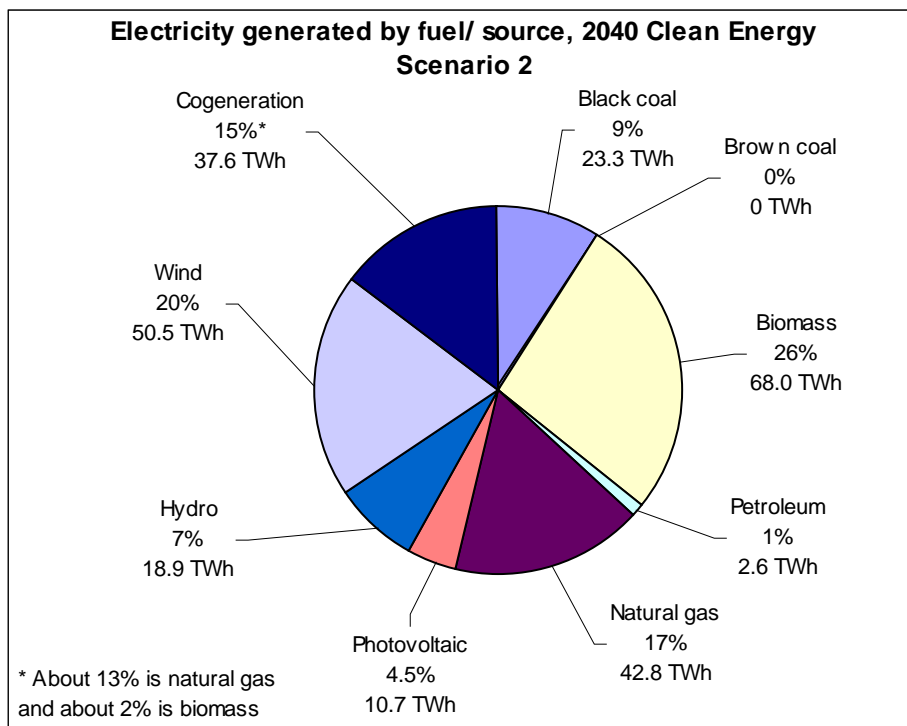
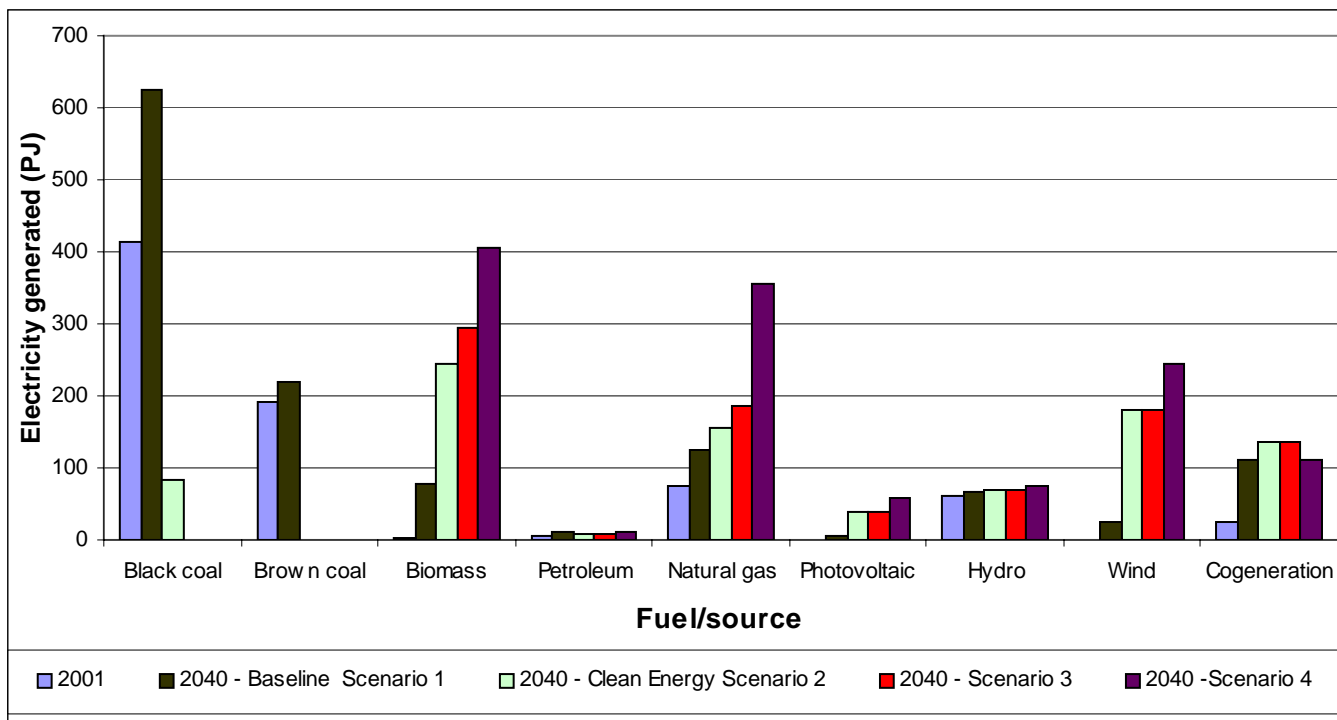


Fig. 9.2: Electricity generated by fuel/source, 2001 and all 2040 Scenarios



9.6. Decarbonising transport

Although the subject of the present report is stationary energy, we cannot ignore transport entirely because it is an input to stationary energy use. In Section 6.6 we considered a somewhat more efficient transport system based on the 2001 fuel mix. These efficiencies could be achieved by improving urban public transport and facilities for walking and cycling, combined with a comprehensive mix of transport and planning policies to make these modes more attractive, a small shift from road to rail freight (based on improved rail infrastructure), and improved fuel efficiency of road and air transport. This results in an increase of 45% in energy demand by transport between 2001 and 2040³.

On the supply side we now investigate simple measures for reducing the greenhouse intensity of this demand. In the spirit of this report we keep with small improvements to existing technologies and assume that almost all road vehicles in 2040 are highly efficient hybrid petrol-electric or diesel-electric vehicles with half the greenhouse gas emissions per km travelled of the present road fleet. This is consistent with current fuel efficiency achievements of hybrid vehicles. These vehicles do not require an external source of electricity – rather the batteries are charged from the petrol or diesel engine, supplemented by regenerative braking. In addition it is assumed that the small minority of vehicles that are unsuitable for hybrid propulsion (e.g. because of size or type of use) have diesel engines fuelled by a 100% bio-oil from crops. It is further assumed as a rough approximation that the 45% increase in transport energy demand applies to each of cars, trucks and aircraft.

Thus, in this scenario, CO₂ emissions from road transport in 2040 decrease to 27.5% below those in 2001, while emissions from civil air transport increase to 45% above the 2001 value. But in 2001, road transport accounted for 90% of Australia's Transport emissions and civil air transport only 6%. Therefore, assuming to first approximation a similar pattern in 2040, the net effect is that transport emissions in this scenario in 2040 will be 25% below those of 2001. An effect of this will be to reduce slightly CO₂ emissions from stationary energy in 2040. However, since this is a small effect, we have not included it in our 2040 scenarios for stationary energy.

By 2040 it is probable that petrol and diesel will be scarce and priced considerably above current levels (Hall et al., 2003). So we assume that, in the absence of major technical breakthroughs, hybrid vehicles will be the standard kind of vehicle in large-scale mass production and so will be only a little more expensive than ordinary vehicles. Therefore it is plausible to assume that this supply-side transport scenario will have no additional net costs in 2040.

³ Without these efficiency improvements, transport energy demand could have increased by about 100%. Nevertheless, we consider that strong demand-side measures could potentially limit the growth in vehicle-km travelled to much less than the 45% increase used here.

10. Scenarios for a clean energy future in 2040

10.1. Scenario results: changes in greenhouse gas emissions from stationary energy

Baseline – Scenario 1

In the Baseline Scenario for 2040, as shown in Table 10.1, total demand for primary energy in stationary consumption is 33% higher than in 2001, while CO₂ emissions are 21% higher. It will be noted that these increases are significantly less than the 57% increase in final energy demand.

Primary energy demand grows more slowly than final energy demand because of significant increases in the efficiency of electricity generation, arising both from expected improvements within technologies (coal fired generation) and a shift toward inherently more efficient technologies and fuels (natural gas, cogeneration). The efficiency of other energy production and processing also increases.

The slower growth in emissions is attributed to these factors, plus a greater use of zero and low emission energy sources in both direct combustion and electricity generation.

However, while these relatively modest increases may seem encouraging, relative to growth rates of recent years, they still represent a major increase in Australia's greenhouse gas emissions above 2001 levels. In absolute terms it is an increase of 48 Mt of CO₂.

Table 10.1: 2040 Baseline – Scenario 1 compared with 2001

	Increase in 2040 relative to 2001	
	Energy	CO ₂ emissions
Final energy demand	57%	<i>na</i>
Primary energy:		
Electricity generation	26%	14%
All other stationary energy use	42%	37%
Total stationary energy	33%	21%

Clean Energy – Scenario 2

The overall result of our principal Clean Energy – Scenario 2 for 2040 is that CO₂ emissions are reduced to 130.9 Mt in 2040, compared with 261.7 Mt in 2001. This is a reduction of exactly 50% below stationary energy emissions in 2001 and roughly 35% below stationary energy emissions in 1990. Compared with the Baseline Scenario 1, the decrease in emissions is 59%. These comparisons are shown in Tables 10.2 and 10.3 respectively. The Tables show primary energy demand and associated emissions separated into two components:

- primary energy demand and CO₂ emissions related to electricity generation, and

- primary energy demand and CO₂ emissions related to all other stationary energy activities.

Figures 9.1 to 9.4 graph the absolute numbers for primary energy demand and greenhouse gas emissions in two different formats, again with emissions divided between the two major components. It can be seen very clearly that the adoption of zero and low emission energy supply technologies, and in particular the replacement of coal combustion for electricity generation with other generation technologies, makes a very large contribution to the reduction in emissions achieved in the Clean Energy Scenario.

Another way of understanding this is by noting that final demand for electricity and final demand by all other fuels are higher in the 2040 Clean Energy Scenario than in 2001 by almost the same amount – respectively 24.3% and 25.5%, giving the overall average of 25%. However, while emissions associated with electricity generation fall by 78%, those associated with all other fuels rise by 12%. This difference arises for two reasons. Firstly, because low-cost renewable energy can make a much larger contribution to the supply mix for electricity than to all other fuels, for which useful energy is provided directly by combustion at the point of use.

Table 10.2: 2040 Clean Energy – Scenario 2 compared with Baseline – Scenario 1

	Decrease: Clean Energy relative to Baseline	
	Energy	Greenhouse emissions
Final energy demand	-20%	<i>na</i>
Primary energy:		
Electricity generation	-43%	-81%
All other stationary energy use	-14%	-18%
Total stationary energy	-30%	-59%

Table 10.3: 2040 Clean Energy – Scenario 2 compared with 2001

	Decrease: Clean Energy relative to Baseline	
	Energy	Greenhouse emissions
Final energy demand	+25%	<i>na</i>
Primary energy:		
Electricity generation	-27%	-78%
All other stationary energy use	+21%	+12%
Total stationary energy	-8%	-50%

To understand the difference between Scenarios 1 and 2 it is important to note that the share of electricity in final energy demand is 38.5% in Scenario 1 but only 34.4% in Scenario 2, which is marginally less than the 2001 level of 34.7%. The difference

between the two Scenarios is caused by the fact that end use efficiency increases are greatest in the electricity intensive Commercial/Services and Residential sectors. Since the losses inherent in thermal electricity generation account for most of the difference between final and primary energy demand, a fall in the electricity share of final demand brings a disproportionate fall in primary energy demand, and in greenhouse emissions, all else being equal. This effect demonstrates how important the realisation of full energy efficiency potential is to the final outcome.

The different processes at work can also be understood by comparing increases between 2001 to 2040 for Clean Energy – Scenario 2 in the following sequence.

GDP	+140%	
Baseline final energy demand	+57%	reduction caused by sectoral shifts within the economy and endogenous changes towards more efficient energy technologies
Medium Efficiency final energy demand	+25%	reduction caused by enhanced end use energy efficiency
Primary energy demand	-8%	reduction caused by 1) fall in the share of electricity in final demand, as a result of greater efficiency gains in the previous step in the electricity intensive Commercial/Services and Residential sectors, 2) adoption of cogeneration and other more energy efficient technologies for electricity generation and other energy supply, and 3) shift away from combustion based generation technologies
Greenhouse gas emissions	-50%	reduction caused by shift away from coal and towards low and zero emission fuels and technologies in electricity generation and other energy supply

It is clear that each stage contributes significantly to achieving the final Clean Energy Future:

- changes to the Australian economy that are already in train or can be expected to occur;
- enhanced energy efficiency that is economically beneficial but will require policy initiatives for its realisation, noting that energy efficiency increases in the Residential and Commercial/Services sectors bring further gains in reducing primary energy requirements because of the electricity intensiveness of these sectors;
- adoption of cogeneration and other more energy efficient technologies in energy supply, also requiring policy action; and
- replacement of high emission, mainly coal based energy supply technologies with low and zero emission technologies and fuels, which again will require the adoption and implementation of appropriate policies by governments.

Other low emission futures: Scenarios 3 and 4

Scenario 3 is identical with Scenario 2 except that coal fired power stations have been entirely phased out by 2040, while demand for all forms of energy is the same as in Scenario 2. The total emission reduction, relative to 2001, becomes 54.7% instead of 50%, and relative to 1990 is 40% instead of 36%. The emission reduction resulting from electricity generation is 84.6%, while that from all other energy sources remains unchanged, as shown in Figures 10.1 to 10.4.

In Scenario 4, energy demand is at the higher Baseline level, with final demand for stationary energy reaching 157% of the 2001 level by 2040, rather than the 125% of Scenarios 2 and 3. In view of growing international concern about climate change, and the cost effectiveness of a higher level of end use energy efficiency, such a large increase in demand seems an unlikely scenario. It is included here as a basis for comparison, and because it demonstrates the crucial role that enhanced energy efficiency will have if a clean energy future is to be achieved.

With the same energy supply mix as Scenario 3, CO₂ emissions in Scenario 4 in 2040 from electricity and stationary energy are 76% and 42% below the 2001 level, respectively. In this case wind energy generation becomes 247 PJ (69 TWh) and capacity is 26 GW, a more formidable challenge than the 182 PJ (50.5 TWh) and 19 GW required for Scenarios 2 and 3. Bioenergy generation becomes 1,044 PJ and its land requirements are 1.1 Mha, which is still less than the current area of plantation forest.

Changes in CO₂ emissions in all three scenarios are set out in Table 10.4.

Table 10.4: Change in CO₂ in 2040 for Scenarios 2, 3 and 4, relative to 2001

Scenario and Description	From electricity	From all other stationary energy	From all stationary energy
2 Clean Energy Future	-78%	+12%	-50%
3 Clean Energy Future plus zero coal in electricity	-85%	+12%	-55%
4 Baseline energy demand, energy supply as in Scenario 3	-76%	+34%	-42%

Fig. 10.1: CO₂ emissions from electricity generation and all other stationary energy consumption in 2001 and all 2040 Scenarios

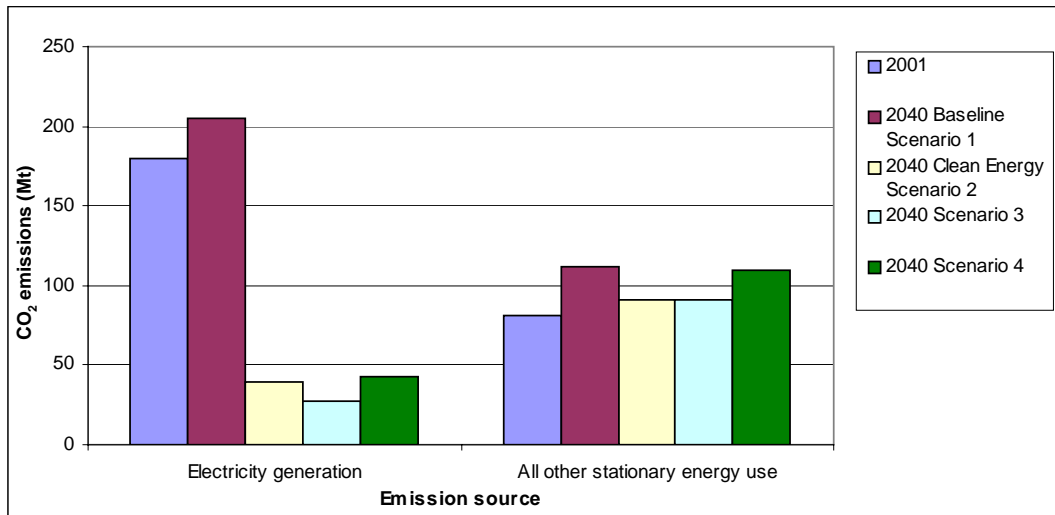


Fig. 10.2: Composition of total CO₂ emissions from stationary energy in 2001 and all 2040 Scenarios

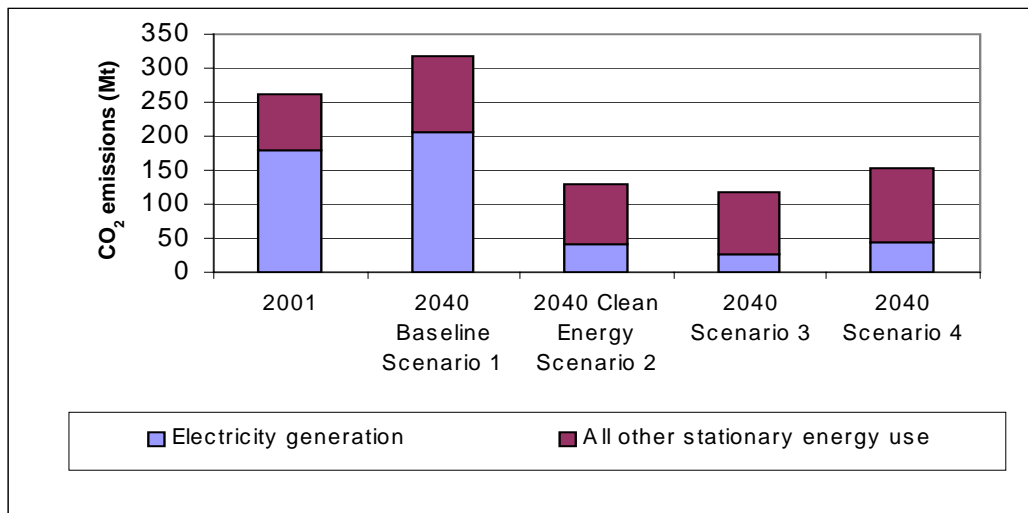


Fig. 10.3: Primary energy demand from electricity generation and all other stationary energy consumption in 2001 and all 2040 Scenarios

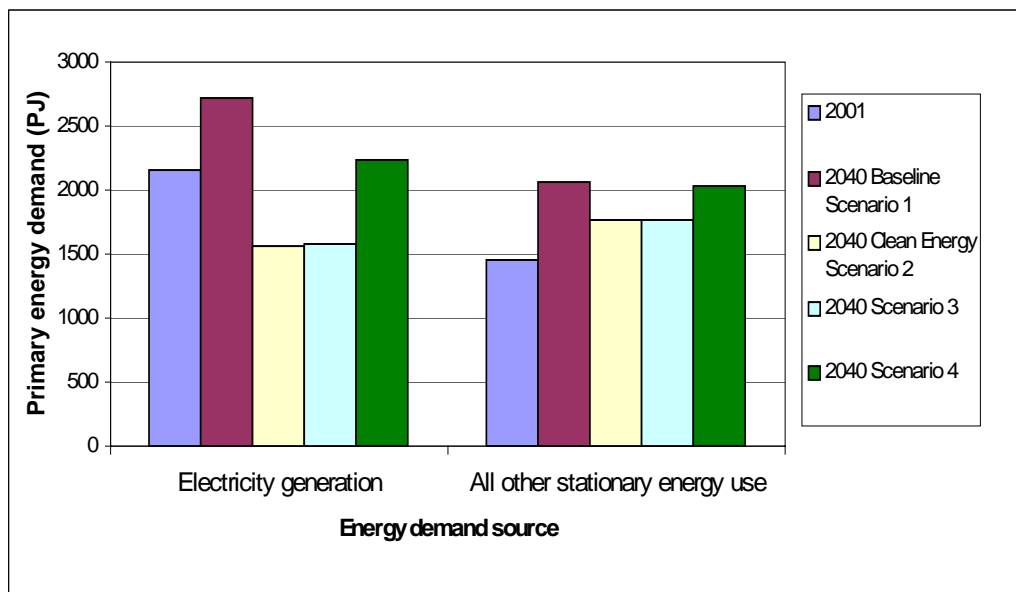
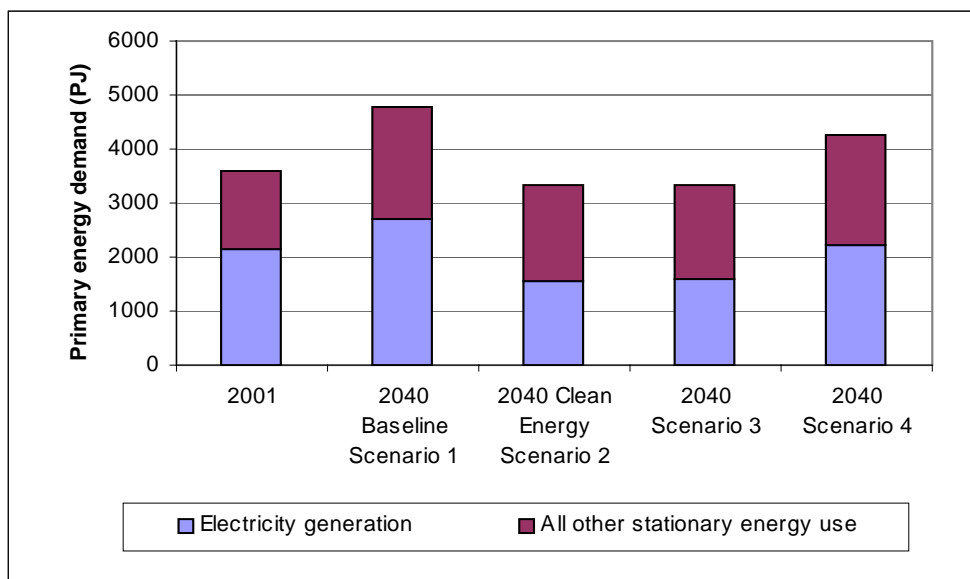


Fig. 10.4: Composition of total primary energy demand from stationary energy in 2001 and all 2040 Scenarios



10.2 Costs of the various scenarios

This report does not attempt to provide a full economic analysis of the 2040 scenarios. Indeed, as discussed in Section 2.1, we believe that this would be inappropriate for a time so far in the future, and we question the validity of the most commonly used integrated energy/macroeconomic models under these circumstances. Furthermore, there are some very large uncertainties, most notably the prices of fossil fuels and the extent of international and national constraints on greenhouse gas emissions in the

long-term future. There can be little doubt that oil will be scarcer and more expensive in 2040 than it is today and that this will drive up the prices of Australia's LNG and coal exports. This in turn will draw up the prices of domestic natural gas and black coal that are capable of being exported. The extent of these increases cannot be predicted. Therefore, we do not think that a detailed attempt to evaluate the costs and economic benefits of a 'business-as-usual' scenario would be a meaningful exercise. Neither cost-benefit analysis nor the standard type of macroeconomic modelling seems appropriate.

The uncertainty about these key input cost parameters also calls into question the value of applying very detailed and complex energy system costing models, at least in the first instance. As a first step in analysing the economics of our scenarios, we offer here approximate estimates of the cost of electricity generation in the Baseline scenario (Scenario 1) and the Clean Energy scenarios (Scenarios 2 and 3), making several different but plausible alternative assumptions in each case. While this does not provide a complete economic assessment of the impact of Clean Energy scenarios, it serves to highlight the impact on electricity costs of different assumptions about fuel prices, electricity demand and supply mix.

The method of funding our Clean Energy Scenarios (see Section 10.3) can be summarised as follows:

In the cases where the fossil-fuelled scenarios are clearly more expensive than the Clean Energy Scenario, there are no costs to fund.

In the cases where the fossil-fuelled scenarios are approximately the same cost or cheaper than the Clean Energy Scenario, the economic savings made by efficient energy use, together with the transfer of a fraction of the existing 'perverse' subsidies to the production and use of fossil fuels¹, pay for the additional costs of clean energy supply.

The cost estimates have been constructed on the basis of levelised costs in 2040, using a real discount rate of 8%. Because of the complexities involved, we have not attempted to estimate the costs of transmission and distribution.

The following further simplifications and assumptions are adopted.

- Electricity prices in \$/MWh are average long-run prices, not short-run marginal. In other words they comprise the annualised capital, fuel, operation and maintenance costs.²
- Since the future costs of hydro and petroleum are uncertain and are the same in all scenarios, they have been omitted from the costings.
- For simplicity we do not consider the fuel costs of peak-load plant, which are small when spread over a year.
- Also for simplicity, it is assumed that, in the Clean Energy scenarios, solar electricity is peak-load costing \$20/MWh more than conventional (hydro+gas

¹ See Section 10.3.

² Note that \$10/MWh = 1 c/kWh.

turbine) peak-load generation. It is further assumed that in the Baseline scenario the very small quantity of solar electricity costs the same as conventional peak-load.

- We examine the Baseline scenario (i.e. Scenario 1) with four different sets of fossil fuel prices. These four cases A-D all have the same electricity generation (352 TWh including cogeneration) and fuel mixes in 2040.
- In Baseline Cases A-D we assume (as ABARE does to 2020) that the proportion of electricity generated from natural gas increases steadily. The result is that, in all our fossil fuel cases, by 2040 67% of total electricity generation (including cogeneration) comes from coal and 16% from natural gas.
- The Clean Energy scenarios all have the same electricity generation (255 TWh including cogeneration) in 2040. Scenarios 2 and 2a have the same low coal contribution (just under 9%), but different fossil fuel prices, while Scenario 3 has zero coal.
- For cogeneration, it is assumed that the electricity cost equals the grid electricity cost for that fuel. (Sales of useful heat are assumed to offset any higher price of cogenerated electricity compared with conventional fossil fuelled grid electricity.).
- Coal-fired power stations are retired at the ends of the operating lifetimes that they can reach without a major refurbishment. This lifetime is taken to be 35 years.

Baseline Case A

In this case it is assumed that national policy will require the greenhouse gas emission intensity of coal-fired power stations in 2040 to be less than or equal to that of the best practice combined cycle natural gas power station in 2001, i.e. about 0.34 Mt CO₂ emitted per TWh of electricity sent out.³ Since the newest coal-burning technologies of 2003, such as ultra-supercritical boilers, have much higher emissions than this target, IGCC with geosequestration of CO₂ from both coal- and gas-fired power stations would seem to be the main option to explore. Therefore, the price of coal-fired electricity is likely to be around 10 c/kWh at the point of generation (see Section 8.4). Allowing 1 c/kWh for the additional cost of electricity generated from natural gas transmitted by pipeline to the eastern States from the North-West Shelf, the price of combined cycle gas-fired electricity with geosequestration is assumed to be around 7 c/kWh.

Baseline Case B

We assume no geosequestration, but rather that a carbon tax is placed on fossil fuels equivalent to their quantifiable external costs. As set out in Appendix A, we take the ExternE results for the costs of greenhouse gas emissions plus one-quarter of ExternE's air pollution costs for each of coal-fired and natural gas-fired electricity, and add them to the 2001 generation costs. The result is that electricity from coal is priced at 9.25 c/kWh and electricity from natural gas 7.0 c/kWh.

³ Such a policy would greatly reduce emissions for electricity generation, but not to the levels in our Clean Energy Scenarios.

Baseline Case C

We assume no geosequestration, but rather that the price of coal-fired electricity has risen from its present range of 3.6-4.0 to 5.0 c/kWh (2001 value) and that the price of base-load natural gas-fired electricity has risen from around 4 c/kWh to 5.0 c/kWh. For NSW this is approximately equivalent to assuming that the cost of steaming coal doubles to about \$2/GJ and that the cost of natural gas increases from \$3/GJ to \$4/GJ. For the purpose of comparison, we assume that these fossil fuel prices apply to both the Clean Energy scenario and to this fossil scenario.

Baseline Case D

As in Case C, but no significant increase in the cost of coal- and gas-fired electricity, which is held at 4 c/kWh for each. We compare Case D with a version of the Clean Energy Scenario (Scenario 2A) that has the same fossil fuel prices as Case D.

Clean Energy Scenarios

Our estimate of the costs is based on the following additional assumptions:

- Efficient energy use measures and solar hot water are implemented to the extent that they are cost effective over the lifetimes of the building, appliance or equipment concerned. Therefore, there are no net costs of efficient energy use (see Section 6.8). However, there are up-front costs. Because there are so many different technologies in third category, their average cost will be estimated as an output of the costs of energy supply in Table 10.5.
- Medium efficiency of energy use reduces demand for stationary energy in 2040 by 20%, as derived in Chapter 6. Further cost-effective reductions may be possible, although they are not considered in this study.
- The indirect economic benefits of efficient energy use that must be considered here include a reduction in the generation, transmission and distribution infrastructure required for 2040, as estimated below. This benefit will be offset to some extent by the costs of the energy efficiency measures, additional transmission and distribution costs of a more distributed electricity supply system and by the increase in peak-load gas turbine capacity required to back up wind power. These costs are very difficult to estimate accurately. For a first approximation we assume that the additional transmission and distribution costs of the centralised fossil fuel and more distributed Clean Energy scenarios are approximately equal. Because we expect most of the efficient energy use measures to pay for themselves within 8-10 years (compare Ministerial Council on Energy, 2003), the Clean Energy scenarios offer additional economic savings because they substitute for new power stations with lifetimes of 35-40 years. However, we do not attempt to calculate them, beyond suggesting that their magnitude is of the order of \$10 billion.
- The price of renewable energy technologies, except for biomass, is as given in Column 3 of Table 7.3.

- Specifically, for the 65 TWh (234 PJ) of biomass energy (final consumption) required for Scenario 2, it is assumed that 15 TWh comes from bagasse and sugar-cane ‘trash’ at a generation cost of 5 c/kWh; 39 TWh from wheat stubble at the generation cost of 6 c/kWh; 10 TWh from forest residues also costing 6 c/kWh, and the remaining 1 TWh from oil mallee and other eucalyptus crops with multiple economic benefits that reduce the cost of electricity to 7 c/kWh.
- For the 77.4 TWh (343 PJ) of biomass energy (final consumption) required for Scenario 3, it is assumed that 15 TWh comes from bagasse and sugar-cane ‘trash’ at a generation cost of 5 c/kWh; 39 TWh from wheat stubble at the generation cost of 6 c/kWh; 10 TWh from forest residues also costing 6 c/kWh, and the remaining 13.4 TWh from oil mallee and other eucalyptus crops with multiple economic benefits that reduce the cost of electricity to 7 c/kWh.
- For direct solar electricity, we assume that the additional cost is 2 c/kWh above the average peak-load price paid by consumers.

Indicative comparison of costs

Based on these assumptions, Table 10.5 shows the results of our estimates of the relative costs of four different cases for electricity generation:

Table 10.5: Cost of Baseline Scenario, Cases A-D, and Clean Energy scenarios with various fuel prices in 2040

Scenario	Electricity demand, 2040 (TWh)	Coal electricity price, 2040 (\$/MWh)	Natural gas electricity price (\$/MWh)	Wind electricity price, 2040 (\$/MWh)	Solar electricity price, 2040 (\$/MWh)	Total cost of electricity 2040 (\$ billion)	Average cost of electricity ^a (\$/MWh)
1: Cost A	352	100	70	55	Extra 20	29.5	90
1: Cost B	352	92.5	70	55	Extra 20	27.7	84
1: Cost C	352	50	50	55	Extra 20	16.4	50
1: Cost D	352	40	40	55	Extra 20	13.2	40
2: Cost C	255	50	50	55	Extra 20	12.2	54
2: Cost D	255	40	40	55	Extra 20	11.1	50
3: Cost C	255	N/A	50	55	Extra 20	12.3	56

Notes:

- a. This equals the total cost in billions of dollars (Column 7) divided by the energy generated by the sources considered here. The latter is equal to the total demand (Column 2) minus the generation from hydro and oil (not shown).
For other assumptions, see text.

The results are encouraging. Although the cost of electricity expressed in dollars per MWh (see Column 8 of Table 10.5) is lowest in Baseline Case D, there are fewer megawatt-hours generated in the Clean Energy scenarios. As a result, the total costs in billions of dollars of the Clean Energy scenarios are less than or approximately equal to those of all the Baseline scenario cases, even Baseline Case D with low-cost coal and gas. It appears that the only way the Baseline energy supply could compete with our Clean Energy scenarios would be to adopt an important component of the latter scenarios, namely, to implement Medium Efficiency energy use. In practice, this

option seems very unlikely, since cheap fossil fuels discourage the efficient use of energy.

The calculation is now refined by including the average costs of efficient energy use, which are derived as an output of Table 10.5. For fuel cost combination D, the difference in the total cost of electricity in 2040 between Scenarios 1 and 2 is \$(13.2 - 11.1) billion = \$2.1 billion. The difference in demand is (352 - 255) TWh = 97 TWh. Therefore, the breakeven cost of efficient energy use is $\$2100/97 \text{ MWh} = \$21.6/\text{MWh}$. In other words, so long as the cost of efficient energy use is less than \$21.6/MWh saved, Scenario 2 (Clean Energy) is less expensive than Scenario 1 (Baseline). Similarly, for the fuel cost combination C, the breakeven cost of efficient energy use is \$43.3/MWh saved. In other words, in Case C efficient energy use could make a much greater, cost-effective contribution to the Clean Energy scenarios. In Cases A and B, efficient energy use would be competing with the costs of wind power and biomass electricity.

Including part of the environmental and health costs of the fossil fuel scenarios, either by using the IEA estimates of the costs of geosequestration of CO₂ (Baseline Case A) or by using the ExternE estimates of the external costs of fossil fuels (Baseline Case B), makes the Baseline cases much dearer than our Clean Energy Scenario.

10.3 Paying for cleaner energy scenarios

Any additional costs of the Cleaner Energy Scenario could be readily paid out of the existing financial subsidies to the production and use of fossil fuels. A recent estimate of the minimum level of these subsidies is \$6.5 billion p.a. (Riedy and Diesendorf, 2003). These subsidies include:

- electricity price subsidies to aluminium smelting;
- tax benefits for salary packaging motor vehicles;
- Greenhouse Gas Abatement Program (which goes mostly to fossil fuels);
- fuel excise reduction;
- fuel sales grants scheme;
- automotive industry support;
- land for roads and car parking;
- reduced import duty on 4WDs;
- inappropriate company tax concessions;
- R&D support for fossil fuels;
- non-recovery of government agency costs (e.g. AGSO, DITR, various State departments).

Subsequently this work has been extended by Riedy (2003), who has calculated additional subsidies that lift the total to \$9 billion per year. Riedy has classified the subsidies into 'positive', 'negative' and 'perverse' subsidies. The latter category comprises subsidies that are both economically inefficient and environmentally damaging. Such subsidies amount to \$5.2 billion per year. A small fraction of these could be used on a temporary basis to speed up the transition to a 50% reduction in CO₂ emissions from stationary energy.

Finally, it is important to realise that the macroeconomic benefits of increasing energy efficiency are conceptually identical to the macroeconomic benefits of increasing

labour market efficiency. While the latter has been the objective of government policy in Australia for over 15 years, the former is generally seen as a peripheral problem to be pursued primarily for environmental reasons. In fact, minimising the amount of energy required to produce a given level of output is as economically beneficial as minimising the amount of labour or capital input. Reducing energy consumption per unit of output will free up resources, particularly resources that would otherwise be directed towards energy generation and distribution, that can be directed towards more productive purposes.

11. Innovative Scenarios for Beyond 2040

As discussed in Chapter 1, before the end of the 21st Century, Australia and other rich countries may have to reduce their anthropogenic greenhouse gas emissions by 80% or more. Furthermore, the energy sector, as the principal cause of these emissions, must carry the principal burden of this reduction.

The first step is for Australia to move to an economy where there is no longer any increase in the consumption of materials and energy. Any growth in GDP must be decoupled from these flows. There are examples where this has been achieved partially and temporarily, without a decline in living standards: Denmark enjoyed steady economic growth in the 1980s without growth in stationary energy; China's economy in 1996-1999 grew at over 7% p.a. while reducing greenhouse gas emissions. So, for all scenarios beyond 2040, we assume that the main drivers of energy demand are exhausted: energy intensive industries have peaked; economic structure has shifted further towards the service sector, within which travel has peaked; population has stabilised at around 25 million; and efficient energy use has been further implemented. The result is that energy consumption has been reduced to the 2001 level by 2050.

In our Clean Energy – Scenario 2, the main contributions to stationary energy come from natural gas, biomass, wind power and solar heat at low temperatures. But, in the long run, probably before the end of the 21st century, Australia's reserves of natural gas will become scarce. Biomass energy may have to take on a major role in fuelling transport and would then be making substantial additional demands on land use. Furthermore, wind power above 20 GW of capacity may be reaching the limits of available land.

Therefore, to gain further reductions in CO₂ emissions post-2040, it is essential that, in parallel with the further development of existing commercial technologies -- such as energy efficient appliances, equipment and buildings, wind and biomass -- that innovation is sought in new and existing technologies. To this end, we sketch three scenarios for 2040-2100 that are based on major improvements to existing technologies. In each case we assume that by 2040:

- Scenario 3 (i.e. zero coal-fired electricity) has been implemented;
- population growth has ceased;
- decline in household size has ceased;
- growth in GDP has been almost completely delinked from energy consumption.

First it is necessary to consider a scenario that is unlikely to work in the long term.

11.1 Scenario 5: Geosequestration of CO₂ from distributed sources

This scenario continues with the same energy supply mix as our Scenario 3 discussed in Chapter 10. The only difference is that CO₂ emissions from power stations and other large point sources that produce or burn natural gas or biomass are captured and subject to geosequestration.

Biomass energy produced in an environmentally sound manner should have no net CO₂ emissions, because the emissions produced by combustion are balanced by the

CO₂ absorbed during regrowth.¹ So, in theory, geosequestration of emissions from the combustion of biomass produces net emission reduction that can be offset against emissions from fossil fuels in the rest of the energy supply mix.²

In practice this would be an expensive scenario, because:

- CO₂ emissions from point sources in NSW would have to be piped 500-700 km to southern Victoria for geosequestration;
- instead of about 25 large centralised power stations, there would be hundreds of smaller natural gas and biomass fuelled, distributed power stations from which to separate the CO₂ emissions and pipe them into a pipeline distribution system that feeds into the main transmission pipelines.

Furthermore, this would only be a temporary solution, because natural gas is expected to become scarce in the second half of C21, especially if LNG exports continue at high levels.

11.2. Scenario 6: Low-cost renewable electricity without additional storage

Electricity

There are several possibilities for generating large quantities of low-cost electricity in the longer term future, which are not restricted by land-use limits. These sources include rooftop and building-integrated photovoltaics, solar thermal electricity and hot-rock geothermal, as discussed in Chapter 7. Here we focus on cheap photovoltaics.

If current R & D on thin film and other innovative solar PV systems is successful, we might obtain modules at US\$0.5 per watt, inverters at A\$0.5 per peak watt and installation at A\$0.5 per peak watt (compare prices in Section 7.5), giving a price of electricity generated on suburban roofs of around 10 c/kWh in Australian currency. This would be competitive with centralised supply in every capital city and so all households with sufficient insolation on roofs or walls could switch to solar.

At first thought, this suggests that all natural gas-fired power stations, apart from cogeneration plants, could be replaced with direct solar. However, there would be times when the skies are overcast and there is little wind. Clearly, in the absence of cheap electricity storage, electricity generation comprising 39% solar and 20% wind cannot be backed up by 33% biomass and 7% stored hydro-electricity, especially since a significant fraction of the biomass would be in the form of cogeneration. In addition, a large amount of peak-load back-up would be required. This could take the form of gas turbines fuelled with (say) biofuels 67% and natural gas 33%. The largest contribution to capacity would be from gas turbines backing up the wind and solar. Although the capacity of these peak-load generators would have to be high, the capacity factor would be low. If this back-up provided (say) 15% of total grid electricity generation, and the 1% petroleum is replaced with biodiesel, the final electricity generation mix would become: 44% biomass, 24% solar, 20% wind, 7%

¹ See Azar et al. (2003). In practice, there will be some CO₂ emissions if the biomass crops are harvested and transported by means of fossil fuels. However, with good system design, these can be kept small.

² If there are no fossil fuels in the energy supply mix, then geosequestration of emissions from biomass combustion could be used to reduce the concentration of CO₂ in the atmosphere.

hydro and 5% natural gas. Since electricity demand is postulated to be at the 2001 level, the quantity of biomass used annually for electricity generation would be only slightly greater than that of Scenario 3. In Scenario 6, the only CO₂ emissions from electricity generation would come from the small quantity of natural gas burnt as part of the peak-load back-up, amounting to about 4.1 Mt or 2.3% of the CO₂ emissions from electricity in 2001.

All other energy

Cheap photovoltaics would not be able to reduce emissions from the rest of stationary energy which come from natural gas, petroleum and coal in that order. Most of the 24 Mt of CO₂ emissions from petroleum could be replaced completely with bio-diesel, and this would be encouraged by the high prices of diesel expected in 2040. If the coal used (as coke) in metallurgical processes (about 130 PJ) could be replaced by either charcoal (produced from biomass, see Section 7.1) or hydrogen (produced by electrolysis using renewable electricity), then a further reduction of about 13 Mt CO₂ would be achieved. This would of course require the adoption of different metallurgical processes from blast furnace iron and steel production. The result is that CO₂ emissions from stationary energy that is not electricity are reduced to about 53 Mt (including energy used in oil refining and gas processing to supply natural gas and petroleum fuels for transport), which is a reduction of about 42% compared with 2001 emissions from the same category of stationary energy.

Total stationary energy

Scenario 6 starts with Scenario 3 and replaces most natural gas used for electricity generation with PV and all coal and petroleum for stationary energy with bioenergy or electricity. The net effect on stationary energy is that CO₂ emissions are reduced to 22% of the 2001 level. So, even without the assumption of additional low-cost storage, a reduction of nearly 80% in emissions from stationary energy could be achieved. Even greater reductions would be possible by using solar thermal systems with concentrators to produce both high-temperature heat and electricity.

11.3. Scenario 7: Cheap renewable electricity with cheap storage

As discussed in Sections 7.8 and 7.9, several kinds of storage are possible, for instance:

Advanced batteries with low-cost residential PV systems.

In this case an electricity supply mix of 39% direct solar, 33% biomass, 20% wind, 7% hydro and 1% biofuels is feasible and zero CO₂ emissions could be achieved from electricity generation. Low-cost advanced batteries would make solar energy a 'dispatchable' source of electricity, thus increasing its economic value. But, since PV systems do not address the non-electricity part of stationary energy, they are at best a partial solution.

Hydrogen produced by means of the electrolysis of water by low-cost renewable energy.

With low-cost storage the only limitation on total wind power capacity is the availability of sufficiently windy sites. Hydrogen may be converted back into

electricity in fuel cells. However, since we can eliminate almost all emissions from electricity generation with low-cost solar and no storage (as in Section 11.2), our main interest in hydrogen is for the production of process heat at high temperature by combustion (substituting for natural gas), as a chemical reductant in metallurgical processes, and for mechanical energy (substituting for petroleum or biodiesel in stationary energy). To satisfy this demand and also to fuel large motor vehicles³ (trucks and buses), would require substantial production of hydrogen, taking into account the low efficiencies involved. Currently wind power appears to be potentially one of the lowest cost renewable energy sources. To meet the kind of hydrogen demand envisaged here, the development of off-shore sites may be required.⁴

Low-cost, high temperature solar thermal systems with low-cost thermal storage

These technologies would directly address the non-electricity part of stationary energy, as well as electricity. Together with biomass energy, wind power and some hydro-electricity, they would enable a complete elimination of CO₂ emissions from stationary energy. Because thermal storage is potentially much less expensive than electrical storage, this pathway could turn out to be one of the most cost-effective.

11.4. Concluding remarks

Simply by considering some major improvements in a few existing technologies, such as PV or high-temperature solar thermal with thermal storage, it is clear that there are several alternative pathways to 80% (or more) reductions in CO₂ emissions from stationary energy. Furthermore, Scenarios 2 and 3, that led to 50-55% reductions (as discussed in Chapter 10), can form the foundations of Scenarios 6 and 7 which achieve 80-100% reductions. The scenarios take account of limited land area and limited reserves of oil and, in the long term, natural gas. Entirely new technologies do not have to be postulated, although no doubt they will appear, giving us even more choices.

The main conclusion is that Australia should keep open its future energy options by:

- fostering the cleaner, youthful energy industries that form the basis for Scenarios 2 and 3, namely efficient energy use, biomass, wind and solar hot water; and
- expanding R & D support for a small portfolio of technologies that have the capacity to lead us from Scenarios 2 and 3 to a completely clean energy future. Among these are PV, thermal energy storage, high-temperature solar thermal, off-shore wind and further work on gasification and pyrolysis of biomass.

The R & D that is needed is not simply science and engineering, but must also encompass socio-economic, business development and policy aspects, which are most important for implementation. Specific policies and strategies are recommended in the next Chapter.

³ Hydrogen is less suitable for motor cars because of its low energy density which entails a much larger fuel tank than for liquid petroleum or liquid biofuels, unless there is a substantial improvement in fuel efficiency.

⁴ To the best of our knowledge there have been no published studies of Australia's off-shore wind energy potential. However, on the basis of near-coastal ocean depths, the potential is likely to be less than that of Europe.

12. Policy options and strategies

This chapter first sets out some axioms and broad principles and then proposes specific greenhouse response policies and strategies for all levels of government, business and other stakeholders in order to achieve our principal scenarios for 2040.

12.1. Axioms and principles

1. The human-induced greenhouse effect is real; its main cause is the combustion of fossil fuels; its result is global climate change which is already occurring; and it requires urgent, substantial, international, national and local action.
2. The main drivers of increasing combustion of fossil fuels are economic growth, the widespread use of inappropriate technologies and population growth.
3. The goal, core objectives and Precautionary Principle of ecologically sustainable development should be applied to this situation. Those accepted by the Australian Government (1992) are:

Goal:

Development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.

Core Objectives:

- To enhance individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations.
- To provide for equity within and between generations.
- To protect biological diversity and maintain essential ecological processes and life support systems.

One of the key Guiding Principles, *the Precautionary Principle*, is:

Where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

4. Following modelling by the IPCC, global greenhouse gas emissions will have to be reduced by 60-70% compared with current levels before the end of the 21st century.
5. Taking into account the needs of developing countries, this means that Australia's total greenhouse gas emissions may have to be reduced by at least 80% compared with current levels before the end of the 21st century.
6. The energy sector, as the principle source of Australia's emissions, cannot be sheltered from the implications of this large volume of emissions and therefore its emissions must be reduced by at least 80% compared with current levels before the end of the 21st century.
7. All levels of government, business, trade unions, community-based non-government organizations and individuals must play active roles in this transition.

8. The main barriers to making the transition are neither technical nor economic¹, but rather are social and institutional.² Therefore, the enhanced greenhouse effect cannot be simplistically attributed to perverse individual behaviour. An effective response requires governments to intervene to change the institutional structures and an economic system that fosters energy waste and excessive use of fossil fuels.
9. The environmental and social benefits of the efficient use of energy and the use of renewable sources of energy are large and should be reflected as far as possible in pricing and government funding.
10. Government action in Australia is currently inadequate for achieving a transition to an ecologically sustainable and socially equitable energy system. An adequate response must address all aspects and portfolios.
11. Australia is well placed to gain competitive advantage from building up its industries in efficient energy use and renewable energy. Given nurturing in their early years, these industries can provide substantial exports and import substitution.

The implications of these axioms and principles are that Australia needs visions of clean energy futures and public debate about policies and strategies for implementing them. It also needs firm targets and timescales for reducing greenhouse gas emissions in the energy sector and a wide range of economic social and regulatory instruments to encourage implementation, namely:

- shaping the market for energy services³ in order to remove barriers to efficient energy use, renewable energy and natural gas;
- taxes and user charges;
- regulations and standards;
- organisational structures and processes;
- education, information, training; and
- targeted funding for infrastructure, R, D & D, retooling of manufacturing industry and alleviating energy poverty among low-income earners.

The barriers to efficient energy use, renewable energy and natural gas have been discussed by IPCC (2001b, Chap.5), Watt and Outhred (1999) and Greene and Pears (2003) and references therein. They need not be repeated here. They are implicit in the following specific proposed policies and strategies, which contain both short-term and long-term measures. The numbering is for ease of reference and does not reflect priority. The distinction between policies and strategies is not a sharp one, so we do not attempt to separate them here. There is a great need for both general and specific actions. Section 12.2 recommends policies and strategies that apply to all levels of government

¹ Taking into account the large economic subsidies to the production and use of fossil fuels and the failure so far to include environmental and health costs in the prices of fossil fuels.

² This is not simply an axiom, but is also a finding of IPCC (2001b) and is supported by the results of this and other Australian studies, such as Watt and Outhred (1999), Greene and Pears (2003) and references therein.

³ Rather than for energy generation or use per se.

and would assist cleaner energy technologies in general. Section 12.3 addresses more specific policies and strategies for particular energy technologies and systems.

12.2. Policies for all spheres of government

1. Introduce separate targets for greenhouse gas reductions for Australia, each State and Territory, and each Local Government area. Require each responsible level of government to develop a publicly available strategic plan and action plan of implementation and to report publicly on progress each year.
2. Introduce separate targets for greenhouse gas reductions for the in-house operations of the Australian Government, each State and Territory Government, and each Local Government. Require mandatory annual public reporting of their own energy consumption and GHG emissions by all these governments and their public services.
3. Legislate to require businesses with annual turnover greater than \$10 million to implement Policy 2.
4. Introduce in-house carbon levies to fund emission reduction within government's own operations, and encourage or require adoption of such internal levies by participants in Greenhouse Challenge and other government programs.⁴
5. Introduce minimum energy efficiency and greenhouse standards for the procurement by government of buildings, office and other equipment, appliances and hot water.
6. Substantially increase the Mandatory Renewable Energy Target (MRET) as an industry development measure to build industry capacity and capability. In the longer term this can be dovetailed into an emissions trading scheme as costs of renewable energy fall.
7. Increase funding for R, D & D on efficient energy use and renewable energy technologies, on socio-economic and policy aspects, and on the organisational and institutional changes required for dissemination of the technologies.
8. Foster public education and information about efficient energy use and renewable sources of energy.
9. Modify the National Electricity Code in order to:
 - include constraints on CO₂ emissions that are progressively tightened over the years;
 - recognise the additional economic value of renewable energy sources;
 - ensure that the sale of electricity to the National Electricity Market by natural gas and renewable energy generators is not treated less favourably than from any other energy source or technology.

⁴ Such an approach means that governments and businesses will start to see carbon price signals, but the money will stay within the government programs and businesses and can be used to fund actions that reduce emissions and in many cases repay rapidly the initial investments.

10. Support the promotion of Australian technology and expertise internationally through the establishment of a specific export development fund to promote Australia as a provider of renewable energy technology, goods and services, especially in the Asian and Pacific-rim markets.⁵
11. In all policy contexts recognise the importance of minimising legislative and regulatory uncertainty in order to maintain investment confidence.

12.3. Specific policies to assist specific technologies and systems

For convenience, these recommendations have been organised in technology groups.

Efficient energy use⁶

1. Implement national mandatory energy and greenhouse labelling for all appliances and equipment with the capacity to use more than 50 watt of electricity or 5 MJ/hour of natural gas.
2. Implement national mandatory minimum energy and greenhouse performance standards for all appliances and equipment with the capacity to use more than 50 watt of electricity or 5 MJ/hour of natural gas. Make standards increasingly stringent every 5 years, publishing schedules for improvement 3-5 years ahead, so that businesses can plan, and with requirements based on the world's best practice, not just removal of the worst products from the marketplace.
3. Legislate for mandatory energy performance standards for all homes, with new and renovated homes to meet standards forthwith and existing homes to achieve specified standards increasing in 5-year steps. Since NatHERS simulation is only concerned with the building envelope, develop a more comprehensive indicator of factors influenced during construction, such as heater/cooler efficiency and fuel, cooking fuel, hot water system efficiency and fuel, installed lighting density, provision of solar clothes drying facilities (clothesline), etc.⁷
4. For all homes mandate energy and greenhouse gas ratings and require that these ratings be published in all advertisements and contracts for the sale or rental of the homes.⁸
5. For all commercial buildings mandate minimum energy and greenhouse performance standards based on the Australian Building Greenhouse Rating Scheme. Building owners to be given options to comply, including the use of Green Power and Renewable Energy Certificates (RECs) under MRET. The minimum performance standards should initially include a 5-star requirement for

⁵ For some young technologies, such as photovoltaics, the domestic market is still too small to support the industry, and so exports can play a vital role in industry development.

⁶ For more detail see BCSE (2003).

⁷ SEDA's Energy Smart Homes point score system is a step towards such an indicator and NatHERS now includes a statement of star rating for heater, cooler and water heater, but neither integrate the envelope/heater/cooler combination to provide a space conditioning energy estimate.

⁸ As currently practised in the A.C.T.

new buildings including fitout, and a requirement for existing commercial buildings to be progressively improved to achieve 4-star rating.

6. Increase funding for the Cities for Climate Protection (CCP) program for local governments from the present level of \$13M over 5 years to 10 times that level for the next 5 years and maintain that level to 2020 at least. The present funding only provides on average about \$3,500 p.a. per Council. Considering the large number of local governments in Australia and the wide range of ways they could reduce GHG emissions, there would be no problem in spending the enhanced funding effectively. Require each local government to report annually on the use of the funding.
7. Award one-off grants to manufacturers of energy-consuming appliances and equipment, so enable them to retool in order to meet the mandatory energy performance standards.

Biomass energy

8. Change the MRET regulation to actively encourage dedicated tree energy crops for the purpose of growing biomass for fuel on land that has been cleared before 1990.
9. Pay an agreed contribution for the planting of energy (and other) crops grown for the purpose of limiting dryland salinity, erosion and other forms of land degradation.
10. Introduce biomass establishment grants for growing energy crops.
11. Provide specific support for the development of a national bioenergy roadmap for Australia and its implementation.
12. Provide a bioenergy showcase program to demonstrate a full-scale, integrated energy crops/energy conversion project in Australia.
13. Encourage the shift to highly efficient, low emission, biomass-burning stoves and heaters, especially in urban areas. The aim is to phase out polluting open fires and inefficient burners and to encourage the use of highly efficient biomass burners, such as pellet stoves and heaters. An initial step should be to ban open fires and open fireplaces in metropolitan and urban areas.

Wind power

14. With wide public consultation, develop and implement consistent planning guidelines across all levels of government for the establishment of wind farms.
15. Develop grid management policies that allow for the inclusion into Market rules of 24-48 hour wind farm output forecasting data. The use of such data will allow for the greater penetration of wind energy and optimised cost and/or emissions reductions.

16. Extend State and federal incentives for small renewable energy generation systems, such as solar thermal and solar photovoltaic rebates, to include small wind turbines of less than 100 kW capacity that service a similar need and market.

Solar hot water and direct solar electricity

17. Mandate that electric hot water services in mainland Australia be sold packaged with a lifetime Green Power purchasing requirement. The purchase package would have to include the installation of a time-of-day meter in cases where it is not already connected.⁹
18. Mandate that a solar, heat pump or solar compatible natural gas hot water system with low standby losses be installed in every proposal for a new or substantially renovated residential building. Where natural gas and sunshine are both available, mandate that the only system that may be installed be gas boosted solar.
19. Local governments to implement rules protecting solar access of all existing and new buildings.
20. Local governments to remove planning requirements on the installation of solar hot water and photovoltaic modules on residential buildings.¹⁰
21. Because of the huge potential for solar photovoltaic and solar thermal electric systems in Australia, include specific tranches for each of these technologies in the R, D & D funding addressed in Section 12.2.

Electricity generation and retailing

22. Mandate that there will be no new or refurbished base-load or intermediate-load power stations with emission intensities greater than that of the best available combined-cycle natural gas power station. Refurbishment is defined as an investment greater than \$50 million 2003 Australian dollars.¹¹
23. Mandate generator efficiency standards for existing base-load and intermediate-load power stations to ensure that the existing stock of power stations is reducing emissions and improving efficiency.
24. Require electricity retailers to reduce progressively the greenhouse intensity of electricity sold. Retailers must be able to meet these requirements in part by providing programs to reduce their customers' energy use.¹²
25. Establish a target for cogeneration and provide grants on a dollar for dollar basis to assist in funding feasibility studies for specific projects.

⁹ So that consumers can contribute to the additional infrastructure costs of using peak-load electricity.

¹⁰ Currently, different Councils impose different conditions (including no constraints in some areas). Planning requirements generally take weeks to satisfy, and so disadvantage solar compared with electric and gas hot water.

¹¹ Until such time as the market reflects the full economic, environmental and health costs of burning coal, a mandatory constraint on emissions seems to be the only way of cleaning up electricity supply.

¹² This will encourage electricity retailers to become energy service providers rather than suppliers of a commodity.

Transmission and distribution

26. Treat the funding of new electricity transmission and distribution lines for wind power, biomass, other renewables and natural gas and on the same basis as the historic funding of network expansion for centralised power generation from fossil fuels.¹³ Therefore, ‘smear out’ the cost over electricity charges for all consumers¹⁴. The impact may be softened by government capital contributions.
27. Similarly, treat the funding of new additions to the natural gas network on the same basis as the historic funding of network expansion. Therefore, ‘smear out’ the cost over gas charges for all consumers. The impact may be softened by government capital contributions.
28. Require all proposals for new transmission and distribution lines for the purpose of meeting increasing demand to assess the alternative option of reducing demand. This assessment should be adjudicated by State Environment Protection Authorities.¹⁵
29. Mandate that all new electricity connections for residential and business use have a time-of-day meter; that complete replacement of all existing meters with time-of-day meters be implemented over a decade; and that energy retailers must bill customers with these meters according to a published time-of day tariff.¹⁶
30. Revise the National Electricity Code to ensure that distributed generators receive fair network access and pricing, considering location of generators and time of day of generation.¹⁷

Prices and subsidies

31. Remove all subsidies and cross-subsidies from electricity and fuel prices in rural areas, and replace with direct payments of rural allowances.¹⁸
32. When existing State Government contracts with aluminium smelters come up for renewal, require State Governments to remove *de facto* subsidies for electricity

¹³ Transmission lines would never have been built to serve customers beyond the cities without this principle. Furthermore, we take into account the fact that cleaner energy scenarios have lower energy demand than baseline fossil fuel scenarios. This saves money that would otherwise have to be spent on extra generation, transmission and distribution for the latter scenarios. (See Section 10.3 under ‘Clean Energy Scenario 1, 3rd dot point.’)

¹⁴ Since customers benefit from accessing additional generation, whether it is distributed or centralised.

¹⁵ This is to counter a perceived cultural and institutional bias towards increasing supply.

¹⁶ This will encourage efficient energy use by making electricity consumers pay a price for energy consumption during peak periods (e.g. from air conditioning) that better reflects infrastructure costs, and will also encourage the installation of solar electricity by reflecting its economic value better.

¹⁷ Despite the good intentions of those who drafted the Code, it was framed at a time when the grid was (and still is) characterised by large thermal generators clustered in a few locations and joined to the major customer load centers by a few transmission lines. Renewable energy and most natural gas power plants tend to be smaller and less centralized.

¹⁸ This would permit residents of rural areas the option to spend the payments on efficient energy use and renewable energy that are often more cost-effective in rural areas than supply from centralised power stations.

and infrastructure. Use part of the savings to facilitate the creation of new jobs in any region in which a smelter is subsequently closed down.¹⁹

33. Reform the pricing of access to and use of electricity transmission and distribution grids, in order to avoid overcharging small, dispersed generators of electricity that connect to the distribution network alone, or use only a short distance of transmission line.

12.4. Costing the recommendations

At first sight there appear to be many policies and strategies. However, it must be kept in mind that these span all three levels of government, all portfolios and a variety of types of measures that interlock and complement one another. They involve economic instruments, regulations and standards, targeted funding, organisational change, and education.

Only a few of the recommended policies involve significant costs.

- expansion of MRET; we envisage that this would be the largest item, possibly amounting to \$400-\$500 million p.a. until a self-funding carbon tax or tradeable emission permit system is implemented;²⁰
- expansion of Cities for Climate Protection (\$130 million over 5 years);
- expansion of R, D & D (\$30 million p.a.);
- assistance to farmers for limiting dryland salinity and other forms of land degradation by planting biomass for energy crops, which will have to be done anyway (\$50 million p.a.);
- the creation of biomass establishment grants and showcase, and cogeneration grants. (\$5 million p.a. for 5 years.);
- retooling grants to manufacturers. (\$15 million p.a. for 3 years.);
- replacement of existing electricity meters with time-of-day meters over a decade, which will be paid by electricity consumers and merely brings forward an investment that will have to be made anyway (not costed).

These costs initially amount to less than \$630 million p.a. and are all temporary. The first and largest is paid for by electricity consumers and the others by government. They could be funded by reducing some of the perverse subsidies (over \$5 billion p.a.) to the production and use of fossil fuels (see Section 10.3).

¹⁹ This is recommended on the basis that the aluminium industry is a huge greenhouse polluter, employs very few people in relation to the amount of capital invested, and receives large *de facto* subsidies (Turton, 2002), and that Australia is one of only a few countries where aluminium smelting is based substantially on burning coal.

²⁰ MRET is paid for by electricity consumers, rather than government, and corresponds to an increase in electricity price about 0.2 c/kWh. However, a reduction in demand for electricity, resulting from enhanced efficiency of energy use, could maintain electricity bills at the same level as before MRET.

13. Comparison with other 'deep cuts' studies

This chapter reviews briefly some of the other scenario studies of 'deep cuts' in CO₂ emissions from Australia and overseas.

13.1. ABARE's MENSA model, Australia

MENSA was developed from the International Energy Agency's MARKAL model by the Australian Bureau of Agricultural and Resource Economics (ABARE). It is the principal 'bottom-up' model of the Australian energy system. 'Bottom-up' or 'engineering' models start with a large database on the performances and costs of all conceivable energy supply and energy using technologies. Then, given scenarios for future growth in the demand for energy services, these models calculate the combination of technologies that gives the least cost within the energy sector. By its very nature MENSA cannot examine the impact of changes in the energy sector upon the rest of the economy.

However, a strength of MENSA is that, unlike 'general equilibrium' models, it does not assume that the present energy system or future business-as-usual energy scenarios are necessarily least-cost. As a result, MENSA and similar models generally find that some reductions in greenhouse gas emissions can be achieved with economic savings.

In the early 1990s, within the Ecologically Sustainable Development (ESD) Energy Production Working Group, MENSA was used to answer the question:

"If the government imposed a 20% reduction on greenhouse gas emissions from the electricity industry within a certain period and if the non-technical barriers to efficient energy use and renewable energy were removed, what would happen to the existing array of energy technologies and what would those changes cost?"

At the time of doing this study, Australia's proposed greenhouse gas reduction target was the Toronto Target, a 20% reduction in CO₂ emissions below the 1990 level by 2005. Applying this target as a constraint gave the result that by 2005 all brown coal power stations had been phased out and generation from black coal decreased by 80-90%. Their places were taken by natural gas and the cheaper renewable sources of energy. The cost of this transition was found to be about 2% of the total annual cost of the energy sector.

This rapid (15 year) phase-out scenario entailed that most coal-fired power stations had to be shut down before the ends of their operating lives. As a result, costs were higher than they would have been under scenarios that allowed them to retire at the ends of their lifetimes (30-40 years) and then replaced them with a combination of efficient energy use, natural gas generation and renewable energy sources.

This early work with MENSA also suffered because of the gaps in the database on technologies for efficient energy use. Subsequently, this part of MENSA's database was improved and it was found that some scenarios for greenhouse gas reductions in the residential sector led to substantial net cost savings.

References: ESD (1991); Naughten et al. (1994).

13.2. 'Deep cuts' study by the Australia Institute

The 'deep cuts' study by the Australia Institute (TAI) was one of the inspirations for the present study (see Turton et al., 2002).

TAI considers a 60% cut in greenhouse gas emissions from the energy sector (including transport) by 2050. It requires that technologies used be already proven, although not necessarily currently commercial. Unlike the MENSA model, it does not attempt an economic optimization and indeed argues that that would be inappropriate for such a large step into the future. However, it requires that the costs of energy production in 2050 must be no greater than current average energy prices in Western Europe, which are 50-100% higher than current energy costs in Australia. Having stated that, it does not present the actual costs of its 2050 scenario.

The basic assumption of the study is that the economy drives greenhouse gas emissions. So the study develops projections for the growth or decline of each sector of the economy. It then provides an analysis of opportunities for reducing emissions in each sector by implementing efficient energy use and fuel switching. The study covers the whole energy sector, including transport, and also all of the non-energy sources of greenhouse gas emissions. These are the main strengths of the study.

The study finds that, using available technologies, Australia could feasibly cut its greenhouse gas emissions by 60% by 2050. To achieve this would entail significant trade-offs: for example allocation of a significant fraction of Australia's arable land to biomass crops and plantations.

However, the study was conducted without external funding and this has inevitably resulted in several limitations:

- The description of the electricity supply system is very general and incomplete. We are told that grid-connected wind power will provide 50% of electricity, but it is unclear how much electricity and heat will come from natural gas and biomass.
- The reader is given the impression that most of the electricity supply system will actually be in the form of local cogeneration, which is presumably either entirely separate from the transmission grid or at best involved in small transfers in each direction between the grid and the cogeneration plant. If so, how will the large fluctuations in wind electric power be stabilised? Hydro-electricity will not be sufficient. An electricity grid with 50% windpower will require much long-term storage, which is not specifically described in the study.
- There are some inconsistencies in the treatment of population growth. For instance, a statement in the Summary assumes that a 60% decrease in greenhouse gas emissions by 2050 is equal to a 60% decrease in *per capita* emissions over the same period, which is incorrect when there is population growth.
- The study's principal scenario is one with a significant growth in aluminium production, in other energy intensive extractive and process industries, and in beef

production (a major source of methane emissions). Sensitivity analyses of alternative economic structures, with a stronger shift towards elaborately transformed manufacturing and services, would probably have demonstrated that the same emission reductions could be achieved at lower cost (or greater reductions at the same cost).

13.3. Ecofys study on the EU

This study (Harmelink et al., 2003) focuses on the electricity industry and achieves a 60% reduction in CO₂ emissions between 1997 and 2020, based mostly upon existing technology. Although such a rapid change in the industry would be technically possible, it would inevitably result in the premature retirement of many fossil-fuelled power stations. The cost of these ‘stranded assets’ would be substantial. However, it could be argued that, after internalising external costs, there would be net benefits, and the costs of ‘inaction’ would be much higher. However, this study does not attempt to evaluate costs apart from roughly estimating that this package costs 10- to 30 Euro per capita per year.

On the demand side, the EU has the advantage over Australia that the former’s population growth is much less. Therefore, over the 23 year period considered, efficient energy use can readily compensate for the effect of GDP growth. Even so, the reader is left with the feeling that the full potential of efficient energy use has not been achieved. The study focuses on ways of using *electricity* more efficiently and so misses out on opportunities to reduce electricity use by switching from electricity to solar for space heating and water heating.

On the supply side it is surprising that the study does not increase the use of natural gas, but rather assumes that biomass can rapidly fill the gap left by coal. Indeed, the report seems to assume that retired coal-fired power stations can readily be transformed into biomass power stations, which is doubtful. The most cost-effective biomass-burning power stations are smaller, situated near the biofuel sources and so are less centralised than coal-fired power stations, as discussed in Chapter 7.

In the Ecofys study wind power is a distant second in substituting for coal. This is surprising, considering Europe’s huge off-shore wind energy potential. In this study it appears that nuclear energy maintains most of its existing contribution.

13.4. Royal Commission on Environmental Pollution on the UK

The aim of the study by the UK Royal Commission on Environmental Pollution is to develop scenarios that achieve a 60% reduction in CO₂ emissions from the energy sector by 2050 compared with the 1998 level (RCEP, 2000). The study disaggregates energy uses into the forms of electricity, high-temperature heat, low-temperature heat and transport.

It develops four scenarios with different levels of energy demand and different supply mixes in 2050. All scenarios have substantial implementation of efficient energy use, with the least efficient having the same energy use in 2050 as in 1998. This is more readily achievable in the UK, which has a much lower rate of population growth than

Australia. All scenarios have substantial contributions from renewable sources of energy. Two of the scenarios also have large contributions from fossil fuels with CO₂ capture or an equivalent amount of nuclear power. The other two scenarios have neither of these conventional technologies.

Features of this study are:

- the careful calculation of available energy resources as a function of cost;
- a conclusion that energy demand must be curbed substantially or renewable energy and fossil or nuclear energy would be very intrusive environmentally;
- an observation of the need for a culture change within government;
- a recommendation for challenging national targets for improving energy efficiency and developing new energy sources;
- the strong recommendation for the introduction of a carbon levy, where the amount raised is spent to reduce fuel poverty in low-income homes and to assist the development of efficient energy use and renewable energy technologies.

13.5. Department of Trade & Industry on the UK

This study for the UK Department of Trade & Industry (DTI) focuses on the potential contribution of new and renewable energy sources to the reduction of greenhouse gas emissions in the UK. A valuable component is a consultancy by Future Energy Solutions from AEA Technology plc (Marsh et al., 2003) which builds on the earlier UK studies (RCEP, 2000). Like RCEP, the study considers both stationary energy and transport, and uses the IEA's 'bottom-up' MARKAL model of the energy sector. It finds that annual abatement costs in reaching the 60-70% greenhouse reduction target are generally less than 0.5% GDP. Annual GDP growth is only reduced by about 0.01% p.a. over the 50-year period. Achieving high levels of energy efficiency is a key factor in keeping down abatement costs. Reductions in CO₂ emissions are achieved through approximately equal contributions from the demand and supply sides.

13.6. Pew Center study on the USA

The Pew Center (Mintzer et al., 2003) considers three 'base-case' US energy scenarios to 2035. An economic model drives the increase in consumption. The study then applies carbon constraint policies to each of the base cases in order to reduce emissions in 2035 to 38% below the year 2000 level.

Across the three scenarios, efficient energy use and different mixes of supply technologies, existing and new, achieve the target. Coal use declines, but still is important, and natural gas use increases greatly, both for centralised and distributed generation. It is assumed that geosequestration locks up the CO₂, despite the high costs and limited contribution of this technology (see Chapter 8). Hydrogen is assumed to be important in all scenarios, but it is generated from coal in one and natural gas in another, not renewables. In all three scenarios renewable energy sources

are only allowed to make modest contributions: wind contributing only 6-12.5% of electricity generation and biomass less than half of wind.

In summary, in this study the 'new' technologies are mixed up with the existing, but the only innovations occur in the use of fossil fuels.

13.7. US Interlaboratory studies

The first report (Interlaboratory Working Group, 1997) presents the results of a study conducted by five U.S. Department of Energy laboratories on the U.S. potential to reduce greenhouse gas emissions using energy-efficient and low-carbon technologies. Like the UK studies outlined above, the US study uses a 'bottom-up' engineering-economic model and places strong emphasis on efficient energy use. It focuses on four energy sectors: buildings, industry, transportation and utilities. The calculations show that numerous cost-effective energy-efficient technologies remain under-utilised in each sector. The report quantifies the reductions in CO₂ emissions that could be attained by 2010. It also describes a wide array of advanced technology options that could be cost-competitive by the year 2020, given a strong and sustained national commitment to energy research and development.

For the assessment of potential carbon reductions by 2010, the study defines a Business-as-Usual (BAU) forecast as well three alternative scenarios. The BAU scenario, based on the Energy Information Administration's Annual Energy Outlook, 1997, projects an increase of 390 million tonnes of carbon (MtC) per year (from 1340 to 1730 MtC) between 1990 and 2010. In the 'efficiency' scenario, the nation actively pursues policies and programs to promote market acceptance of energy efficiency while expanding commitments to research and development. In the two high-efficiency/low-carbon scenarios, under a carbon cap and trading system, permits for carbon sell for either US\$25 or US\$50/tonne C. The study concludes that, along with utility sector investments, a vigorous national commitment to develop and deploy energy-efficient and low-carbon technologies could cost-effectively reduce U.S. carbon emissions by approximately 390 MtC per year.

The second report (Interlaboratory Working Group, 2000) builds on the first report by extending the quantitative analysis from 2010 to 2020 and qualitative analysis out to 2050. Unlike the first report, the second identifies specific policies and programs needed to motivate consumers and business to purchase the energy efficient and renewable energy technologies that make up its scenario.

13.8. Study for WWF (USA)

A study conducted by the Tellus Institute and the Center for Energy and Climate Solutions develops policies for the *PowerSwitch!* Program of World Wildlife Fund in the USA (Bailie et al., 2003). The study is similar in several ways to the present Clean Energy Scenario study for Australia, also considering the effect of small improvements to existing technologies. But the US study focuses on the electricity sector, rather than the whole of stationary energy, and takes a shorter time horizon than ours, 2020. Within this domain it explores the ways and means, and costs and benefits, of reducing CO₂ emissions by 60% relative to the 2000 level by 2020.

The study takes its baseline energy scenario from the US Department of Energy's Energy Information Administration (DoE/EIA). Then, by drawing upon the work of the American Council for an Energy Efficient Economy, it develops its energy efficient scenario.

To overcome the diverse market barriers, the study considers and proposes a portfolio of diverse policies. To foster efficient energy use, there are building codes, minimum energy performance standards for equipment and appliances, tax incentives and a National Public Benefits Fund that is obtained from a small surcharge on electricity prices and is used to foster efficient energy use. On the supply side, there is a Renewable Portfolio Standard (similar in some ways to Australia's MRET), which fosters bioenergy, wind power and heat pumps based on geothermal energy; and tradeable emission permits that place caps on CO₂ and oxides of sulphur and nitrogen, and mercury. There are also specific strategies to foster cogeneration.

The proposed policies are applied to the National Energy Modeling System of DoE/EIA. This yields a 60% reduction in CO₂ emissions from the US electricity generation, with economic savings to households and businesses that total US\$80 billion per year. Electricity prices increase, but demand decreases, with the net effect that electricity bills are lower. It is unclear whether the study considers the cost of premature retirement of coal-fired power stations.

13.9. Discussion

Almost all the studies reviewed here achieve large reductions in CO₂ emissions by a combination of strong energy efficiency and decarbonisation of supply. All regard energy efficiency as offering a wide range of cost-effective measures, however they find that energy efficiency alone is insufficient for large reductions.

There are big differences in the treatments of the supply side. The two UK studies and the study by the Australia Institute make substantial use of several renewable sources of energy. However, the two US studies use much smaller proportions, with the Pew Center focusing on cleaning up fossil fuels and the Interlaboratory Working Groups focusing on the demand side.

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Appendix A: External costs of fossil fuels

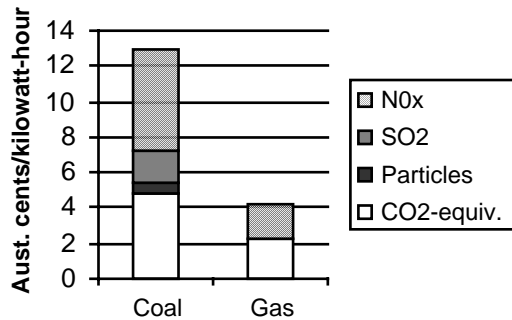
If we consider the environmental and health damage caused by the production and use of fossil fuels, the economic value of efficient energy use and renewable energy sources may be further increased. In recent years there has been much progress in the analysis of the *external* costs (costs of environmental and health damage that are not taken into account in the market prices) of energy supply in the US and EU. These costs are based on the full fuel cycles, e.g. from the mining of coal through to the disposal of fly ash from a coal-fired power station. They also trace all the main pathways of the pollutants from the points of emission to the various receptors (people, soils, crops, forests, buildings, etc.). The most comprehensive and recent set of studies is the ExterneE project carried out in 1998 on behalf of the European Commission.

There is of course much uncertainty in such calculations and the 1998 ExterneE studies can be considered to be very cautious and conservative, because:

- They evaluate only a limited range of greenhouse impacts and focus on the impacts of the well-known air pollutants, oxides of nitrogen and sulfur, to which they add the impacts of fine particles and aerosols which became pollutants of concern in the mid-1990s. They omit health hazards that they cannot quantify, such as those of heavy metals, VOCs, fluoride, land degradation and waste management.
- They consider only the impacts of the most modern combined-cycle power stations, with flue gas desulfurization (i.e. collection of SO₂ emissions from smokestacks), electrostatic precipitators (to collect dust from smokestacks) and low NO_x emissions. They point out that, for existing power stations, the emissions of NO₂ and SO₂ can be several times higher.
- They calculate the value of deaths from air pollution by multiplying the reduction of life expectancy by the value of life per year. Most earlier studies obtained much higher values by multiplying the number of deaths by the value of statistical life.

With these assumptions, ExterneE's calculated external costs of fossil-fuelled power stations, as reviewed by Rabl and Spadaro (2000), are shown in Figure A.1. To convert the results from Euro cents to Australian cents per kilowatt-hour of electricity generated, we have assumed that A\$1 = 0.56 Euro. These results are intended to be added onto the existing economic costs of electricity generation from fossil fuels.

Figure A.1: Typical damage costs of new baseload coal and gas-fired power stations assuming average European conditions



Compared with these results for fossil fuels, the ExternE studies find that the external costs of wind power, photovoltaic electricity and well designed biomass energy technologies are negligible.

The application of these European results to Australia is controversial, because exposure to sulfur dioxide and other air pollutants from power stations is much less here than in Europe and North America. So it could be argued that the European results should be scaled down to the lower population densities found in Australia. On the other hand, the ExternE studies omitted many pollutants and considered only the most efficient combined-cycle power stations, which do not exist among Australian coal-fired stations. So it is possible that the European results describe approximately the *present* situation in Australia. This can only be resolved by detailed measurements and calculations.

In applying the ExternE results to Australia in Fossil Case B (Section 10.2), we tentatively adopt the ExternE greenhouse costs and add to this one-quarter of the ExternE estimate of the air pollution costs.

Appendix B: Can renewable energy replace coal when demand is growing rapidly?

Coal-burning provides about 84% of Australia's electricity generation. Coal-burning makes by far the largest contribution to Australia's greenhouse gas emissions in millions of tonnes (Mt) of CO₂ and also in terms of Mt CO₂ per unit of electricity generated. Coal-burning is a big contributor to air and water pollution and land degradation. And coal mining is one of the three most dangerous occupations. Any sustainable development pathway must grapple with the nettle of reducing coal use through a combination of using energy more efficiently and supplying energy with much cleaner energy sources.

Some people argue that, since emissions from coal power stations in Australia are rising an order of magnitude faster than they can be currently reduced by renewable energy, we should only address the causes of rising demand and forget about renewable energy.

This argument is fallacious. While it is true that the absolute growth of renewable energy generation is currently much less than the absolute growth in coal-fired generation in Australia, the *percentage* growth rate in renewable energy, especially wind power, is much higher than that of coal. It is essential to keep in mind the properties of exponential growth. Even though renewable energy has started from a small base, it is growing globally each decade by a factor of about 10.

For example, Australian wind energy capacity was only 104 MW at the end of 2002, but at 25% per annum, assuming no constraints, it would reach 20 GW in 2025, substituting for a lot of coal along the way. With a more modest growth rate of 20% p.a. it would reach 20 GW around 2030 and at 15% p.a. it would reach 20 GW around 2040. For comparison, ABARE (2001, Fig. 12) assumes that wind power will grow at a rate of 25.2% p.a. from 1998-99 to 2019-20.

Therefore, to substitute for a substantial proportion of coal burning, we must maintain a high rate of growth in renewable energy capacity *and* implement efficient energy use.