

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.

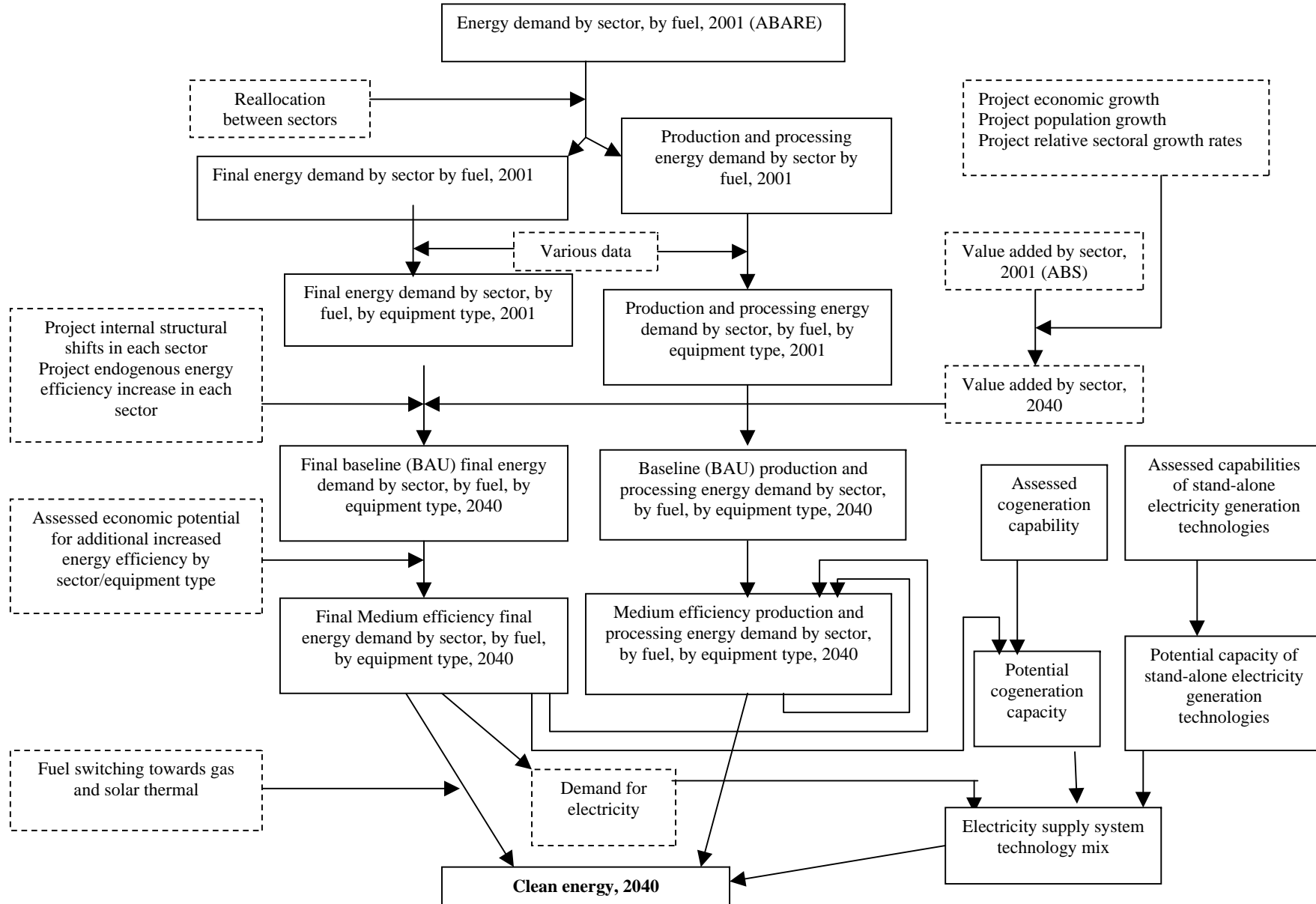
Finally, the demand for energy by the endogenous (energy production and processing) sectors was determined. This was done by using the change in demand for the different types of fuel from 2001 to 2040 to determine the activity level in each of the industries concerned and applying additional improvements 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.