MEDIUM-TERM FORECASTS OF ENERGY USAGE: AN APPLICATION OF THE MMRF-GREEN TOPS-DOWN MODEL

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Abstract

MMRF-Green is a bottoms-up model of the economies of Australia's six states and two territories. It models each region as an economy in its own right, with region-specific prices, region-specific consumers, region-specific industries, and so on. This theoretical structure is supported by a database containing explicit representations of intra-regional, inter-regional and international trade flows based on regional input-output data developed at the Centre of Policy Studies.

Each solution of MMRF-Green produces pictures of Australia's regions at a high level of detail for a particular year. The model can also produce a sequence of annual solutions, linked together by ensuring, for example, that the quantities of opening capital stocks in any year equal the quantities of closing stocks in the previous year. This allows the model to make forecasts for the regional economies at a high level of detail over periods of policy relevance (say up to 10 years). The starting point for these forecasts is a set of scenarios for the macro economy supplied by a specialist-forecasting agency. The role of MMRF-Green is to forecast a microeconomic picture consistent with the macroeconomic scenarios and other inputs.

The objective of this paper is to describe the latest set of forecasts for energy use and greenhouse-gas emissions derived from the model. These forecasts have been made for the Australian Greenhouse Office (AGO), which is the sponsor of the work. Three scenarios are reported and discussed. Most attention is given to the central case, which is our preferred scenario. The other two cases are upper and lower scenarios that provide plausible ranges for the forecast values of critical variables.

Key words: Forecasts, Greenhouse emissions, Energy usage, Australian economy, CGE modelling.

1. Introduction

The Centre of Policy Studies (CoPS) has been commissioned by the Australian Greenhouse Office (AGO) to conduct projections of greenhouse gas emissions primarily for the stationary energy sector to 2020. The analysis is being undertaken using MMRF-Green, a multi-sector dynamic model of Australia's six states and two territories.

We present projections for three scenarios: Baseline; High emission; and Low emission. The first scenario is treated as the central case, and is the primary focus in our explanation of results. Our description of the remaining scenarios concentrates on highlighting the main differences between them and the central case.

The remainder of the paper is organized as follows. MMRF-Green is described in Section 2. In Section 3, we discuss key baseline assumptions and present projections for the baseline. In Section 4, we report and discuss projections for the two alternative scenarios. Brief concluding remarks are in Section 5.

2. Forecasting with MMRF-Green

MMRF-Green is a dynamic, multi-sectoral, multi-regional model of Australia, with enhanced capabilities for analysis of environmental policies. It is very detailed, distinguishing up to 45 industries, 50 commodities, 8 states/territories and 56 sub-state regions.

MMRF-Green is founded on the MMR model.[1] The current version of MMRF-Green was built in three stages. In the first stage, MMR was transformed into a dynamic system by the inclusion of dynamic mechanisms taken from the MONASH model. These were added as self-contained blocks, allowing MMRF-Green to include MMR as a special case. The second stage involved a range of developments designed to enhance the model's capacity for environmental analysis. In the third stage, a regional disaggregation facility was added, which allows state-level results to be disaggregated down to sub-state regions.

2.1 Overview of MMR

MMR divides Australia into the six states and two territories. There are five types of agents in the model: industries, capital creators, households, governments, and foreigners. The number of industries is limited by computational constraints. Currently, MMRF-Green identifies 45 sectors (see Table 1). These are aggregates of the 116 individual industries recognised in the primary database (see Peter *et. al.*, forthcoming 2001). For each sector in each region there is an associated capital creator. The sectors each produce a single commodity and the capital creators each produce units of capital that are specific to the associated sector. Each region in MMR has a single household and a regional government. There is also a federal government. Finally, there are foreigners, whose behaviour is summarised by export demand curves for the products of each region and by supply curves for international imports to each region.

MMR determines regional supplies and demands of commodities through optimising behaviour of agents in competitive markets. Optimising behaviour also determines industry demands for labour and capital. Labour supply at the national level is determined by demographic factors, while national capital supply responds to rates of return. Labour and capital can cross regional borders so that each region's stock of productive resources reflects regional employment opportunities and relative rates of return.

The specifications of supply and demand behaviour co-ordinated through market clearing equations comprise the general equilibrium (GE) core of the model. There are two blocks of

[1] A progress report on the development of the MMR model is given in Meagher and Parmenter (1993). In 1996, MMR was adapted for forecasting by the inclusion of enough dynamics to accumulate variables such as capital stocks and foreign debt over medium-run periods. This version was called the MMR Forecasting (MMRF) model. A detailed description of MMRF is given in Peter *et al* (forthcoming, 2001).

equations in addition to the core. They describe regional and federal government finances and regional labour markets.

Data requirements for MMR

The GE core of MMR requires a multi-regional input-output table together with values for the elasticities of substitution in the CES nests of the specifications of technologies and preferences. The government finance block requires data on regional and Federal government revenues and outlays. The regional labour market block requires regional demographic, employment and labour force data.

The Australian Bureau of Statistics (ABS) (see Peter *et. al*, forthcoming 2001) publishes suitable regional data for the government finance and labour market blocks. However, it does not compile multi-regional input-output (IO) tables. Disaggregating the national IO table used in the national GE model, MONASH, created IO data for the GE core. The regional disaggregation of the national IO table involved three steps: (i) splitting of columns using regional proportions of industry outputs and final demands; (ii) splitting of rows using inter-regional trade data available from published sources (e.g., Quinlan, 1991); and (iii) application of RAS procedures to ensure equality in the multi-regional input-output table between the outputs and sales of regional sectors.

For values of primary-factor and domestic-import substitution elasticities, MMR relies on the MONASH national database. There are no reliable estimates of substitution elasticities between domestic products from different regional sources. High numbers are assumed to be appropriate - five times the values for domestic/import substitution elasticities. This means that different domestic varieties of a good are closer substitutes than are domestic and imported varieties.

Computing solutions for MMR

MMR is a system of non-linear equations. It is solved using GEMPACK, a suite of programs for implementing and solving economic models. A linear, differential version of the MMR equation system is specified in syntax similar to ordinary algebra. GEMPACK then solves the system of non-linear equations as an Initial Value problem, using a standard method, such as Euler or midpoint. For details of the algorithms available in GEMPACK, see Harrison and Pearson (1996).

2.2 From MMR to MMRF-Green: Inclusion of MONASH dynamics

There are two main types of inter-temporal links incorporated into MMRF-Green: physical capital accumulation and lagged adjustment processes.

Physical capital accumulation

It is assumed that investment undertaken in year t becomes operational at the start of year t+1. Under this assumption, capital in industry i in state/territory s accumulates according to:

$$K^s_{t+1}(i) = (1 - DEP^s(i)) \times K^s_t(i) + I^s_t(i) \qquad (1)$$

where:

$K^s_t(i)$ is the quantity of capital available in industry i located in s at the start of year t;

$I^s_t(i)$ is the quantity of new capital created for industry i during year t; and

$DEP^s(i)$ is the rate of depreciation in industry i, treated as a fixed parameter.

Given a starting point value for capital in t=0, and with a mechanism for explaining investment through time, equation (1) can be used to trace out the time paths of industry capital stocks.

Investment in industry i in state/territory s in year t is explained via a mechanism of the form

$$\frac{K^s_{t+1}(i)}{K^s_t(i)} - 1 = F^s_{it}[EROR^s_t(i)] \qquad (2)$$

where

$EROR_t^s(i)$ is the expected rate of return on investment in industry i in s in year t; and

$F_{it}^s[\ ]$ is an increasing function of the expected rate of return with a finite slope.

The expected rate of return in year t can be specified in a variety of ways. As in MONASH, in MMRF-Green two possibilities are allowed for, static expectations and forward-looking model-consistent expectations. Under static expectations, it is assumed that investors take account only of current rentals and asset prices when forming current expectations about rates of return. Under rational expectations the expected rate of return is set equal to the present value in year t of investing $1 in industry i in region r, taking account of both the rental earnings and depreciated asset value of this investment in year t+1 as calculated in the model.

Lagged adjustment processes

MONASH contains a number of lagged adjustment processes, but just one is included in MMRF-Green. This relates to the operation of the labour market in year-to-year policy simulations.

In comparative static analysis, one of the following two assumptions is made about the national real wage rate and national employment:the national real wage rate adjusts so that any policy shock has no effect on aggregate employment; or the national real wage rate is unaffected by the shock and employment adjusts.

MONASH's treatment of the labour market allows for a third, intermediate position, in which real wages can be sticky in the short run but flexible in the long-run and employment can be flexible in the short-run but sticky in the long-run. The same idea is applied in MMRF-Green. For year-to-year policy simulations, it is assumed that the deviation in the national real wage rate increases through time in proportion to the deviation in aggregate employment from its basecase-forecast level. The coefficient of adjustment is chosen so that the employment effects of a shock are largely eliminated after about ten years.

2.3 MMRF-Green: Environmental enhancements

MMRF-Green has been enhanced in a number of areas to improve its capability for environmental analysis. These enhancements include:

1. an energy and gas emission accounting module, which accounts explicitly for each of the 45 industries and eight regions recognised in the model;
2. equations that allow for inter-fuel substitution in electricity generation by region; and
3. mechanisms that allow for the endogenous take-up of abatement measures in response to greenhouse policy measures.

Emissions accounting

MMRF-Green tracks emissions of greenhouse gases at a detailed level. It breaks down emissions according to: emitting agent (45 industries and residential); emitting state or territory (8); and emitting activity (5). Most of the emitting activities are the burning of fuels (black coal, natural gas, brown coal or petroleum products[2]). A residual category, named Activity, covers emissions such as fugitives and agricultural emissions not arising from fuel burning.

The resulting 45 x 8 x 5 matrix of emissions is designed to include all emissions except those arising from land clearing. Emissions are measured in terms of carbon dioxide equivalents, $C0_2$-e. The main source of data for the matrix of emissions is the 1999 National Greenhouse Gas Inventory published by AGO.

[2] Each of these fuels is identified as a separate commodity within the model (see Table 1).

Inter-fuel substitution

Inter-fuel substitution in electricity generated is handled using the "technology bundle" approach (e.g., Hinchy and Hanslow, 1996). Five power-generating industries are distinguished based on the type of fuel used (see Table 1). There is also an end-use supplier (*Electricity Supply*). The electricity generated in each state/territory flows directly to the local end-use supplier, which then distributes electricity to local and inter-state users. The end-use supplier can substitute between the five technologies in response to changes in their production costs. For example, the Electricity supply industry in NSW might reduce the amount of power sourced from coal-using generators and increase the amount sourced from gas-fired plants. Such substitution is price-induced; the elasticity of substitution between the various types of electricity used by the Electricity supply industry in each state is set to 5.

For other energy-intensive commodities used in industry, MMRF-Green allows for substitution possibilities by including a weak form of input-substitution specification. If the price of say, Cement, rises by 10 per cent relative to other inputs to construction, the Construction industry will use 1 per cent less Cement and, to compensate, a little more of labour, capital and other materials. In most cases, as in the Cement example, we have imposed a substitution elasticity of 0.1. For important energy goods, Petroleum products, Electricity supply, and Urban gas distribution, the substitution elasticity in industrial use is 0.25. This input substitution is driven by price changes, and so is especially important in emission-policy scenarios, which makes outputs of emitting industries more expensive.

Endogenous take-up of abatement measures in response to greenhouse policy measures

In basecase simulations, non-combustion emissions are modelled as directly proportional to the output of the related industries. In the policy scenarios, we allow for abatement of these emissions. The amount of abatement is directly related to the price of emissions permits (or the level of the carbon penalty). The constants of proportionality are derived from point estimates, from various sources, of the extent of abatement that might arise at a particular tax level.

3. Baseline

3.1 Assumptions Used in the Baseline

In forecasting with MMRF-Green, we impose on the model a large amount of information from specialist external forecasting agencies. The model is then used to trace out the implications of the external forecasts and policies changes at a level of detail consistent with the requirements of the AGO.

In generating the Baseline forecasts, we use :

1. State/territory macroeconomic forecasts from Access Economics;
2. National-level assumptions for changes in industry production technologies and in household preferences from CoPS;
3. Forecasts for the quantities of agricultural and mineral exports, and estimates of capital expenditure on major minerals and energy projects from various sources, such as state government agencies, the Australian Bureau of Agricultural and Resource Economics (ABARE), and the National Electricity Market Management Company (NEMCO); and
4. Policy measures directly affecting the level of greenhouse emissions from the AGO.

3.1.1 Macroeconomic Inputs (Table 2)

Table 2 shows the assumptions for selected macroeconomic variables in terms of average annual growth rates over the period 1999 to 2020.

Real GDP is assumed to grow at an average annual rate of 3.0 per cent (row 8). The states/territories with the best growth potential are NT (4.1 per cent per annum annual growth in real GSP) and WA (4.0 per cent). The states with the worst growth potential are TAS (1.6 per cent)

and SA (2.0 per cent). In general, the forecast growth rates are in line with the long-run growth potential for each economy. Note, however that for QLD and WA the forecast growth rates are below the average rates of the last five years. Factors such as the prospect of a prolonged period of slow growth in Japan and slower long-term growth in the US economy, make it unlikely that the foreign-export-oriented states like QLD and WA can sustain their recent strong performance.

Over recent years, real private consumption has grown faster than real GSP in most regions. However, this trend is not expected to continue. As can be seen by comparing rows 1 and 8 in Table 2, we expect that real consumption will grow roughly in line with real GSP in each region over the forecast period.

Growth in real investment (row 2) at the national level is forecast to be a fairly modest 3.3 per cent. This reflects initial conditions. 1999 was a very strong year for investment, and only modest investment growth is required to maintain the historically normal economy-wide investment/capital ratio of three per cent. Forecast differences across regions reflect a combination of different initial conditions, different industrial compositions and specific assumptions about large projects such as the Comalco aluminium plant in QLD.

Over the past fifteen years real international exports (row 6) and real international imports (row 7) have grown rapidly relative to real value added (row 8) in each region. This reflects several factors: declining transport costs; improvements in communications; reductions in protection in Australia and in our major trading partners; and technological changes favouring the use of import-intensive goods such as computers and communication equipment. All these factors are expected to continue through the forecast period, leading to further increases in the ratios of the volume of international trade to real value added.

3.1.2 Assumptions for Changes in Technology and Tastes (Table 3)

Table 3 shows our assumptions for changes in the preferences of households and for changes in the production technologies of industries. These are applied uniformly across regions. The numbers are based on extrapolated trends calculated from a MONASH simulation for the period 1986-87 to 1996-97.

Our assumptions for household tastes are summarised in the first column of numbers in Table 3. A positive (negative) number indicates that we are assuming the household usage of the relevant commodity will increase (decrease) relative to the movements that are implied in the forecasts by changes in household aggregate expenditure and by changes in relative prices. For example, we assume that consumption of *Financial and business services* will increase at a rate 1.9 per cent a year faster than can be explained on the basis of changes in prices and changes in the average budget of households.

The second column of numbers in Table 3 shows our initial assumptions for the average annual rates of change in the usage of commodities as intermediate inputs per unit of production in industries, and as inputs per unit of capital creation. Negative numbers indicate that technological change is commodity-saving. Positive numbers indicate that it is commodity-using. For example, we assume initially that in each year industries will increase their usage of *Communication services* by 5.0 per cent more than their outputs.

The exogenous shocks to produced-input technologies impose a cost/saving on the industries that use the inputs. For example, industries that utilise communication services will suffer a cost increase when forced to use 5.0 per cent more of those services per unit of output. To offset these cost effects, we make a simultaneous uniform adjustment to the technology coefficients applying to all the user's inputs (produced and primary) so that there is no net effect on the user's costs.

The assumptions in the second column for energy commodities are of special importance to this study. They show that, based on historical trends, through the forecast period industries will become more intensive in their use of natural gas and less intensive in their use of black and brown coal.[3] The intensity with which industries use crude oil is assumed not to change. For derived fuels,

[3] We assume that there is more scope for improved efficiency in the use of black coal than for brown coal based on improvements already achieved.

industries will become more intensive in their use of LPG, and less intensive in their use of other petroleum products. We assume zero change in the intensity of use of electricity: increased electricity efficiency for electrical equipment is offset by more intensive usage of electrical equipment. To understand the numbers for the electricity-generator products, note that these products are sold only to the electricity supply industry. Thus our assumptions for the generator products are indicative of historical trends in the fuel mix of electricity supply.

Our initial assumptions for each industry concerning average annual changes in primary-factor usage per unit of output are shown in the final column of Table 3. Primary-factor inputs in MMRF-Green comprise labour, capital and agricultural land. For example, our initial assumption for *Agriculture* is that output will increase on average by 1.2 per cent a year relative to the industry's overall usage of primary factors.

For the electricity industries, we assume improvements in the efficiency of use of primary factors at an average annual rate of 1.0 per cent.

3.1.3 Assumptions for Exports (Table 4), and for Large Projects

Table 4 shows assumptions for the quantities of agricultural and mineral exports. These reflect ABARE projections to 2005, and exogenously imposed long-term trends for the remaining years to 2015.

MMRF-Green's theory of investment relates year-to-year changes in capital expenditure to year-to-year changes in rates of return. This is adequate for most industries where the evolution of investment through time is relatively smooth. However, for industries in the resource and electricity sectors, investment is seldom smooth. Accordingly, in forecasting we complement the standard MMRF-Green investment theory with extraneous information relating to incremental investment changes in the resource and electricity industries. Currently, our primary source of information for planned projects in the resource sector is ABARE (2001), "Minerals and Energy: Major Development Projects" *Australian Commodities*, 8(4), December quarter, pp. 647-666. Our primary source of information for future electricity investments is NEMCO, which provides data via personal communication. Information from these sources covers the years through to 2006. Thereafter, we impose long-term trends based partly on trends projected for the years 1995 to 2006.

Notable projects accommodated for in our Baseline scenario are:

- the Victoria-Tasmania natural gas interconnection, which is assumed to begin operation in 2004;
- the Victoria-Tasmania electricity connection (Basslink);
- the PNG-QLD natural gas pipeline;
- the expansion of both aluminium smelting and alumina refining capacity in QLD, WA and the NT; and
- several new gas-fired electricity plants, mainly in QLD, NSW and WA.

3.1.4 Assumptions for Greenhouse Policies

The following five policy measures are included in the Baseline scenario.

1. Energy Market Reform (EMR). We assume that EMR will bring an extra 0.5 per cent per annum increase in primary factor productivity in the electricity industries. This is in addition to the trend rate of improvement of 1.0 per cent per annum. Thus in the baseline scenario, productivity increases by 1.5 per cent per annum.
2. Mandatory Renewable Energy Target (MRET). We assume that electricity generated from Biomass, hydro and other renewable means will increase from around 62 Pj in 1999 to around 94 Pj in 2010. This is equivalent to an increase of 9500 GWh on 1997 levels.
3. Generator Efficiency Standard (GES). We assume that efforts in updating generators will result in a reduction 2 million tonnes of emissions from black coal generators, of 2 million tonnes from brown coal generators, and of 1 million tonnes from gas generators. This is implemented endogenously via increases in the fuel efficiencies of the affected generators.

4. Greenhouse Gas Abatement Programs (GGAP). We assume that GGAP will reduce emissions from the stationary energy in line with an AGO supplied confidential schedule
5. Queensland state government initiatives. We assume that from 2005 the share of electricity generated from black coal in Queensland will be reduced to less than 85 per cent. This is based on the announced policy that Queensland government will require retailers to buy 15 per cent of electricity from gas and renewable sources from 2005.

3.2. Baseline Projections

We report three tables of detailed projections:

Table 5.1: Macroeconomic indicators (repeat of Table 2, included for sake of completeness)

Table 5.2: Output by industry

Table 5.3: Emissions by state and major source category

3.2.1 Output of Electricity and Other Industries (Table 5.2)

Table 5.2 gives baseline projections for the 45 industries distinguished in the model. At the Australia-wide level, *Communication services* is the fastest growing industry. This reflects our assumption that changes in technology through the projection period will strongly favour intermediate usage of these services (column 2 of Table 3), and that rapid productivity growth (column 3 of Table 3) will reduce their price relative to consumer prices in general. Similar factors explain the relatively strong growth forecast for *Financial and business services.*

Another fast growing industry is *Electricity generation - gas*. This reflects, in the main, announced and planned construction of new plants. Strong growth in gas-fired electricity capacity lowers the price of gas-fired electricity relative to coal-fired electricity. This restricts the growth prospects for other types of electricity generation, especially *Electricity generation – black coal.*

Other industries with relatively strong growth forecasts include *Air passenger transportation, other transport services* and *Other metal products*. These industries participate heavily in the strong growth forecast for international tourism and manufactured exports. In addition, changes in technology are assumed to favour intermediate usage of *Other metal products* (column 2 of Table 3).

Forecasts for *Agriculture*, the mining industries, *Petroleum products* and *Alumina and aluminium* are, in the main, based on extrapolations of the current views of the ABARE (see Table 4). These include slow growth for *Crude oil* in VIC, reflecting the run down of the Bass Straight reserves (Table 4). The prospects for *Brown Coal* reflect those of brown-coal electricity generation with an allowance for greater efficiency of fuel use in power generation.

The manufacturing industries with the weakest growth prospects (other than petroleum) are *Water transport services - freight* and *Cement*. The weak prospects for the *Water transport services - freight* industry reflect weak prospects for commodity exports and the water front reform that has improved the productivity of handling the shipment of bulk commodities. Cement is restricted by adverse shifts in technology in the construction sector.

In all regions, forecast growth of *Electricity supply* lags behind forecast GSP growth. At the Australia-wide level, electricity supply is forecast to grow at an average annual rate of 2.3 per cent, which is 0.7 percentage points less than forecast growth in real GDP. Our below-average forecast for growth in electricity is explained by the interaction of three forces. First, we are projecting quite strong growth in all-factor productivity for the industry (see the final column of Table 3). This makes its products relatively cheaper and encourages substitution towards electricity by customers. Second, we assume no change in the efficiency with which industries use electricity, and negligible change in consumer tastes (Table 3). This means that technological and taste changes have little direct influence on the industry's growth prospects. Against these two forces is weak growth in household demand due to a low income elasticity. Household consumption makes up around 35 per cent of sales of electricity. The income elasticity applied to those sales is around 0.2. Thus even though aggregate consumption is projected to growth at an average annual rate of 3.0 per cent, household demand for electricity increases at an average annual rate of less than 1.0 per cent.

Most of the remaining industries have close to average growth prospects.[4] Two offsetting forces - strong export growth and increasing import competition, affect *Food, beverages and tobacco*. The same forces strongly influence the prospects of *Chemical products (excl petrol), Motor vehicles and parts* and *Other manufacturing*. The prospects of *Non-metal construction materials excl Cement* are governed by those for *Construction services* (industry 29). These, in turn, reflect our macro assumptions for investment (Table 2). *Wholesale, retail trade and accommodation* sells widely throughout the economy. Its growth rate, though, is slightly below that of GDP because of adverse taste and technology shifts against its products (Table 3). *Dwelling ownership*, *Public services* and *Other services* are very consumption oriented. Accordingly, their prospects are explained by appropriate weighted averages of the growth rates assumed for private and public consumption (Table 2). Strong reliance on public consumption explains the relatively poor prospects for *Public services*.

For most industries, especially services, regional differences in growth forecasts mirror regional differences in the GSP forecasts in Table 2. Hence, growth tends to be relatively strong in WA and NT and relatively weak in TAS and SA.

3.2.2 Projections for $C0_2$-e Emissions by Major Source Category (Table 5.3)

Table 5.3 presents baseline projections for CO_2-equivalent emissions by state and major source category. The table includes the average annual growth rate of emissions from 1999 to 2020 and the levels of emissions (Mt) in 1999 and 2020.

Total emissions are projected to grow at an average annual rate of 1.7 per cent, 1.3 percentage points less than the projected GDP growth rate. This is in line with recent history. The main reasons why growth in aggregate emissions is forecast to be less than GDP growth are:

- the slow growth of Agriculture (a major contributor);
- the shift towards Natural Gas and away from coal for electric power generation (see Table 5.2);
- improvements in electricity-supply efficiency[5]; and
- faster-than-average growth of the service sectors, which do not emit much.

In 2020, the national total for all emissions (excluding land clearing) is projected to be 659 Mt.

Table 5.3 also shows projections for emissions in a number of sub-categories. Of these, emissions from agriculture are projected to grow fastest (average annual growth of 2.5 per cent), in line with the overall growth in agricultural production (Table 5.2). The category for which emissions grow slowest is the energy sector, with average growth of 1.5 per cent per annum. Within the energy sector, emissions from fuel combustion are forecast to grow at an average annual rate of 0.9 per cent, while fugitive emissions are forecast to grow at an annual rate of 1.7 per cent. The relatively slow growth from fuel combustion reflects, in the main, the relatively slow growth in emissions from electricity (average annual growth of just 0.9 per cent). The weak growth in electricity emissions is explained by a combination of increased fuel efficiency in generation, slow growth in electricity supply (Table 5.2), and a trend throughout the forecast period towards relatively clean gas-fired electricity. In our forecast, electricity generating industries reduce their requirement for fuel per unit of output at an average annual rate of 0.6 per cent. According to Table 5.2, electricity supply grows at an annual average rate of 2.3 per cent. Combining this with the assumed improvement in fuels efficiency, suggest a growth rate of 1.7 per cent for emissions from electricity. The difference between this and the final projection for emissions growth (0.9 per cent per annum) reflects the effects of fuel switching. As noted in Section 3.2.1, the gas share is projected to increase in line with announced and planned increases in gas-fired electricity capacity.

[4] Recall from Table 2 that the average annual rate of GDP growth is 3.0 per cent

[5] We define supply efficiency as a weighted average of the use of primary fuels per unit of electricity generation. Our assumptions for improvements in the use of individual fuel are given in the second column of numbers in Table 3. For example, the black coal electrricity generation industry uses 1.1 per cent less black coal per unit of production in each year. For Australia as a whole, the average of those improvements is 0.6 per cent per annum, implying that electricity generating industries use annually 0.6 per cent less fuel per unit of output.

Of the other major categories shown in Table 5.3, emissions from industrial processes are forecast to grow by 2.2 per cent per annum, and emissions from waste are forecast to grow by 1.7 per cent per annum. The forestry sink is forecast to increase at an average annual rate of 2.7 per cent, in line with growth in forestry output (Table 5.2).

At the state/territory level, we find that aggregate emissions are projected to grow fastest in the states with the highest projected growth rates - NT, WA and QLD. Emissions in TAS are projected to fall. The reason is clear when we compare the level values of emissions in 1999 and 2020. TAS has a large forest sector and uses hydroelectricity, which emits nothing. The bulk of TAS's emissions come from Agriculture. In 1999, the large forestry sink in TAS outweighed emissions from agriculture. Through the projection period, the increase in the forestry sink is larger than the increase in emissions from agriculture. This causes the fall in gross emissions in TAS (Table 5.3).

4. High and Low Scenarios

4.1 Methodology

In computing the Baseline scenario, we took on board forecasts and information available from outside sources, such as Access Economics. To accommodate this information, numerous naturally endogenous variables were exogenised. These included the volumes of agricultural exports and most macro variables.

To allow such naturally endogenous variables to be exogenous, an equal number of naturally exogenous variables were made endogenous. For example, to accommodate forecasts for the volumes of agricultural exports we made endogenous variables that locate the positions of foreign demand curves. To accommodate forecasts for macro variables, we made endogenous various macro coefficients such as the average propensity to consume.

However, when accommodating the effects of policy measures or changes to the general economic environment, the naturally endogenous variables, such as the volumes of agricultural exports and macro variables, which were exogenous in the baseline must be made endogenous. This allows them to respond to the exogenous changes under consideration. Correspondingly, naturally exogenous variables, such as the positions of foreign demand curves and macro coefficients, must be exogenous. They are set at the values revealed in the baseline.

In making these closure changes we make the following assumptions regarding important aspects of the economy.

Labour markets

At the national level, we assume that the deviation in the consumer's real wage rate (i.e., the nominal wage rate deflated by the CPI) from its baseline level increases in proportion to the deviation in employment from its baseline level. At the regional level, we assume that labour is mobile between state economies. Labour is assumed to move between regions so as to maintain inter-state wage and unemployment rate differentials at their levels in the baseline. Accordingly, regions that are favourably affected by a shock will experience increased employment and population at the expense of regions that are less favourably affected.

Private consumption and investment

Consumption expenditure of the regional household is determined by Household Disposable Income (HDI) We assume that in each year, investment in each regional industry will deviate from its value in the baseline in line with the deviation in the expected rate of return on the industry's capital stock. Investors are assumed to be myopic, implying that expected rates of return move with contemporaneously observed rates of return.

Rates of return on capital

In deviation simulations, MMRF-Green allows for short-run divergences in rates of return on industry capital stocks from their levels in the baseline forecasts. Such divergences cause divergences in investment and hence capital stocks. The divergences in capital stocks gradually erode the divergences in rates of return, so that in the long-run rates of return on capital over all regional industries return to their baseline levels.

Production technologies

MMRF-Green contains many types of technical change variables. In the deviation simulation we assume that all technology variables, other than those used in the implementation of shocks, have the same values as in the baseline simulation.

4.2 Description of the Alternative Scenarios

In simulating the high emission scenario, AGO have requested that we assume:

- Average annual growth of GDP will be 4 per cent as opposed to 3 per cent in the baseline[6];
- Energy technical efficiency will improve at the rate of 0.6 per cent per annum as opposed to 0.5 per cent per annum in the baseline; and
- Electricity supply efficiency will improve at the rate of 0.5 per cent per annum as opposed to 0.6 per cent per annum in the baseline.

In simulating the low emission scenario, we aassume:

- Average annual growth of GDP will be 2 per cent[7];
- Energy technical efficiency will improve at the rate of 0.8 per cent per annum; and
- Supply efficiency will improve at the rate of 0.5 per cent per annum.

4.3 High-scenario projections

Tables 6.1 to 6.3 present projections for the high emission scenario.

In the high emission scenario, national GDP grows at an average annual rate of 4 per cent instead of 3 per cent, resulting in higher growth in consumption, investment, public consumption, and international trade. Aggregate employment and capital stock also grow faster under the high emission scenario (Tables 5.1 and 6.1).

The higher GDP growth results in a higher growth in electricity demand (Tables 5.2 and 6.2). Improvement in energy technical efficiency also has an impact on electricity demand. Under the high emission scenario, energy technical efficiency is assumed to improve at an average annual rate of 0.6 per cent. This is slightly higher than the rate in the baseline, 0.5 per cent. The higher rate of improvement in energy technical efficiency in the high emission scenario, relative to the baseline scenario, causes the ratio of electricity demand to GDP to increase by less in the high emissions scenario.

Total emissions are projected to grow at an average annual rate of 2.5 per cent, 0.8 percentage points higher than in the baseline. The level of total emission is projected to reach 798 million tonnes by 2020 as compared with 659 million tonnes in the baseline (Tables 5.3 and 7.3).

Emissions from the stationary energy sector are projected to grow at an average annual rate of 2.3 per cent, 0.9 percentage points higher than in baseline. The level of emissions from the

[6] We induce the extra GDP in each year via an improvement in all-primary factor technological change affecting all industries except the electricity generators. The rate of primary-factor technological improvement in electricity generation is tied down by our assumption about EMR.

[7] GDP is reduced via an economy-wide deterioration in all-primary factor technological change affecting all industries except the electricity generators (see the previous footnote).

stationary energy sector is projected to reach 425 million tonnes as compared with 351 million tonnes in the baseline.

4.4 Low emission scenario

In the low emission scenario, we assume that national GDP grows at an average annual rate of 2 per cent, compared with 3 per cent in the Baseline. This results in lower growth in consumption, investment, public consumption, and international trade. Aggregate employment and capital stock also grow slower under the low emission scenario (Tables 5.1 and 7.1).

As a result of lower GDP growth, demand for electricity grows by less than in the baseline (Table 5.2 and 7.2). A higher rate of improvement in energy technical efficiency re-enforces the effects of a lower GDP growth, leading to a one percentage point reduction in the rate of growth in electricity demand as compared with baseline.

The gas share in electricity generation that is determined endogenously increases from 10.7 per cent in 1999 to 13.5 per cent in 2020.

In the low emission scenario, total emissions are projected to grow at an average annual rate of 0.6 per cent, 1.1 percentage points lower than in the baseline. The level of total emission is projected to reach 528 million tonnes by 2020 as compared with 659 million tonnes in baseline (Tables 5.3 and 7.3).

5. Conclusions

In this paper we have described a method for producing detailed forecasts of greenhouse gas emissions, and for producing alternative time paths representing high and low possibilities. The vehicle for the forecasting is the MMRF-Green dynamic CGE model. The forecasts include input from specialist macro forecasters and experts in commodity markets. They also include detailed scenarios on changes in technology and household tastes, without which realistic structural forecasts would be impossible. The role of MMRF-Green is to translate all these inputs into forecasts for variables that are relevant to public and private sector organisations with responsibilities that require them to take views about the future structure of the economy.

Using CGE models for detailed forecasting is a relatively unexplored area of research. However, our success in using the MONASH model and MMRF-Green for this purpose suggests that the research field could well be a rich one. Current development work on MMRF-Green is focussing on improvements to its core input/output data file. These include changes to the industrial classification to bring it into line with the current classification used by the Australian Bureau of Statistics, and updating to reflect a more recent year of historical observations. Other work involves better modelling of forestry sinks agricultural emissions from non-combustion sources, and the incorporation of endogenous take-up of abatement technologies.

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Table 1: Sectors Recognised in MMRF-Green

Name	Description
1. Agriculture	All primary agricultural activities plus fishing
2. Forestry	All forestry activities, including logging and management
3. Iron ore	Mining of iron ore
4. Non-iron ore	Mining of non-iron ores, including gold and base ores
5. Black coal	Mining of black coal - thermal and metallurgical
6. Crude oil	Production of crude oil
7. Natural gas	Production of natural gas at well
8. Brown coal	Mining of brown coal
9. Food, beverages and tobacco	All secondary agricultural activities
10. Textiles, clothing, footwear	Manufacture of textiles, clothing and footwear
11. Wood and paper products	Manufacture of wood (including pulp) and paper products
12. Chemical prods. excl. petrol	Manufacture of basic chemicals and paints
13. Petroleum products	Manufacture of petroleum products
14. Building prods (not cement & metal)	Manufacture of non-metallic building products excl. cement
15. Cement	Manufacture of cement
16. Iron and steel	Manufacture of primary iron and steel.
17. Alumina and aluminium	Manufacture of alumina and aluminium
18. Other metal products	Manufacture of other metal products
19. Motor vehicles and parts	Manufacture of motor vehicles and parts
20. Other manufacturing	Other manufacturing including electronic equipment
21. Electricity – black coal	Electricity generation from black coal thermal plants
22. Electricity – brown coal	Electricity generation from brown coal thermal plants
23. Electricity – gas	Electricity generation from natural gas thermal plants
24. Electricity – oil prods.	Electricity generation from oil products thermal plants
25. Electricity – other	Electricity generation from other sources (mainly hydro)
26. Electricity supply	Distribution of electricity from generator to user
27. Urban gas distribution	Urban distribution of natural gas
28. Water and sewerage services	Provision of water and sewerage services
29. Construction services	Residential building and other construction services
30. Trade services	Provision of wholesale and retail trade services
31. Road transport services – passenger	Provision of road passenger transport services
32. Road transport services – freight	Provision of road freight transport services
33. Rail transport services – passenger	Provision of rail passenger transport services
34. Rail transport services – freight	Provision of rail freight transport services
35. Water transport services – passenger	Provision of water passenger transport services
36. Water transport services – freight	Provision of water freight transport services
37. Air transport services – passenger	Provision of air passenger transport services
38. Air transport services – freight	Provision of air freight transport services
39. Other transport services	Provision of water, air and rail transport services
40. Communication services	Provision of communication services
41. Financial/business services	Provision of financial and business services
42. Dwelling ownership	Services of dwellings
43. Public services	Provision of public services
44. Other services	Provision of all other services
45. Private motor vehicle ownership	Services of private motor vehicles

Table 2: Macroeconomic Assumptions for the Baseline scenario (average annual growth rates, 1999-2020)

	Variable		NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
1.	Real private consumption		2.8	2.8	3.6	2.1	3.7	1.5	4.5	2.5	3.0
2.	Real investment		3.1	2.1	4.3	1.8	4.8	2.0	6.1	2.8	3.3
3.	Real public consumption	-- total	2.8	2.4	3.6	1.8	4.2	1.4	4.6	2.6	2.9
4.		-- regional	2.8	2.4	3.6	1.8	4.2	1.4	4.6	2.1	2.9
5.		-- federal	2.8	2.4	3.6	1.8	4.2	1.4	4.6	2.6	2.9
6.	International export volumes		5.4	7.2	5.0	5.1	6.0	4.5	6.3	7.1	5.9
7.	International import volumes		5.2	5.9	5.9	3.3	7.0	3.0	8.5	8.0	5.7
8.	Real GDP/GSP		2.9	2.8	3.4	2.0	4.0	1.6	4.1	2.3	3.0
9.	Aggregate employment		1.1	1.1	1.8	0.5	2.0	0.3	1.8	1.3	1.3
10.	Aggregate capital stock		4.5	4.2	4.6	3.5	5.5	2.3	8.3	4.2	4.5
11.	Consumer real wage		0.2	-0.1	0.1	0.2	-0.2	0.2	-0.9	-0.5	0.0
12.	Producer real wage		-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
13.	CPI		2.1	2.1	2.5	2.6	1.8	2.5	2.4	2.1	2.2
14.	GDP/GSP deflator		2.5	2.3	2.9	3.0	1.8	2.9	1.1	1.5	2.4

Table 3: Industry Technology and Household Taste Assumptions for the Baseline scenario (average annual percentage changes)*

Commodities	Household Preferences[a]	Technology:		Industries
		Intermediate input-using[b]	Primary-factor using[c]	
Agriculture	#	0.0	-1.2	Agriculture
Forestry	#	1.7	0.0	Forestry
Iron ore	#	-0.3	-2.0	Iron ore
Non-iron ore	#	-1.6	-1.2	Non-iron ore
Black coal	#	-1.1	0.0	Black coal
Crude oil	#	0.0	0.0	Crude oil
Natural gas	-1.3	0.5	0.0	Natural gas
Brown coal	#	-0.5	0.0	Brown coal
Food, beverages and tobacco	0.6	0.2	-0.6	Food, beverages and tobacco
Textiles, clothing and footwear	-2.7	-0.4	-0.9	Textiles, clothing and footwear
Wood and paper products	0.1	0.1	-0.1	Wood and paper products
Chemical products excl. Petrol	2.1	2.6	0.0	Chemical products excl. Petrol
Petroleum products	0.0	-1.0	0.0	Petroleum products
Building prods (not cement & metal)	0.1	0.5	-0.6	Building prods (not cement & metal)
Cement	#	-1.2	-0.2	Cement
Iron and steel	#	1.3	-0.7	Iron and steel
Alumina and aluminium	#	2.0	-1.2	Alumina and aluminium
Other metal products	-1.3	1.3	0.0	Other metal products
Motor vehicles and parts	0.0	2.5	-0.2	Motor vehicles and parts
Other manufacturing	0.7	3.7	-0.9	Other manufacturing
Electricity supply	0.3	0.0	-1.0	Electricity supply
Urban gas distribution	0.3	0.6	-1.4	Urban gas distribution
Water and sewerage services	-0.5	-0.2	-1.2	Water and sewerage services
Construction services	0.0	1.8	0.0	Construction services
Wholesale trade, retail trade, accommodation	-2.1	-1.8	0.0	Wholesale trade, retail trade, accommodation
Road transport services	-1.6	0.5	-0.4	Road transport services – passenger
Rail transport services	-0.1	-0.2	-1.1	Rail transport services – passenger
Water transport services	-6.2	-5.0	-0.6	Water transport services – passenger
Air transport services	1.7	-2.1	-1.8	Air transport services – passenger
Other transport services	-0.3	0.8	0.0	Other transport services
Communication services	0.0	5.0	-2.2	Communication services
Financial and business services	1.9	3.3	-0.9	Financial and business services
Dwelling ownership	0.0	0.0	-0.8	Dwelling ownership
Public services	0.1	0.0	-0.2	Public services
Other services	1.2	1.6	0.0	Other services
Private motor vehicle ownership	-0.9	0.0	0.0	Private motor vehicle ownership

* The symbol # indicates that the underlying flow is negligible.

(a) Annual rate of shift of consumption function.

(b) Annual rate of change of use of the commodity identified on the left-hand panel per unit of output of industries using the commodity.

(c) Annual rate of change of use of all primary factors (labour, capital and land) per unit of production of the industry identified in the right-hand panel.

Table 4: Assumptions for Exports for the Baseline Scenario (average annual percentage changes) *

Variable	NSW	VIC	QLD	SA	WA	TAS	NT	ACT
Export volumes:								
Agriculture	2.2	2.9	1.9	1.6	3.3	3.3	1.8	#
Iron ore	#	#	#	-2.6	3.0	-3.4	#	#
Non-iron ore	-2.1	31	-0.4	-2.2	4.5	-2.5	3.3	#
Black coal	2.4	#	3.1	#	#	#	#	#
Crude oil	#	-0.5	#	#	1.5	#	1.5	#
Natural gas	#	#	#	#	4.0	#	#	#
Petroleum products	1.5	1.5	1.5	#	1.5	#	#	#
Alumina and aluminium	2.0	3.1	7.9	#	4.6	1.5	4.9	#

* The symbol # indicates that the underlying flow is negligible.

Table 5.1 Baseline: macroeconomic indicators (average annual growth rates, 1999-2020)

Variable	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Real private consumption	2.8	2.8	3.6	2.1	3.7	1.5	4.5	2.5	3.0
Real investment	3.1	2.1	4.3	1.8	4.8	2.0	6.1	2.8	3.3
Real public consumption	2.8	2.4	3.6	1.8	4.2	1.4	4.6	2.6	2.9
International export volumes	5.4	7.2	5.0	5.1	6.0	4.5	6.3	7.1	5.8
International import volumes	5.2	5.9	5.9	3.3	7.0	3.0	8.5	8.0	5.7
Real GDP/GSP	2.9	2.8	3.4	2.0	4.0	1.6	4.1	2.3	3.0
Aggregate employment	1.1	1.1	1.8	0.5	2.0	0.3	1.8	1.3	1.3
Aggregate capital stock	4.5	4.2	4.6	3.5	5.5	2.3	8.3	4.2	4.5
CPI	2.1	2.1	2.5	2.6	1.8	2.5	2.4	2.1	2.2
Population	1.1	1.1	1.8	0.5	2.0	0.3	1.8	1.3	1.3

Table 5.2: Baseline: output by industry (average annual growth rates, 1999-2020)

Industry	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Agriculture	2.3	2.9	2.9	1.7	3.7	3.3	1.8	3.6	2.7
Forestry	2.9	3.0	3.1	2.1	3.8	2.8	0.0	2.8	3.0
Iron ore	0.0	0.0	0.0	-2.3	2.7	1.2	0.0	0.0	2.7
Non-iron ore	-1.9	-0.4	-0.3	-1.7	3.5	-2.4	1.6	0.1	2.0
Black coal	2.1	0.0	2.9	-2.3	2.2	-0.1	0.0	0.0	2.5
Crude oil	0.0	-0.5	0.0	0.0	1.5	0.0	1.5	0.0	0.0
Natural gas	0.0	2.5	3.8	4.2	4.0	0.0	2.8	0.0	3.5
Brown coal	0.0	1.1	0.0	0.0	0.0	0.0	0.0	0.0	1.1
Food, beverages and tobacco	3.3	4.1	4.5	3.1	5.0	2.9	3.8	3.8	3.9
Textiles, clothing and footwear	2.2	3.6	2.0	1.3	5.7	0.7	-0.3	2.6	3.0
Wood and paper products	2.1	2.5	1.7	1.0	3.5	1.8	1.0	3.0	2.2
Chemical products excl. Petrol	3.7	4.1	3.9	3.3	6.5	3.3	4.5	5.8	4.1
Petroleum products	0.9	1.3	1.6	1.4	2.1	0.0	0.0	0.0	1.2
Building prods (not cement & metal)	2.3	1.8	3.2	1.3	3.9	0.8	3.2	0.8	2.5
Cement	0.2	0.2	1.3	0.1	1.5	-0.9	0.4	0.0	0.5
Iron and steel	3.8	4.6	3.6	4.1	4.4	4.4	8.3	6.0	4.0
Alumina and aluminium	2.2	3.2	5.2	0.0	4.8	1.7	3.5	0.0	4.1
Other metal products	3.8	4.7	4.1	3.3	7.1	1.7	2.1	3.2	4.6
Motor vehicles and parts	1.5	2.4	2.4	1.6	4.0	0.0	0.0	0.0	2.2
Other manufacturing	4.8	4.3	4.5	4.1	5.5	3.7	3.4	4.6	4.6
Electricity – black coal	2.1	0.0	2.6	-2.3	3.2	0.0	0.0	0.0	2.2
Electricity – brown coal	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	2.2
Electricity – gas	4.7	2.4	4.9	3.1	4.1	0.0	3.6	0.0	3.9
Electricity – oil prods.	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.2
Electricity – other	0.6	0.6	3.4	0.0	2.9	0.8	0.0	0.0	0.9
Electricity supply	2.2	2.2	2.7	1.4	3.1	0.8	2.8	1.8	2.3
Urban gas distribution	3.0	3.1	3.9	2.3	4.5	1.7	3.9	2.7	3.1
Water and sewerage services	2.9	2.8	3.1	2.0	3.7	1.3	3.8	2.1	2.9
Construction services	3.1	2.0	4.4	1.8	4.7	1.9	5.7	2.9	3.3
Wholesale trade, retail trade, accommodation	1.8	2.0	2.6	1.0	3.0	0.9	3.7	1.5	2.1
Road transport services – passenger	2.1	2.1	2.4	1.9	2.9	1.2	2.8	2.0	2.2
Road transport services – freight	3.5	3.9	4.2	3.0	5.1	3.0	4.6	3.4	3.9
Rail transport services – passenger	2.0	2.0	2.3	2.0	0.0	0.0	0.0	0.0	2.1
Rail transport services – freight	2.5	2.7	3.0	1.9	3.4	2.3	2.0	2.2	2.7
Water transport services – passenger	1.3	2.7	2.0	1.4	4.0	0.3	3.3	4.1	1.6
Water transport services – freight	0.0	0.6	0.5	0.1	1.0	-0.3	0.9	0.9	0.5
Air transport services – passenger	4.0	6.0	6.2	4.3	6.8	4.8	7.1	5.3	5.3
Air transport services – freight	2.6	2.5	2.9	1.5	3.5	1.0	4.2	2.8	2.7
Other transport services	3.1	3.6	3.9	2.7	4.7	2.5	4.7	3.3	3.5
Communication services	7.7	7.9	7.9	7.1	8.5	6.6	8.5	8.2	7.8
Financial and business services	5.6	5.6	6.1	5.0	6.3	4.4	6.5	4.8	5.7
Dwelling ownership	4.1	3.7	3.7	2.7	5.1	1.9	5.1	2.8	3.8
Public services	2.7	2.5	3.6	1.8	4.0	1.4	4.6	2.7	2.8
Other services	3.7	3.8	4.5	3.6	4.2	3.1	4.5	3.6	3.9
Private motor vehicle ownership	1.3	1.4	2.8	0.4	2.5	0.1	3.7	1.4	1.7

Table 5.3 Baseline: $C0_2$-e Emissions by Major Source Category

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Average annual growth rates (1999-2020)									
Energy sector, total	1.1	1.4	1.8	0.1	2.7	0.5	2.3	1.1	1.5
Fuel combustion	1.1	1.4	1.7	0.0	2.7	0.6	2.5	1.1	1.4
Electricity	0.6	1.1	1.1	-2.3	1.9	0.0	2.9	0.0	0.9
Transport	1.1	1.5	2.0	0.5	2.4	0.2	3.1	0.7	1.5
Other industries	1.7	2.3	2.4	1.4	3.8	0.8	1.6	1.6	2.2
Household consumption	1.6	1.5	3.1	1.4	2.8	0.5	4.6	1.3	1.9
Fugitive emissions from fuels	2.0	0.5	2.8	2.9	2.9	-0.2	1.5	0.0	1.7
Industrial processes	1.3	2.1	3.3	0.2	3.5	-0.6	1.5	1.2	2.2
Agriculture	2.1	2.7	2.7	1.5	3.4	3.1	1.6	3.4	2.5
Waste	1.6	1.6	2.3	1.4	2.0	1.0	2.3	1.4	1.7
LUCF	2.6	2.8	2.8	1.9	3.5	2.5	0.0	2.6	2.7
Total	1.3	1.5	2.0	0.5	2.9	0.0	2.0	1.0	1.7
Levels(Mt CO2-e) (1999)									
Energy sector, total	113.9	124.1	64.0	17.0	36.8	3.4	2.3	2.1	363.6
Fuel combustion	108.4	110.3	57.7	16.6	33.1	3.4	1.8	2.1	333.5
Electricity	49.1	63.6	29.1	6.1	14.0	0.0	0.1	0.0	162.1
Transport	28.4	19.4	13.4	4.9	7.4	1.4	0.9	1.3	77.2
Other industries	29.7	26.2	14.7	5.3	11.5	1.9	0.7	0.7	90.8
Household consumption	1.1	1.1	0.5	0.2	0.2	0.1	0.0	0.1	3.4
Fugitive emissions from fuels	5.5	13.8	6.3	0.3	3.7	0.0	0.6	0.0	30.1
Industrial processes	2.2	1.4	2.0	1.1	2.3	0.7	0.8	0.0	10.4
Agriculture	29.9	18.1	21.6	8.0	13.2	3.2	1.2	0.1	95.2
Waste	5.5	4.8	2.3	1.3	1.2	0.3	0.2	0.6	16.3
LUCF	-5.2	-5.3	-4.1	-2.4	-2.5	-6.7	0.0	-0.3	-26.5
Total	146.2	143.0	85.9	25.1	51.0	0.9	4.5	2.5	459.0
Levels (Mt CO2-e) (2020)									
Energy sector, total	145.2	166.8	94.8	17.4	66.8	3.9	3.8	2.7	501.4
Fuel combustion	136.7	151.4	83.1	16.8	59.8	3.8	3.0	2.7	457.4
Electricity	55.7	80.1	37.0	3.7	21.2	0.0	0.2	0.0	197.9
Transport	36.3	26.9	20.6	5.5	12.3	1.5	1.8	1.6	106.4
Other industries	43.1	42.9	24.5	7.3	25.9	2.2	1.0	1.1	148.0
Household consumption	1.6	1.6	1.0	0.3	0.5	0.1	0.1	0.1	5.1
Fugitive emissions from fuels	8.5	15.4	11.7	0.6	7.0	0.0	0.8	0.0	43.9
Industrial processes	2.8	2.1	4.2	1.2	4.8	0.6	1.1	0.0	16.8
Agriculture	47.1	32.2	38.5	11.2	27.5	6.2	1.6	0.2	164.6
Waste	7.7	6.8	3.8	1.8	1.9	0.3	0.4	0.8	23.5
LUCF	-9.2	-9.8	-7.5	-3.6	-5.2	-11.6	0.0	-0.5	-47.4
Total	193.7	198.2	133.7	28.0	95.8	-0.5	6.9	3.2	659.0

Table 6.1 High emission scenario: macroeconomic indicators (average annual growth rates, 1999-2020)

Variable	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Real private consumption	3.8	3.8	4.7	3.2	4.7	2.6	5.3	3.5	4.0
Real investment	4.0	2.9	5.2	3.0	5.7	3.1	6.7	3.5	4.0
Real public consumption	3.7	3.3	4.6	2.9	5.0	2.5	5.5	3.5	3.8
International export volumes	6.8	8.5	6.5	6.6	7.1	6.0	7.4	8.2	7.1
International import volumes	6.2	6.8	6.8	4.4	7.7	4.1	9.3	8.9	6.6
Real GDP/GSP	3.9	3.8	4.5	3.2	4.7	2.8	4.9	3.2	4.0
Aggregate employment	1.2	1.2	2.0	0.9	1.9	0.6	1.8	1.4	1.4
Aggregate capital stock	4.9	4.6	5.0	4.1	5.8	2.9	8.5	4.5	4.9
CPI	2.1	2.1	2.5	2.6	1.8	2.5	2.4	2.1	2.2
Population	1.2	1.2	2.0	0.9	1.9	0.6	1.8	1.4	1.4

Table 6. 2 High emission scenario: output by industry (average annual growth rates, 1999-2020)

Industry	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Agriculture	3.3	3.8	3.9	2.8	4.6	4.4	2.8	4.6	3.7
Forestry	3.9	3.9	4.1	3.2	4.6	3.9	0.0	3.6	4.0
Iron ore	0.0	0.0	0.0	-1.1	4.0	2.5	0.0	0.0	4.0
Non-iron ore	-0.9	0.7	0.9	-0.5	4.9	-1.2	2.9	1.1	3.3
Black coal	3.5	0.0	4.5	-1.2	3.2	1.1	0.0	0.0	4.0
Crude oil	0.0	-0.5	0.0	0.0	1.5	0.0	1.5	0.0	0.0
Natural gas	0.0	3.4	4.9	5.8	2.9	0.0	3.7	0.0	3.3
Brown coal	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	1.9
Food, beverages and tobacco	4.3	5.0	5.7	4.3	5.9	4.1	4.3	4.6	5.0
Textiles, clothing and footwear	3.5	4.7	3.2	2.7	6.9	2.2	-0.1	3.3	4.2
Wood and paper products	3.2	3.6	2.7	2.4	4.5	3.1	1.9	3.8	3.3
Chemical products excl. Petrol	5.0	5.4	5.1	4.8	7.6	4.9	4.9	6.9	5.3
Petroleum products	1.9	2.2	2.6	2.8	3.0	0.0	0.0	0.0	2.2
Building prods (not cement & metal)	3.4	2.8	4.3	2.7	4.6	2.0	3.9	1.5	3.5
Cement	1.2	1.2	2.3	1.4	2.1	0.2	1.2	0.7	1.5
Iron and steel	5.1	5.8	4.9	5.6	5.3	5.9	8.1	7.2	5.3
Alumina and aluminium	3.8	4.7	6.7	0.0	6.0	3.3	4.9	0.0	5.5
Other metal products	5.1	5.8	5.3	4.7	8.2	2.9	2.8	3.9	5.8
Motor vehicles and parts	2.5	3.5	3.4	3.1	4.7	0.0	0.0	0.0	3.3
Other manufacturing	6.1	5.4	5.7	5.5	6.4	5.1	4.0	5.6	5.8
Electricity – black coal	2.9	0.0	3.6	-1.6	4.2	0.0	0.0	0.0	3.1
Electricity – brown coal	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
Electricity – gas	5.5	3.1	5.9	4.2	4.9	0.0	4.6	0.0	4.8
Electricity – oil prods.	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.2
Electricity – other	4.1	3.7	7.0	0.0	6.3	2.4	0.0	0.0	3.6
Electricity supply	3.1	3.0	3.7	2.5	3.8	1.8	3.7	2.6	3.2
Urban gas distribution	4.2	4.2	5.2	3.6	5.3	3.1	4.9	3.8	4.3
Water and sewerage services	4.0	3.8	4.3	3.2	4.6	2.5	4.7	3.1	3.9
Construction services	4.0	2.9	5.3	3.1	5.1	3.1	6.4	3.6	4.1
Wholesale trade, retail trade, accommodation	2.8	3.0	3.6	2.2	3.8	2.2	4.6	2.4	3.1
Road transport services – passenger	3.0	3.0	3.3	2.9	3.8	2.2	3.7	2.9	3.1
Road transport services – freight	4.6	4.8	5.3	4.2	5.9	4.2	5.4	4.1	4.9
Rail transport services – passenger	2.6	2.6	2.9	2.6	0.0	0.0	0.0	0.0	2.7
Rail transport services – freight	3.7	3.6	4.4	3.1	3.8	3.5	2.5	3.0	3.9
Water transport services – passenger	2.6	3.9	3.5	2.5	5.0	1.6	4.8	5.1	2.9
Water transport services – freight	1.2	1.6	1.7	1.4	2.2	1.0	1.9	1.7	1.7
Air transport services – passenger	5.6	7.5	7.8	6.2	8.1	6.7	8.6	6.6	6.8
Air transport services – freight	3.6	3.5	3.9	2.7	4.2	2.1	5.0	3.7	3.6
Other transport services	4.3	4.8	5.2	4.0	5.7	3.8	5.8	4.5	4.7
Communication services	8.8	9.0	9.0	8.3	9.4	7.8	9.4	9.2	8.9
Financial and business services	6.7	6.6	7.2	6.3	7.2	5.6	7.4	5.7	6.8
Dwelling ownership	5.2	4.8	4.9	3.9	6.0	3.1	6.1	3.9	5.0
Public services	3.7	3.5	4.6	3.0	4.8	2.5	5.4	3.7	3.8
Other services	4.8	4.9	5.6	4.8	5.1	4.4	5.5	4.6	5.0
Private motor vehicle ownership	2.3	2.4	3.8	1.5	3.2	1.2	4.7	2.4	2.7

Table 6.3 High emission scenario: $C0_2$-e Emissions by Major Source Category

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Average annual growth rates (1999-2020)									
Energy sector, total	2.0	2.2	2.8	1.2	3.4	1.6	3.0	1.8	2.3
Fuel combustion	2.0	2.3	2.7	1.1	3.5	1.6	3.4	1.8	2.3
Electricity	1.4	1.9	2.1	-1.4	2.9	0.0	3.9	0.0	1.7
Transport	2.0	2.3	2.9	1.5	3.1	1.2	4.0	1.4	2.3
Other industries	2.7	3.2	3.4	2.6	4.5	1.9	2.3	2.4	3.2
Household consumption	2.8	2.6	4.4	2.9	3.5	2.0	5.7	2.7	3.1
Fugitive emissions from fuels	3.4	1.0	4.3	4.4	2.3	1.0	1.5	0.0	2.5
Industrial processes	2.4	3.2	4.5	1.3	4.5	0.5	2.5	1.9	3.3
Agriculture	3.0	3.5	3.5	2.5	4.2	4.1	2.4	4.2	3.4
Waste	2.5	2.6	3.3	2.5	2.9	2.1	3.2	2.4	2.7
LUCF	3.5	3.6	3.7	2.9	4.2	3.5	0.0	3.3	3.6
Total	2.2	2.3	3.0	1.6	3.6	0.0	2.8	1.9	2.5
Levels(Mt CO2-e) (1999)									
Energy sector, total	113.9	124.1	64.0	17.0	36.8	3.4	2.3	2.1	363.6
Fuel combustion	108.4	110.3	57.7	16.6	33.1	3.4	1.8	2.1	333.5
Electricity	49.1	63.6	29.1	6.1	14.0	0.0	0.1	0.0	162.1
Transport	28.4	19.4	13.4	4.9	7.4	1.4	0.9	1.3	77.2
Other industries	29.7	26.2	14.7	5.3	11.5	1.9	0.7	0.7	90.8
Household consumption	1.1	1.1	0.5	0.2	0.2	0.1	0.0	0.1	3.4
Fugitive emissions from fuels	5.5	13.8	6.3	0.3	3.7	0.0	0.6	0.0	30.1
Industrial processes	2.2	1.4	2.0	1.1	2.3	0.7	0.8	0.0	10.4
Agriculture	29.9	18.1	21.6	8.0	13.2	3.2	1.2	0.1	95.2
Waste	5.5	4.8	2.3	1.3	1.2	0.3	0.2	0.6	16.3
LUCF	-5.2	-5.3	-4.1	-2.4	-2.5	-6.7	0.0	-0.3	-26.5
Total	146.2	143.0	85.9	25.1	51.0	0.9	4.5	2.5	459.0
Levels (Mt CO2-e) (2020)									
Energy sector, total	177.2	199.9	118.7	21.9	77.1	4.9	4.5	3.2	605.9
Fuel combustion	165.9	182.6	102.9	21.1	71.0	4.8	3.6	3.2	553.7
Electricity	66.1	95.8	45.7	4.5	26.0	0.0	0.2	0.0	236.9
Transport	44.0	32.3	25.3	6.9	14.3	1.9	2.1	1.8	128.5
Other industries	53.8	52.5	30.6	9.3	30.2	2.8	1.2	1.3	181.7
Household consumption	2.0	2.0	1.3	0.5	0.5	0.1	0.1	0.1	6.6
Fugitive emissions from fuels	11.3	17.3	15.9	0.8	6.1	0.0	0.8	0.0	52.2
Industrial processes	3.6	2.7	5.4	1.5	5.9	0.8	1.3	0.0	21.3
Agriculture	57.4	38.6	46.4	13.9	32.7	7.6	2.0	0.2	198.9
Waste	9.6	8.4	4.7	2.3	2.3	0.4	0.4	1.0	29.1
LUCF	-11.1	-11.5	-9.0	-4.4	-6.0	-14.3	0.0	-0.6	-57.0
Total	236.8	238.0	166.3	35.3	111.9	-0.6	8.2	3.8	798.2

Table 7.1 Low emission scenario: macroeconomic indicators (average annual growth rates, 1999-2020)

Variable	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Real private consumption	2.0	2.0	2.7	1.1	2.9	0.5	3.8	1.7	2.2
Real investment	2.4	1.4	3.6	0.8	4.0	1.1	5.6	2.3	2.6
Real public consumption	1.9	1.6	2.7	0.8	3.6	0.5	3.9	1.7	2.0
International export volumes	4.1	6.0	3.7	3.6	5.1	3.1	5.3	6.0	4.6
International import volumes	4.4	5.1	5.0	2.3	6.5	2.1	7.9	7.3	4.9
Real GDP/GSP	2.0	2.0	2.4	0.9	3.3	0.6	3.3	1.5	2.1
Aggregate employment	1.0	1.1	1.7	0.3	2.2	0.1	1.9	1.2	1.2
Aggregate capital stock	4.1	3.8	4.1	3.0	5.3	1.8	8.0	3.9	4.1
CPI	2.1	2.1	2.5	2.7	1.7	2.5	2.4	2.1	2.2
Population	1.0	1.1	1.7	0.3	2.2	0.1	1.9	1.2	1.2

Table 7.2 Low emission scenario: output by industry (average annual growth rates, 1999-2020)

Industry	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Agriculture	1.3	2.0	2.0	0.6	2.8	2.3	0.9	2.7	1.8
Forestry	2.0	2.3	2.3	1.2	3.1	1.8	0.0	2.1	2.2
Iron ore	0.0	0.0	0.0	-3.4	1.5	-0.1	0.0	0.0	1.4
Non-iron ore	-2.9	-1.4	-1.5	-2.9	2.3	-3.4	0.3	-0.7	0.8
Black coal	0.7	0.0	1.5	-3.4	1.1	-1.5	0.0	0.0	1.0
Crude oil	0.0	-0.5	0.0	0.0	1.5	0.0	1.5	0.0	0.0
Natural gas	0.0	1.1	2.2	2.1	5.4	0.0	1.7	0.0	3.6
Brown coal	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Food, beverages and tobacco	2.3	3.2	3.4	2.0	4.2	1.9	3.3	3.1	3.0
Textiles, clothing and footwear	1.0	2.5	0.9	-0.1	4.6	-0.6	-0.6	1.9	1.8
Wood and paper products	1.0	1.5	0.8	-0.3	2.7	0.6	-0.1	2.3	1.2
Chemical products excl. Petrol	2.4	3.0	2.8	1.9	5.5	1.9	4.1	4.8	2.9
Petroleum products	-0.4	0.1	0.3	-0.1	1.0	0.0	0.0	0.0	0.0
Building prods (not cement & metal)	1.4	0.9	2.3	0.1	3.2	-0.3	2.5	0.2	1.6
Cement	-0.7	-0.7	0.4	-1.0	0.9	-1.8	-0.4	-0.5	-0.3
Iron and steel	2.7	3.4	2.5	2.7	3.5	3.1	8.5	4.9	2.9
Alumina and aluminium	0.9	1.8	3.9	0.0	3.7	-0.1	2.0	0.0	2.8
Other metal products	2.7	3.6	3.0	2.0	6.1	0.6	1.3	2.6	3.5
Motor vehicles and parts	0.6	1.5	1.5	0.2	3.3	0.0	0.0	0.0	1.1
Other manufacturing	3.6	3.2	3.4	2.8	4.6	2.4	2.7	3.6	3.5
Electricity – black coal	1.1	0.0	1.6	-3.0	2.1	0.0	0.0	0.0	1.2
Electricity – brown coal	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Electricity – gas	0.3	0.0	2.8	1.8	3.4	0.0	2.5	0.0	2.7
Electricity – oil prods.	0.0	0.0	0.0	0.0	0.0	0.0	-0.9	0.0	-0.1
Electricity – other	2.2	2.6	5.1	0.0	4.4	0.4	0.0	0.0	1.8
Electricity supply	1.2	1.3	1.6	0.3	2.2	-0.2	1.9	0.8	1.3
Urban gas distribution	1.8	2.1	2.8	1.0	3.7	0.5	2.9	1.8	2.0
Water and sewerage services	1.9	1.8	2.1	0.9	2.9	0.2	2.9	1.2	1.9
Construction services	2.3	1.2	3.5	0.8	4.3	0.9	5.2	2.3	2.5
Wholesale trade, retail trade, accommodation	0.9	1.2	1.6	0.0	2.3	-0.1	2.9	0.8	1.2
Road transport services – passenger	1.3	1.3	1.5	1.1	2.2	0.4	1.9	1.2	1.4
Road transport services – freight	2.6	3.0	3.2	1.8	4.5	1.9	4.0	2.7	3.0
Rail transport services – passenger	1.6	1.6	1.9	1.7	0.0	0.0	0.0	0.0	1.7
Rail transport services – freight	1.2	1.8	1.7	0.7	3.3	1.1	1.6	1.3	1.7
Water transport services – passenger	0.0	1.5	0.6	0.2	3.3	-1.0	1.7	3.0	0.3
Water transport services – freight	-1.1	-0.4	-0.7	-1.1	0.0	-1.6	0.0	0.2	-0.6
Air transport services – passenger	2.6	4.5	4.7	2.4	5.4	3.0	5.5	4.0	3.8
Air transport services – freight	1.7	1.7	2.0	0.4	3.0	0.0	3.6	2.1	1.8
Other transport services	1.9	2.5	2.7	1.6	3.9	1.3	3.5	2.3	2.4
Communication services	6.7	7.0	6.9	6.0	7.7	5.6	7.6	7.3	6.9
Financial and business services	4.6	4.6	5.0	3.8	5.6	3.2	5.7	3.9	4.7
Dwelling ownership	3.0	2.7	2.6	1.6	4.2	0.9	4.2	1.8	2.8
Public services	1.8	1.7	2.6	0.8	3.3	0.4	3.9	1.8	2.0
Other services	2.7	2.8	3.4	2.5	3.4	2.1	3.6	2.6	2.9
Private motor vehicle ownership	0.5	0.6	1.8	-0.6	1.8	-0.9	2.8	0.6	0.8

Table 7.3 Low emission scenario: $C0_2$-e Emissions by Major Source Category

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Average annual growth rates (1999-2020)									
Energy sector, total	-0.1	0.4	0.6	-1.2	2.0	-0.8	1.4	0.0	0.4
Fuel combustion	-0.1	0.4	0.5	-1.2	1.8	-0.8	1.3	0.0	0.3
Electricity	-0.5	0.2	0.1	-3.1	1.0	0.0	1.8	0.0	-0.1
Transport	0.0	0.4	0.7	-0.7	1.4	-1.1	1.8	-0.3	0.3
Other industries	0.4	1.0	1.0	-0.1	2.8	-0.6	0.5	0.5	1.0
Household consumption	0.5	0.4	1.8	-0.1	2.3	-1.0	3.4	-0.1	0.8
Fugitive emissions from fuels	0.7	0.0	1.4	1.0	3.8	-1.5	1.4	0.0	1.1
Industrial processes	0.2	1.0	2.3	-0.9	2.6	-1.5	0.5	0.6	1.2
Agriculture	1.2	1.9	1.8	0.5	2.6	2.2	0.8	2.6	1.7
Waste	0.6	0.7	1.3	0.4	1.3	0.0	1.5	0.5	0.8
LUCF	1.8	2.1	2.1	1.1	2.9	1.6	0.0	2.0	1.9
Total	0.2	0.6	0.9	-0.7	2.2	0.0	1.1	0.0	0.6
Levels(Mt CO2-e) (1999)									
Energy sector, total	113.9	124.1	64.0	17.0	36.8	3.4	2.3	2.1	363.6
Fuel combustion	108.4	110.3	57.7	16.6	33.1	3.4	1.8	2.1	333.5
Electricity	49.1	63.6	29.1	6.1	14.0	0.0	0.1	0.0	162.1
Transport	28.4	19.4	13.4	4.9	7.4	1.4	0.9	1.3	77.2
Other industries	29.7	26.2	14.7	5.3	11.5	1.9	0.7	0.7	90.8
Household consumption	1.1	1.1	0.5	0.2	0.2	0.1	0.0	0.1	3.4
Fugitive emissions from fuels	5.5	13.8	6.3	0.3	3.7	0.0	0.6	0.0	30.1
Industrial processes	2.2	1.4	2.0	1.1	2.3	0.7	0.8	0.0	10.4
Agriculture	29.9	18.1	21.6	8.0	13.2	3.2	1.2	0.1	95.2
Waste	5.5	4.8	2.3	1.3	1.2	0.3	0.2	0.6	16.3
LUCF	-5.2	-5.3	-4.1	-2.4	-2.5	-6.7	0.0	-0.3	-26.5
Total	146.2	143.0	85.9	25.1	51.0	0.9	4.5	2.5	459.0
Levels (Mt CO2-e) (2020)									
Energy sector, total	112.0	135.4	73.3	13.1	57.2	2.9	3.1	2.1	397.6
Fuel combustion	105.6	121.7	64.7	12.7	48.9	2.9	2.4	2.1	359.4
Electricity	44.1	67.0	29.9	3.0	17.5	0.0	0.2	0.0	160.2
Transport	28.1	21.0	15.8	4.2	10.0	1.1	1.4	1.3	82.9
Other industries	32.1	32.3	18.3	5.3	21.0	1.7	0.8	0.8	112.3
Household consumption	1.2	1.2	0.7	0.2	0.4	0.1	0.0	0.0	4.0
Fugitive emissions from fuels	6.4	13.7	8.6	0.4	8.3	0.0	0.8	0.0	38.2
Industrial processes	2.3	1.7	3.3	0.9	4.0	0.5	0.9	0.0	13.6
Agriculture	39.1	27.2	32.2	9.1	23.3	5.1	1.4	0.2	137.5
Waste	6.3	5.6	3.1	1.5	1.6	0.3	0.3	0.7	19.3
LUCF	-7.7	-8.4	-6.3	-3.0	-4.6	-9.5	0.0	-0.4	-40.0
Total	152.0	161.4	105.5	21.6	81.5	-0.7	5.7	2.5	528.0