Developing an Economic Model for Examining Greenhouse Issues in China

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1 INTRODUCTION

In a recent presentation to China's State Information Centre (SIC), I outlined some of the results obtained from economic modelling of the impacts of an Emissions Trading Scheme (ETS) in Australia. The purpose of this paper is to document in detail the modelling and projected impacts. These details provide reference as to what modelling features should be included in a bottom-up regional model of China for the purpose of examining greenhouse issues.

The analysis presented in this paper is based on simulations of a bottom-up regional model of Australia – the Monash Multi-Regional Forecasting (MMRF) model, with key inputs relating to the electricity sector provided by McLennan, Magasanik and Associates (MMA) from modelling using their suite of energy market models.[1] The interaction between the MMRF and MMA models is described throughout the report, as relevant variables are discussed.

Modelling of two scenarios is discussed. The first scenario is a baseline, or 'business as usual', projection for the Australian economy and its states and territories. The baseline is a sequence of annual forecasts constructed using external forecasts for macro variables, extrapolations of recent trends in industry technologies and household tastes, and estimates of the effects of existing energy policies. In effect, the baseline shows what might be expected to happen if there were no national ETS and no change in current greenhouse policies.

The second scenario considers an ETS similar in design to that proposed by the National Emissions Trading Taskforce (see NETT, 2006)[2] and to that outlined by the Prime Minister's Taskforce (Prime Ministerial Task Group on emissions Trading, 2007). The ETS covers all emissions from stationary and transport fuel combustion plus fugitive emissions from coal, oil and gas mining. It excludes emissions from non-combustion sources in agriculture, industrial processes and waste management. Electricity generators using fossil fuels receive a free allocation of permits to compensate for losses in profits, and trade exposed emissions intensive industries are compensated for 100 per cent of increased energy costs. Limited banking of permits is allowed, and offsets are permitted from biosequestration (forestry), agriculture and waste.

The rest of this paper is organised as follows. The version of the MMRF model used in this study, including its limitations, is summarised in Section 2. Details of the inputs and assumptions used for the baseline scenario are given in Section 3. In Section 4, we detail the characteristics of the ETS scenario being examined. The effects of the ETS are reported in Section 5 as deviations between the values of variables in the ETS scenario and their values in the baseline scenario. Concluding remarks are in Section 6.

2 THE MMRF MODEL

2.1 Overview

MMRF is a detailed, dynamic, multi-sectoral, multi-regional model of Australia. The current version of the model distinguishes 58 industries (see Table A), 63 products produced by the 58

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[1] A detailed description of MMA's suite of energy models is given in MMA (2006).

[2] This paper is based, in part, on a modelling report prepared in August and September 2007 by the Centre of Policy Studies for the NETT.

industries, 8 states/territories and 56 sub-state regions[3]. There are five types of agents in the model: industries, capital creators, households, governments, and foreigners. 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 MMRF 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.

MMRF 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 in the long run 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 endowment 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 four blocks of equations in addition to the core. The first two describe regional and federal government finances, and the operation of regional labour markets. The third block contains dynamic equations that describe physical capital accumulation and lagged adjustment processes in the national labour market. The fourth block, which is of direct relevance to this study, contains enhancements for the study of greenhouse gas issues.

A full description of MMRF excluding the changes made specifically for the NETT project is given in Adams *et al.* (2008). An overview of the greenhouse gas enhancements that existed before the NETT work is given in Section 2.2. The changes undertaken for the Treasury modelling are outlined in Section 2.3. Some limitations are described in Section 2.4

2.2 Environmental enhancements

Prior to the NETT project MMRF contained a number of enhancements to improve its capability for environmental analysis. These included:

1. An energy and gas emission accounting module, which accounts explicitly for each industry and region recognised in the model;
2. Equations that allow for inter-fuel substitution;
3. Mechanisms that allow for abatement of non-combustion emissions;
4. Allowance for the operations of the National Electricity Market (NEM); and

[3] Of the 58 industries, three produce primary fuels (coal, oil and gas), one produces refined fuel (petroleum products), six generate electricity and one supplies electricity to final customers. The six generation industries are defined according to primary source of fuel: Electricity-coal includes all coal-fired generation technologies; Electricity–gas includes all plants using gas turbines, Cogen and combined cycle technologies driven by burning gas; Electricity-oil products covers all liquid-fuel generators; Electricity-hydro covers hydro generation; while Electricity-other covers the remaining forms of renewable generation from biomass, biogas, wind etc. Electricity–nuclear is included for the sake of completeness. It can be triggered, if desired, at a specified CO2 price.

Other than the grains industry (industry 4) and the petroleum products industry (industry 20), each industry produces a single product. The grains industry produces grains for animal and human consumption and biofuel used as feedstock by the petroleum products industry. Petroleum products produces five products – gasoline (includes gasoline based biofuel blends), diesel (includes diesel based biofuel blends), LPG, aviation fuel, and other refinery products (mainly heating oil). Thus, in total 63 products are produced by the 58 industries.

5. Improved treatment of services of energy-using equipment in private household demand.

2.2.1 Emissions accounting

MMRF tracks emissions of greenhouse gases at a detailed level. It breaks down emissions according to: emitting agent (58 industries and residential); emitting state or territory (8); and emitting activity (9). Most of the emitting activities are the burning of fuels (coal, natural gas and five types of petroleum products[4]). A residual category, named Activity, covers emissions such as fugitives and agricultural emissions not arising from fuel burning.

The resulting 58 × 8 × 9 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. MMRF accounts for domestic emissions only, so a change in world emissions as a result of an increase of Australian exports of, say, coal is not accounted for.

2.2.2 Inter-fuel substitution

Inter-fuel substitution in electricity generated is handled using the "technology bundle" approach[5]. A variety of power-generating industries are distinguished based on the type of fuel used (see Table A). There is also an end-use supplier (the Electricity supply industry) in each state and territory. The electricity generated flows directly to the local end-use supplier either directly in the case of Western Australia (WA) and the Northern Territory (NT) or indirectly via the NEM for New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA) and Tasmania (TAS) (see Section 2.2.5). The end-use supplier then distributes electricity to local and inter-state users. The NEM (in NEM regions) or the end-use supplier (in non-NEM regions) can substitute between the different generation technologies in response to changes in their production costs. For example, the Electricity supply industry in one region 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 is set to a high number, typically around 5.

For other energy-intensive commodities used in industry, MMRF 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 gas, the substitution elasticity in industrial use is 0.25. This input substitution is driven by price changes, and so is especially important in the policy scenarios, which makes outputs of emitting industries more expensive.

2.2.3 Abatement of non-combustion emissions

In MMRF, non-combustion emissions are generally modelled as directly proportional to the output of the related industries. However, in simulating the effects of a carbon tax, or some other price-related penalty on gas emissions, allowance can be made for abatement of non-

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[4] The five types are gasoline, diesel, LPG, aviation fuel and other petroleum products. Each of these fuels is identified as a separate commodity within the model.

[5] The technology bundle approach has its origins in the work done at ABARE on the MEGABARE model: see Hinchy, M. and K. Hanslow (1996).

combustion emissions. The amount of abatement is directly related to the price of carbon. The constants of proportionality are derived from point estimates of the extent of abatement that might arise at a particular price level.

2.2.4 Transport capabilities

The MMRF database recognises explicitly four transport modes: road, rail, water and air, with road and rail transport separated into passenger services and freight transport components (see Table A). Passenger services are sold directly to categories of final demand. Freight services are sold indirectly as margins on flows of goods and services and for non-margin usage in production.

MMRF allows for substitution between road and rail freight (inter-modal substitution). Specifically, for a flow from region s to region q, substitution is allowed between road freight and rail freight provided by region q. The substitution is based on relative prices. If in region q, the price of road freight increases relative to the price of rail freight, then there will be substitution away from road freight towards rail freight in all margin uses of the two in region q.

2.2.5 The National Electricity Market

MMRF contains a representation of the operations of the National Electricity Market (NEM) in Australia. The NEM covers electricity supply in the NEM-regions: NSW, VIC, QLD, SA, TAS and the Australian Capital Territory (ACT). Final demand for electricity in each NEM region continues to be determined within the CGE-core of the model in the same manner as demand for all other goods and services. All of the electricity used in NEM-region r is purchased from the Electricity retail industry in that region. Each NEM-retailer sources its electricity from the NEM. The NEM does not have a regional dimension: in effect it is a single industry which sells a single product (electricity) to each NEM-retailer. The NEM sources its electricity from generation industries in each NEM region. Thus, the electricity sold by the NEM to the electricity retailer in QLD may originate in Hydro generation in Southern TAS. NEM demand for electricity generation is price-sensitive. For example, if the price of Hydro generation from TAS rises relative to the price of gas generation from NSW, then NEM demand for generation will shift towards NSW gas generation and away from TAS hydro generation.

The explicit modelling of the NEM enables substitution between NEM regions and between different fuel types. It also allows explicitly for inter-state trade in electricity, without having to trace explicitly the bilateral flows. Note that WA and NT are not part of the NEM and electricity supply and generation in these regions continues to be determined on a state-of-location basis.

2.2.6 Services of energy-using equipment in private household demand

The final three industries shown in Table A provide services of energy-using equipment to private households. These *dummy* industries enable households to treat the energy sources and underlying capital equipment for these services as complements, rather than as substitutes, as is the case in the standard model.

Industry 56 provides private transport services to the household sector, using inputs of capital (private motor vehicles), automotive fuel and other inputs required for the day-to-day servicing and running of vehicles. Industry 57 provides the services of electrical equipment (including air conditioners) to households, using inputs of capital (electrical equipment) and electricity. Industry 58 provides the services of appliances used for heating and cooking, using inputs of capital (heat and cooking appliances), gas and electricity. Energy used by these three industries accounts for all of the energy consumption of the residential sector.

Including these industries improves the model's treatment of price-induced energy substitution and its treatment of the relationship between energy and energy equipment in residential demand. For example, in the previous specification of household demand, if the price of electricity fell relative to the price of other goods and services, electricity could be substituted for other commodities, including electrical and heating appliances. Now, with no direct usage of electricity, a change in the price of electricity induces substitution only through its effect on the prices of electrical equipment services and private heating services. If the change in electricity price reduces the price of electrical equipment services relative to the price of other products, then electrical equipment services (including its inputs of appliances and energy) will be substituted for other items in the household budget.

2.3 Further Environmental Enhancements

A number of enhancements were introduced for the NETT work. These covered:

1. Revised mechanisms for modelling abatement of non-combustion emissions;
2. Equations for handling abatement of combustion emissions outside of electricity generation;
3. Equations that allow some industries to be shielded, partly or fully, from the cost impacts of emissions pricing;
4. Scope for the operations of a global emissions trading scheme; and
5. Allowance for land-land substitution in agriculture and forestry.

2.3.1 Mechanisms for the abatement of non-combustion emissions

The initial MMRF treatment of abatement of non-combustion emissions was based on out-of-date single-point estimates of the amount of abatement available at a specific abatement cost (see Section 2.2.3). The revised theory is somewhat more general, allowing for lagged adjustment and employs more up-to-date data. The data and theoretical antecedents come from the GTEM model.

The revised theory is centred on non-combustion emissions per unit of output (or emissions intensity). In particular it assumes that emissions intensity is inversely related to the price of CO2. Algebraically, the theory begins with the following expression for targeted emissions intensity, *LAMBDAT*. For a specific industry,

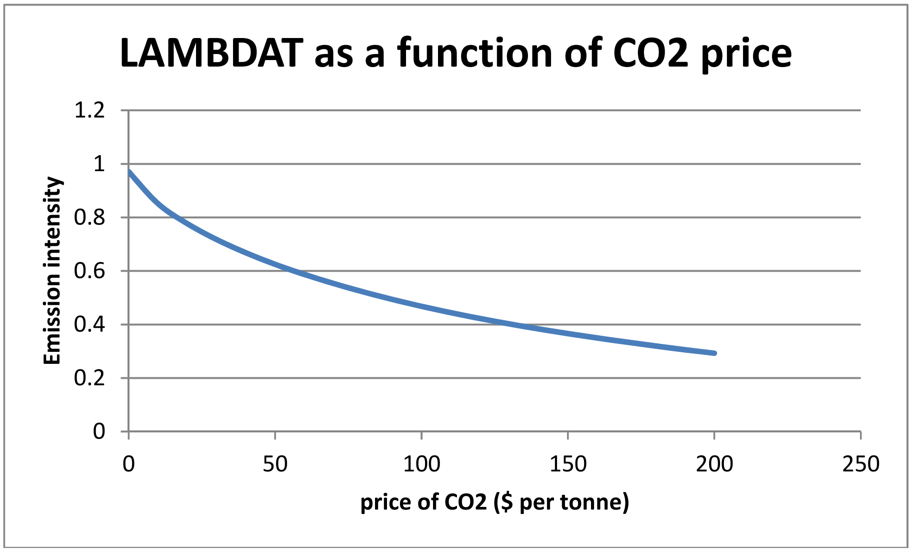
$$LAMBDAT = e^{-ALPHA \times (1+T)^{GAMMA}} \qquad (2.1)$$

where:

T	is the level of the carbon tax ($ per tonne of CO2-e);
ALPHA	is the no-regret (when T = 0) level of abatement; and
GAMMA	is the speed of adjustment of the targeted emissions intensity to the tax rate.

Equation (2.1) posits a logistic shaped relationship between *LAMBDAT* and *T*. Typical values of *ALPHA* and *GAMMA* in the GTEM database are around 0.03 and 0.7. With these settings, the value of LABMDAT when the price of CO2-e is, say, $50 per tonne would be 0.6247. This compares to a value when the price of CO2-e is zero of 0.9704. Thus with a $50 price, targeted emissions intensity is reduced by 35.6% (= 100*(0.6247/0.9704-1)). A chart showing values for

LAMBDAT with ALPHA = 0.03 and GAMMA = 0.7 for various values of carbon price (T) is shown in Figure 2.1.



The ordinary-change form of equation (2.1) is:

$$d_{LAMBDAT} = -LAMBDAT \times ALPHA \times GAMMA \times (T)^{GAMMA-1} \times d_T \quad (2.2)$$

where d_ indicates ordinary change in the associated levels variable.

It is assumed that there is a maximum amount of emissions reduction possible. This is implemented in the GEMPACK code of the model using a conditional IF statement which effectively sets *d_LAMBDAT* to zero when the level of *LAMBDAT* moves below a specified level as the price of emissions rises.

The actual level of emissions intensity is determined via a partial adjustment mechanism. This is required to ensure that the emissions intensities of industries do not respond to vigorously to changes in emissions price, especially at the start of a simulation when the price rises immediately from zero to a value that might be above $20 per tonne. The partial adjustment mechanism is:

$$LAMBDA = -LAMBDA\_L + ADJUST \times (LAMBDAT - LAMBDAT_L) \quad (2.3)$$

where:

LAMBDA is the actual level of emissions per unit of output;

LAMBDA_L is the actual level of emissions per unit of output lagged one year; and

ADJUST is a speed-of-adjustment parameter with a typical value of 0.3.

The ordinary change form of (2.3) is written as:

$$d\_LAMBDA = (1 - ADJUST) \times d\_(LAMBDA\_L\ ) + ADJUST \times d\_LAMBDAT \quad (2.4).$$

It is assumed that the abatement implied by (2.2) and (2.4) is not costless. The cost is the cost of the investment in new technology required to achieve the reduction in emissions intensity. In modelling with MMRF, the cost is imposed by an endogenous all-input technological deterioration in production sufficient to increase the average cost of the affected industry by the value of abatement achieved in each year. The value of abatement is the product of the emissions price and the quantity of emissions abated. Thus, for example, if an industry reduces its emissions by 1 Mt when the emissions price is $50 per tonne, then the model will force a permanent increase in the average cost of the industry equal to $50 million in that year. Note that the abatement is permanent, but the cost, albeit permanent, is equal to the value of avoided emissions in the first year only.

2.3.2 Abatement of combustion emissions outside of electricity generation

Additional substitution possibilities were incorporated into the model to allow for more realistic economic responses to CO2 pricing. In particular:

- The meat and meat products industry was modified to allow it to enable price-based substitution between high and low emissions livestock; and
- Technology bundles were introduced into the household demand for private transport services, corresponding to petrol vehicles, diesel vehicles, hybrid vehicles and electric vehicles, to enable price based substitution between these vehicle types.

In earlier versions of the model, there was little scope for abatement of combustion emissions outside of electricity generation, for example from the use of diesel in mining. This shortcoming was corrected in the NETT modelling by including abatement response functions analogous to equation (2.1) to (2.4). The functions for combustion emissions cover the use of fuels – coal, gas and petroleum products – by most industries for stationary energy. Typical settings for the ALPHA and GAMMA coefficients are around 0.000001 and 2.0. This means that at an emissions price of $50 per tonne, emissions intensity from the burning of fuel will fall from one (at a zero price for emissions) to around 0.97, or by around 3 per cent.

As for non-combustion emissions, this form of abatement is costed, with the cost assumed to be the value of abatement.

2.3.3 Shielding

In the policy framework outlined in the Government's *Carbon Pollution Reduction Scheme Green Paper*, certain industries are shielded from some of the cost effects of the non-zero permit price. For modelling purposes, shielding is defined as the cost-reduction enabled via a general production subsidy necessary to offset the combined direct and indirect effects of an emissions price on their average cost. The direct effects are via the imposition of the penalty on their direct combustion emissions or on the emissions directly associated with their activity (e.g. industrial and fugitive emissions). The indirect effects arise from the increased cost of electricity.

Two industry classes are considered, based on the classification outlined in the Government's *Carbon Pollution Reduction Scheme Green Paper*. One industry class contains trade-exposed industries deemed most adversely affected. The other class contains trade-exposed industries deemed less adversely affected but still requiring shielding. The rate of shielding for the category 1 industries starts at 0.9 and then declines. The rate of shielding for the category 2 industries starts at 0.6 and then declines.

In algebraic terms, for direct emissions:

$$SHIELDING_{DIR} = -COVER \times T \times \left[\frac{QGAS}{OUTPUT}\right]_{INIT} \times OUTPUT \qquad (2.5)$$

where:

$SHIELDING_{DIR}$ (a minus number) is the necessary reduction in average cost;

COVER is the rate of coverage (a number between 0 and 1.0);

T is the level of the carbon tax ($ per tonne of CO2-e);

QGAS is the number of tonnes of CO2-e emissions;

OUTPUT is the output of the industry; and

$[\ \ ]_{INIT}$ indicates the initial, 2005-06, ratio of emissions to output.

According to equation (2.5), the value of shielding is proportional to minus the output of the industry and to the emissions price. The coefficient of proportionality reflects the level of coverage and the fixed initial level of emissions intensity.

For indirect emissions (shielding to offset the increased cost of electricity):

$$SHIELDING_{IND} = -COVER \times [PETS - PREF] \times \left[\frac{ELECTRICITY}{OUTPUT}\right]_{INIT} \times OUTPUT \qquad (2.6)$$

where:

$SHIELDING_{IND}$ (a minus number) is the necessary reduction in average cost;

PETS is the price of a unit of electricity under the policy scenario;

PREF is the price of electricity in the reference case;

ELECTRICTY is the number of units of electricity used; and

$[\ \ ]_{INIT}$ indicates the initial, 2005-06, ratio of electricity use to output.

Equation (2.6) is similar in structure to equation (2.5), with the emissions price-induced increase in the electricity price in (2.6) analogous to the permit price in (2.5).

Having determined the necessary reduction in average cost to offset the increased direct and indirect costs associated with emissions pricing, the model then applies the necessary reduction to each shielded industry via a subsidy on inputs of *other costs*[6]. The subsidy is paid for initially by the Federal government. However, since government budget balances as a proportion of the nominal economy are held fixed at reference case levels in the policy scenarios via endogenous cash payments to households, the shielding subsidy is ultimately paid for by Australian households.

2.3.4 A global emissions trading scheme

The key variables for domestic emissions pricing are the price of emissions, the quantity of emissions covered by the scheme, the value of shielding, and the income raised from the scheme, which is available for recycling. When considering Australia's involvement in a global emissions trading scheme additional variables are required. These include the global price of emissions and Australia's allocation of global permits. Values for these variables will, in the most part, be supplied from external sources. For the NETT project, the global emissions price is sourced from projections from the GTEM model.

By including a global emissions price (in global currency) there needs to be an equation that coverts the global foreign price of emissions into a domestic price using the nominal exchange rate. For the NETT simulations it is assumed that with a global scheme Australian industries can reduce emissions directly or purchase global permits on a secondary market to cover their emissions obligation. Assuming free trade in permits, additional equations are required that

[6] *Other costs* is a miscellaneous cost category used often to impose shocks to the average cost of industries.

trace the quantity of permits traded overseas and the value of those permits. In general, the number of imported permits in each year equals the difference between the quantity of Australian emissions and Australia's annual allocation. The value of those permits, which moves the balance on income account towards deficit, is the imported quantity times the price expressed in Australian dollars.

2.3.5 Land-land substitution

In MMRF, land is an input to production for the agricultural industries and forestry. The standard treatment of land before the NETT project was to treat land as industry specific and in fixed supply by industry. Hence, when a land-using industry expands, the scarcity value of its land increases leading to increased cost, but there is no change in usage.

For the NETT simulations a refined treatment was adopted. Land was no longer considered industry specific, but rather region specific, with a region-wide supply constraint. This meant that within a region, some industries could increase their usage of land. But that increased usage had to be met by reduced usage elsewhere. The mechanism for re-allocating land across users was a Constant Elasticity of Transformation (CET) specification similar to that used in GTEM. With this mechanism in place, in a typical policy simulation, demand for biosequestration offsets pushes up demand for the output of forestry (logging and services associated with plantations). This, in turn, increases forestry's demand for land. Increased forestry demand increases the price of land generally in the region. This causes non-forestry industries to reduce their land usage with subsequent reductions in production, all else unchanged.

2.4 Limitations of the model for the current project

MMRF is a single country model. Hence model-determined interaction between Australia and the rest of the world arising from the ETS is limited to movements *along* the export demand and import supply schedules for Australia's traded goods. We do not model feedback from the model-determined changes in the Australian economy on the *positions* of foreign export demand and import supply schedules. We also assume that the implementation of an ETS in other countries, which would affect Australian export markets and the supply of imports, does not take place.

The model does not endogenously predict the emergence of new industries, such as coal generation with carbon capture and storage, or nuclear.

For the simulations discussed in this report, no attempt is made to include the possible effects of climate change in the baseline projection. That is, there are no assumptions made about the possible costs under 'business as usual' as a result of climate change. For example, we do not assume an increase in the price of water resulting from measures designed to adapt to reduced rainfall and reduced runoff in water catchments. Neither do we include other more serious predictions of climate scientists, such as the flooding of low-lying urban areas or increased bush fire activity.

Not allowing for the possible effects of climate change means that we do not account for any of the possible direct economic benefits arising from the abatement achieved by an ETS. For example, we do not account for the improvements to the foreign competitiveness of water-dependent agricultural and mining industries that would arise if abatement from the ETS were to ease upward pressure on water prices.

3 BASELINE SCENARIO

In Section 3.1 we describe the key assumptions underlying the baseline scenario. Sections 3.2, 3.3 and 3.4 contain baseline projections for industry output, greenhouse gas emissions and electricity generation.

3.1 Key assumptions

In forecasting with MMRF, a large amount of information from specialist external forecasting agencies is imposed on the model. The model then traces the implications of the external forecasts at a level of industrial and regional detail consistent with the requirements of the user.

In generating the baseline scenario, the following data were used:

- State/territory macroeconomic forecasts to 2014 from Access Economics (2006), supplemented by ideas from the Commonwealth Government's Intergenerational Report (2007)
- National-level assumptions for changes in industry production technologies and in household preferences from CoPS;
- Estimates of the net impacts of existing energy-related measures from CoPS and MMA(2006);
- Forecasts, through to 2012, for the quantities of agricultural and mineral exports and for capital expenditure on major minerals and energy projects, based on information in Suevas-Cubria and Riwoe (2006) and ABARE (2006a and 2006b);
- Estimates of changes in electricity generation mix and capacity from (MMA); and
- Forecasts for oil and gas supply from the International Energy Agency (IEA) (2006).

To accommodate this information, numerous naturally endogenous variables in the model are made exogenous. These include 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 are made endogenous. For example, to accommodate forecasts for the volumes of agricultural exports from ABARE we make endogenous variables that locate the positions of foreign demand curves. To accommodate forecasts for macro variables from Access Economics, we make endogenous various macro coefficients such as the average propensity to consume.

3.1.1 Baseline assumptions: macroeconomic variables

Appendix Table A2 lists assumptions for selected macroeconomic variables in the baseline. These reflect Access Economics' forecasts to 2014, supplemented by extrapolations of medium-term trends and by information from the IGR. The following are some features of the macroeconomic assumptions.

- Growth in real GDP at an average annual rate of 3.3 per cent between 2004 and 2010, slowing to an average rate of 2.9 per cent per year between 2010 and 2030. Average annual growth over the full projection period is assumed to be 3.0 per cent. A falling rate of growth is consistent with projections from the Commonwealth Treasury's IGR which, because of the gradual ageing of the population, projects a slowing rate of growth of the working-age cohort and hence of employment and real GDP.

- Consistent with growth patterns over the past five years, QLD and WA are assumed to be the fastest growing state economies, followed by NSW and VIC. SA and TAS are the slowest growing states, though the gap between the slowest and fastest growing regions is significantly less than in recent times.
- Growth rates of employment and real private consumption across regions and across time follow the national pattern for real GDP.
- Over the past fifteen years the volumes of international exports and international imports have grown rapidly relative to real value added in each region. This reflects several factors: declining transport costs; improvements in communications; reductions in protection in Australia and overseas; and technological changes favouring the use of import-intensive goods such as computers. All these factors are expected to continue through the forecast period, leading to further increases in the ratio of the volume of international trade to real value added. Note that with the growth in imports expected to be in line with the growth in exports, little improvement is expected in the current imbalance between export and import volumes, and hence in Australia's current account deficit as a share of GDP.

3.1.2 Baseline assumptions: changes in fuel technology

Appendix Table A3 summarises our baseline technical assumptions for the usage of fuels per unit of industrial output and for the usage of fuels per unit of electricity generation in terms of two commonly used measures of efficiency – energy technical efficiency and supply efficiency. We define energy technical efficiency as (the negative of) a weighted average of the use of primary and derived fuels per unit of output in all industries using those fuels other than the electricity generators. We define supply efficiency as (the negative of) a weighted average of the use of primary fuels per unit of electricity generation. Our detailed assumptions for industry technologies yield energy technical efficiency improvements at an average annual rate of 1.1 per cent over the full projection period and improvements in supply efficiency at an average annual rate of 0.7 per cent.

3.1.3 Baseline assumptions: energy-related measures

In general terms, the demand side measures (MEPS, Greenhouse Gas Abatement Programme, etc.) are incorporated directly into the MMRF baseline via calibrated shifts in industry technologies and household tastes against energy products using data supplied on a confidential basis by the Australian Greenhouse Office (AGO). The technological shifts against the use of energy are made cost-neutral by simultaneous uniform adjustments to the technology coefficients applying to the entire user's inputs (intermediate and primary) so that there is no net effect on the user's costs. The remaining measures (e.g., Mandatory Renewables Energy Targets (MRET)), which are supply-side in orientation, are incorporated indirectly via inputs from MMA on the generation mix and the wholesale electricity price.

3.1.4 Baseline assumptions: electricity generation mix and generation capacity

As part of the integrated modelling undertaken with MMA, the MMA models are used to inform MMRF about changes in generation mix and capacity. The process whereby MMRF accepts MMA numbers of generation is an iterative one, with convergence obtained when MMRF's projections for electricity demand are fully consistent with MMA's projections for generation mix and capacity. Baseline projections from MMRF (or equivalently baseline assumptions from MMA) for electricity generation are discussed in Section 3.4.

3.1.5 Baseline assumptions: oil and gas supply and the foreign price of oil

In the baseline projection we impose strict supply constraints on the production of oil from the mature basins in VIC, WA and NT. These restrictions offset, more or less, prospects for new discoveries in these states, meaning that oil production for Australia as a whole changes little between 2004 and 2030. We also impose supply restrictions on the supply of natural gas in each state, reflecting current estimates of reserves and “normal” rates of depletion.

For the foreign currency price of oil, it is assumed there is no change in real terms between the average real level in 2005 and 2030. This is consistent with current forecasts from the International Energy Association (2006)

3.2 Baseline projections: national industry output

Appendix Table A4 gives baseline projections for growth in national industry output. This discussion focuses on average annual growth rates between 2004 and 2030.

Electricity – wind (industry 34) is the fastest growing industry with a projected average annual growth rate of 12.0 per cent. Prospects for this industry are dominated by the MRET scheme. MRET also stimulates strong growth in other non-hydro sources of renewable generation: electricity – biomass (industry 32) and electricity – biogas (33). Gas generation (industry 29) also has above-average growth prospects, based on projections from the MMA model.

Growth prospects for coal generation (industry 28) are restricted by relatively fast growth in other forms of generation and by relatively slow growth in overall (i.e., total end-use) demand for electricity (industry 35). Slow growth in end-use demand reflects, in the main, the effectiveness of demand-side measures, especially MEPS. We assume that generation from liquid fuel (industry 30) does not change through the projection period, and that production of hydro-electricity (industry 31) is constrained by environmental factors.

The fastest growing industry outside of the electricity sector is gas mining (industry 7), reflecting our assumption of very strong growth in exports.

Forecasts for the agricultural sector (industries 1 and 2) are, in the main, determined by the prospects of downstream food and beverage industries (industries 11, 12 and 13). These have close-to-average growth prospects, reflecting projected strong growth in exports offset by expected increases in import penetration on local markets. Forestry and fishing (industries 3 and 4) are projected to grow relatively slowly due to constraints imposed by environmental and resource factors.

Prospects for the non-energy mining industries (industries 8, 9 and 10) are governed by our assumptions for exports. The prospects of coal mining (industry 5) reflect the prospects for coal exports combined with our forecast for growth in domestic energy demand which is dominated by electricity generation. Production of oil (industry 6) is expected to decline slightly, reflecting estimates of supply availability from current reserves.

Excepting food and beverages, nearly all manufacturing industries have weak growth prospects. In general, their prospects are restricted by a combination of increases in import competition, weak growth in exports, and, in some cases, supply constraints affecting primary domestic sources of supply. Despite projected strong growth in exports, growth in output for the iron and steel industry (industry 23) is projected to be weak due to slow growth in domestic demand. The alumina and aluminium industry (industry 24) has a much larger export propensity and, hence, better overall growth prospects than those of iron and steel.

Most of the remaining industries have close to average growth prospects. The prospects for Construction services (industry 38) reflect our macro assumptions for investment (Appendix Table A2). The trade services industry (industry 39) sells widely throughout the economy. Its growth rate, though, is below that of real GDP because of assumed adverse taste and technology shifts against its products. Public services (50) and other services (51) are very consumption oriented. Accordingly, their prospects are explained by appropriate weighted averages of the growth rates assumed for private and public consumption (Appendix Table A2).

3.3 Baseline projections: emissions by major source category

Appendix Table A5 shows average annual growth rates for emissions (Mt CO2-e) by region and by major source category. The data in this table cover all emissions (Kyoto accounting) except for emissions from forest converted to crop land and grass land.

In aggregate, emissions from stationary energy are projected to grow at an average annual rate of 1.6 per cent between 2004 and 2030. By 2020, emissions are projected to be 21 per cent higher than in 2004, while in 2030 they are expected to be 50 per cent above 2004 levels.

The gap between the average annual growth rate of real GDP (Appendix Table A2) and average annual growth in stationary energy emissions (Appendix Table A5) is (3.0 – 1.6 =) 1.4 percentage points. Part of this difference can be explained by the net impact of the energy-related measures included in the baseline. The residual is attributed to structural effects which operate when there are low-emitting sectors growing at a faster rate than high-emitting sectors.

3.4 Baseline projections: electricity generation

Appendix Table A6 shows average annual growth rates between 2004 and 2030 and across three sub-periods for electricity generation (Pj of generation, converted from GWh) by region and technology type. The structure of generation across regions and time are based on data from MMA (see Section 3.1.5).

Total generation is forecast to increase at an average annual rate of 2.0 per cent over the forecast period, 0.6 percentage points higher than the growth rate in emissions from generation.[7] The difference is due, in the main, to the operation of supply- and demand-side measures that encourage non-coal generation and improved fuel efficiencies in fossil-fuel generation.

[7] Growth in total generation does not necessarily equal growth in the output of the *electricity supply* industry. Electricity supply produces transmission, distribution and retail services. Growth in the volume of these services may differ from growth in generation sent out if, for example, there are improvements in the efficiency of distribution which means more generation can be delivered with the same amount of distribution services.

4 EMISSIONS TRADING SCHEME SCENARIO: ASSUMPTIONS AND INPUTS

4.1 Introduction

The ETS scenario is modelled as deviations away from the baseline projection described in Section 3. Inputs to the deviation simulation are sourced primarily from the projected electricity market outcomes as modelled by MMA(2006) using their suite of bottom up electricity sector models. To accommodate the inputs from MMA, naturally endogenous variables, such as the volumes of agricultural exports and macro variables, which were exogenous in the baseline scenario, are 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, which were endogenous in the baseline, must be exogenous. They are set at the values revealed in the baseline forecast.

4.2 ETS design

Key assumptions of the ETS design are given in Table 1.

Table 1: Features of the ETS design

Assumption	Details
Coverage	Stationary energy, transport and fugitive emissions from 2010.
Offsets	Offsets permitted from biosequestration, agriculture and waste. In the MMRF modelling, the offsets lead to increased demand for forestry and to reduced emissions per unit of production in the agricultural and waste service industries.
Permit allocation to generators	Free permits allocated to electricity generators over the period 2010 to 2030 to offset net loss in profits.
Compensation for trade exposed, emissions intensive industries	Trade exposed, emissions intensive industries were compensated for 100 per cent of increased energy costs. Compensation is given to Iron and steel (23), Alumina and aluminium (24), and Other metal products (25). Compensation is also provided to underground coal miners in NSW and QLD producing for export, and to oil and gas producers facing significant trade exposure (e.g., WA LNG producers).
Recycling of surplus revenue	Remaining permits, beyond those used to compensate generators and trade exposed, emissions intensive industries, were assumed to be auctioned, with surplus revenue recycled as a lump sum to households.
Banking and borrowing	Unconstrained banking of permits is allowed. The impact of banking is reflected in the MMA modelling, and thus influences the permit price adopted in the MMRF model.
Scheme cap	A cap on emissions covered by the ETS is set at 400 Mt in 2030. This is approximately 45 per cent below 2030 levels in the baseline and approximately 8 per cent below current (2007) levels.

4.3 Inputs from MMA

For each year, MMA provides data for:

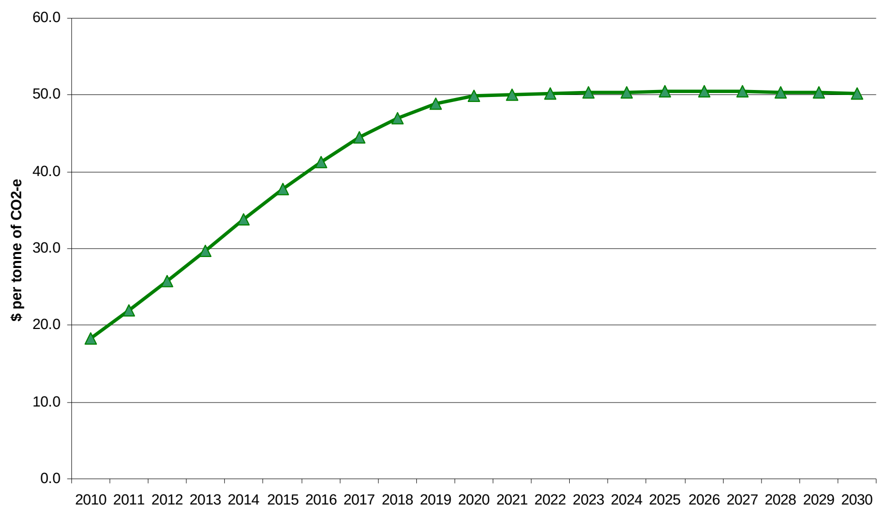
- The price of permits;

- The quantity of offsets;
- Changes in the mix of generation by technology class and region;
- Deviations in generation investment (and hence capacity) by technology class and region;
- Changes in emissions from generation by technology class and region; and
- Total assistance and the value of permits allocated to electricity generators.

4.3.1 Permit price

The time path for the price of permits is shown in Figure 1.

Figure 1: CO2-e prices
($ per tonne of CO2-e)



The ETS scenario involves from 2010 a price on emissions from fuel-combustion and fugitive sources. Prices through time are determined by MMA to achieve specific abatement targets, allowing for banking and offsets, in the electricity generation area. In the MMRF modelling, these prices are applied to all sectors covered by the ETS (stationary, transport and fugitive). As shown in Figure 1, the permit price rises from $18.30 per tonne of CO2-e in 2010, to $50.20 per tonne in 2030.

In modelling with MMRF, the permit price is introduced as a tax imposed per unit of CO2-e released from the combustion of fuels and from fugitive sources.[8] The CGE-core section of the model deals only with *ad valorem* rates of tax. Thus internally the carbon tax is converted to *ad valorem* equivalents using information from the baseline on emissions by source and for the

[8] In principle, the permit price is applied to all emissions from the sectors covered by the scheme. However, in modelling free-compensatory allocation of permits to some sectors, those sectors were actually excluded from the scheme. The excluded sectors are LNG producers in WA, oil producers in VIC, SA and WA and coal exporters in NSW and QLD.

Free allocation of permits to generators is handled as payments to owners of the generators to offset net losses in profits (see Section 4.3.4). Compensation of other trade-exposed sectors is modelled as a production subsidy directed towards the affected industries (see Section 4.3.4).

value of the underlying transaction. For example, according to the baseline, in 2010 emissions from fuel combustion in coal generation is 183.7 Mt. Thus a tax of $18.30 per tonne in that year yields a tax with a value of $3,362 million. The basic value of the use of coal in generation in the baseline in 2010 is around $3,900 million. Thus the *ad valorem* equivalent of the $18.30 per tonne permit price on coal used in generation is 86 per cent (= 100 × 3,362/3,900).

4.3.2 Offsets

Modelling results from MMA show that in 2030 emissions abatement from offsets rise to:

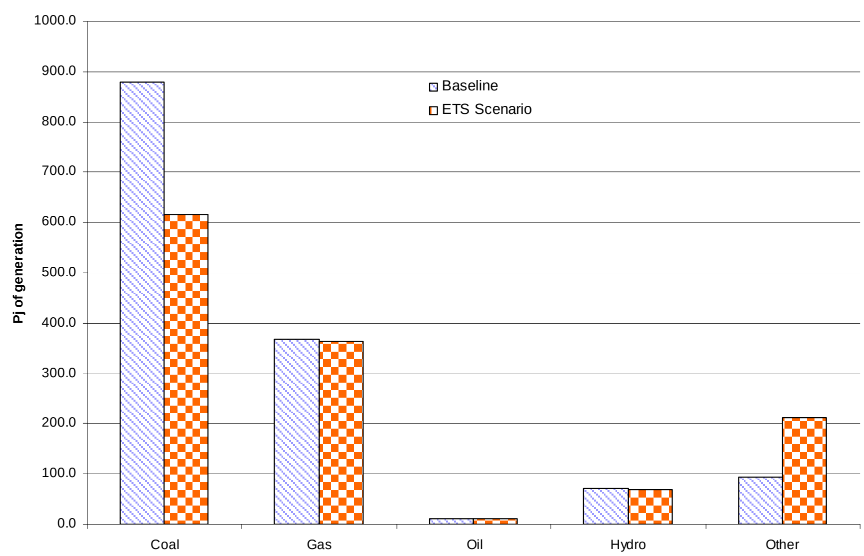
- 18.6 Mt per annum for biosequestration;
- 4.0 Mt per annum for agriculture; and
- 4.7 Mt per annum for waste.

These offsets are introduced into the MMRF modelling as increased demand for forestry and reduced emissions per unit of production in the agriculture and waste service industries. The increase in demand for forestry is calibrated to achieve MMA's profile for biosequestration offsets. The reductions in per-unit emissions for agriculture and waste services are calibrated to achieve, at unchanged levels of production, MMA's profiles for agriculture and waste offsets. Note that the deviations in total emissions from agriculture and waste may differ from the targeted offset numbers to the extent that production of agricultural and waste-service industries is affected by the ETS.

4.3.3 Generation mix by technology type and region

Figure 2 compares Australia's mix of electricity generation in the baseline with the mix of generation assumed in the ETS scenario in 2030.

Figure 2: Generation in 2030
(Pj of generation by broad technology type)



In the MMA modelling, the economy responds to the permit price in part through fuel switching in electricity generation and by reduced final demand for energy. These forces underlie the numbers in Figure 2. Compared to generation in the baseline in 2030, the overall level of generation is reduced, and the mix of generation has changed – there is more non-hydro renewable generation and less coal generation. Due to supply constraint assumptions, there is little change in generation from liquid fuels and hydro. Gas generation changes little from baseline levels.

The MMA story for generation by technology type and region is imposed in the MMRF modelling by allowing cost-neutral shifts in NEM demand for electricity and in retail demand for generation in the non-NEM regions. These shifts in demand are calibrated year-by-year to achieve the levels of generation estimated by MMA.

In the MMA modelling, cleaner technologies for generating electricity from coal are adopted when the price of emissions makes it economical to do so. The uptake of such technologies is imposed in the MMRF simulations via technological shifts in emissions per unit of generation for each technology class in each region. These shifts are calibrated year-by-year to achieve the levels of emissions as estimated by MMA.

4.3.4 Value of permits, permit allocation and compensation

MMA provides data on the total value of permits allocated to generators as an offset to the potential loss in net profit. After the permits have been allocated to generators, the remainder are available for the compensation of trade-exposed emissions intensive industries and for auctioning (with revenue recycled). The allocation to trade-exposed industries and for auction is based on projections from MMRF.

Permits allocated to generators are modelled in MMRF as an income transfer to the owners of the generators. It is assumed that 25 per cent of generators are foreign owned. Thus, before income tax, 25 per cent of the value of permits allocated accrues to foreigners, while the rest stays in Australia. We assume that all of the income staying in Australia net of income tax accrues to, and is consumed by, domestic households. The compensation of trade-exposed sectors is modelled as a production subsidy. The remaining revenue is recycled as a lump sum payment to households and is consumed in Australia.

4.3.5 Modelling of the transport sector and transport abatement

MMRF recognises four petroleum refinery fuels, of which all are used for transport – automotive petroleum, aviation fuel (AvGas and turbine fuel), diesel and Liquefied Petroleum Gas (LPG). These fuels are used for transport in each industry recognised in the model. Five industries specialise in the provision of transport services, and hence are intensive users of transport fuels. Four provide commercial passenger and freight services, by road (industry 45), rail (46), water (47) and air (48). The fifth, *private transport services* (industry 56), provides transport services to the residential sector.[9]

[9] In MMRF, private motor cars are treated as durables, providing services to households. The private transport services industry sells the services of the private stock of motor vehicles used by households for transport. Its intermediate inputs are fuel and materials (repairs, tyres, etc.) used to maintain and to run the private vehicle fleet. Hence the residential sector does not buy motor vehicles directly, nor do they buy the fuels and materials associated with vehicles. Instead, they purchase private motor vehicle services, which are combinations of the services provided by the vehicle stock, and of the fuel and materials associated with vehicles.

The use of fuels and the greenhouse emissions associated with that use are fully accounted for in the MMRF model's greenhouse and energy database. A permit price on the use of fuel for transport is treated like a sales tax imposed on the before-tax value of fuels used in transport. This tax has two direct effects leading to less usage of fuel and hence abatement of greenhouse gas. First, it induces substitution away from fuel and towards capital in the private transport services industry – increased use of more fuel-efficient vehicles by the residential sector. Second, it causes the price of private transport services generally to rise and hence induces substitution away from such services in the household budget – less use of private motor vehicles.

In general, in our modelling of the effects of a permit price imposed on the use of transport fuels we account for abatement through:

- Increased fuel efficiency (price induced substitution against fuel as an input to transport service industries);
- Reduced residential use of vehicles; and
- Inter-modal substitution.

Two types of inter-modal substitution are allowed for: rail-road substitution in freight services, and between private transport services and public transport services (bus and rail) in residential use of transport.

We do not take account of possible abatement from:

- Replacement of oil-based fuel with biofuel – cost curves are currently unavailable; and
- The uptake of fuel cell/hydrogen technology – too much uncertainty concerning economic prices and ultimate abatement.

4.4 Assumptions for the macroeconomy

The following key assumptions are made for key aspects of the economy.

Labour markets

At the national level, we assume that initially the real-wage is sticky and so employment can deviate from its baseline value in response to the ETS. Over time, though, we assume that real wage adjustment steadily eliminates most, if not all, of the short-run employment impacts. This means that in the long run the costs of an ETS are realised almost entirely as a fall in the national real wage rate, rather than as a fall in national employment. This labour market assumption reflects the idea that in the long-run national employment is determined by demographic factors, which are largely unaffected by the adoption of an ETS.

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 projection. Accordingly, regions that are favourably affected by the ETS 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. Since budget constraints are not imposed on the business sector or on governments, regional economies will run trade deficits/surpluses to the extent that aggregate regional expenditure levels are greater than/less than aggregate regional incomes. The deficits or surpluses can be held with other agents in other regions, with foreigners or with both regional agents and foreigners.

We assume that in each year, investment in each regional industry will deviate from its value in the baseline scenario 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 the ETS scenario, MMRF allows for short-run divergences in rates of return on industry capital stocks from their levels in the baseline forecast. 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 and household tastes

MMRF contains many types of technical change variables. Under the ETS scenario, it is assumed that all technology variables, other than those used in the implementation of shocks, have the same values as in the baseline projection.

5 RESULTS: THE ESTIMATED IMPACTS OF AN ETS

5.1 National variables

The ETS reduces real GDP relative to baseline levels.

Figure 3 shows deviations (% and $m) from baseline values for real GDP. With the ETS in place real GDP falls by 1.3 per cent relative to its baseline value in 2030. This is equivalent to a reduction of around $21.5 billion a year in today's dollars. The time required for real GDP in the ETS scenario to recover to its baseline level in 2030 is approximately six months.[10]

The ETS reduces real GDP in two ways. First, the permit price acts as a tax and thus becomes a distortion which reduces economic efficiency. Second, and more importantly, the permit price reduces the incentive for producers to employ variable factors of production - labour in the early years and capital in the later years.[11] With less productive resources, real GDP will be lower than it otherwise would be. Less variable factors are employed because the permit price increases the real cost of these factors. In the short-run, the real wage (Wage rate/CPI) is assumed to be sticky (see Section 4.4), thereby effectively indexing wage rates to the CPI. The permit price puts a wedge between the price of spending (the CPI, for example) and the average price that producers receive for their products, causing wages to rise relative to the price of output, leading to an increase in the real cost of labour. In the long-run, rates of return are fixed at their baseline values (see Section 4.4). Thus, with the permit price putting a wedge between the price of spending (price of investment) and the average price of output, capital rentals rise relative to the average price of output, leading to an increase in the real cost of capital.

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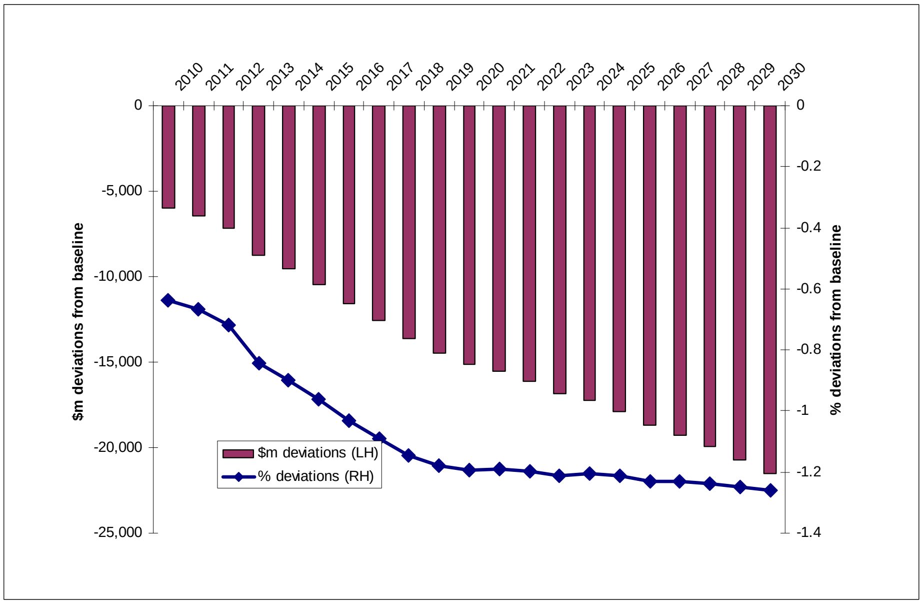
[10] The time (months) required for GDP to recover to its baseline level in 2030 is calculated as 12×(% deviation)/(% annual growth). For example, if the percentage deviation in real GDP in 2030 is 1.3 and the percentage annual growth rate of real GDP in 2030 in the baseline is .5, then months to recover would be 12×1.3/2.5 = 6.2 months. Note that for a given percentage deviation, months to recover is larger the smaller is the underlying growth rate. Hence, in the example above, if the % annual growth rate for GDP in 2030 was 1 instead of 2.5, then months to recover would be 15.6 months rather than 6.2 months.

[11] The burden of the ETS in a particular year equals the permit price times the level of emissions covered by the ETS in that year. In can be shown that the loss of real GDP in dollar terms is related fairly closely to the burden of the ETS. For example, in 2030, the burden of the ETS is $20.9 billion. In that year the loss in real GDP is $21.5 billion.

Figure 3: Deviations in real GDP



Real consumption also falls relative to baseline levels, but this is moderated by ETS revenue returned to households and the distribution to share holders of income from permits allocated to generators.

In these simulations, real consumption is an appropriate measure of economic welfare since it reflects the real purchasing power of income available to Australians. Real GDP is not an appropriate welfare measures since it includes income from labour and capital that accrues to foreigners. Figure 4 shows deviations (% and $m) from baseline values for real consumption.

As shown in Figure 4, imposing the ETS reduces real consumption in 2030 by 1.4 per cent relative to its baseline value. This is similar to the percentage reduction in real GDP. The time required for real consumption to return to its baseline level in 2030 is also similar – around 6.5 months.

The change in real consumption reflects the change in real income available for consumption: we assume that the marginal propensity to consume is one for income gained or lost due to the ETS. In the ETS simulations, the change in real income available for consumption has two main components: changes in income from traditional sources (wages and profits) after income tax; and disbursements from the ETS. The latter consists of dividend income paid to shareholders from permits allocated to generators and recycled auction receipts. Table 2 decomposes the change in real income ($billion) available for consumption in 2030 into the components described above.

Table 2: Household Income Decomposition in 2030

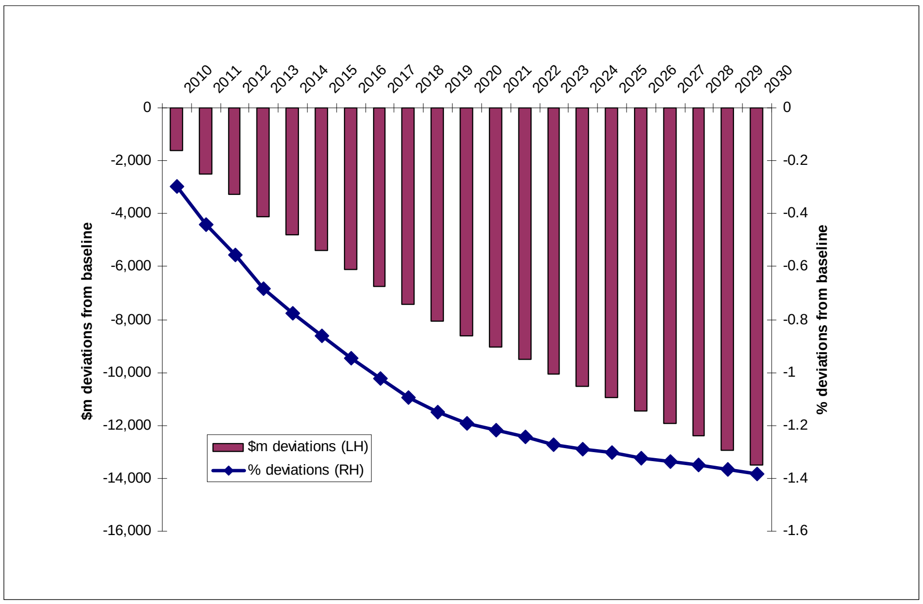
	$b deviation from baseline	% deviation from baseline
Real household income from labour and capital (after income tax)	-27.1	-2.4
Household share of income from permits allocated to generators	5.2	-
Auctioning revenue	8.7	-
Real other income – welfare payments, etc (after income tax)	-0.1	-0.2

Real income for consumption (= real consumption)	-13.6	-1.4

These figures show that the loss of real consumption would be higher were it not for income to households from recycling and from the distribution of permit revenue to generators which accrues to local shareholders. The ETS-related income adds around $13.8 billion to household income in 2030. Real household income from conventional sources falls by $27.1 billion. Thus the net result is a fall of $13.6 billion. With a marginal propensity to consume of close to one, real consumption also falls by $13.6 billion.

The loss of real household income from labour and capital (after income tax) would appear large in light of the reduction in real GDP of around $21 billion. The reason is that real GDP includes real collections of indirect taxes (including the cost of ETS permits) in addition to real payments to labour and capital. In our modelling the ETS causes real indirect tax collections to rise and so real payments to labour and capital fall by more than is suggested by the fall in real GDP.

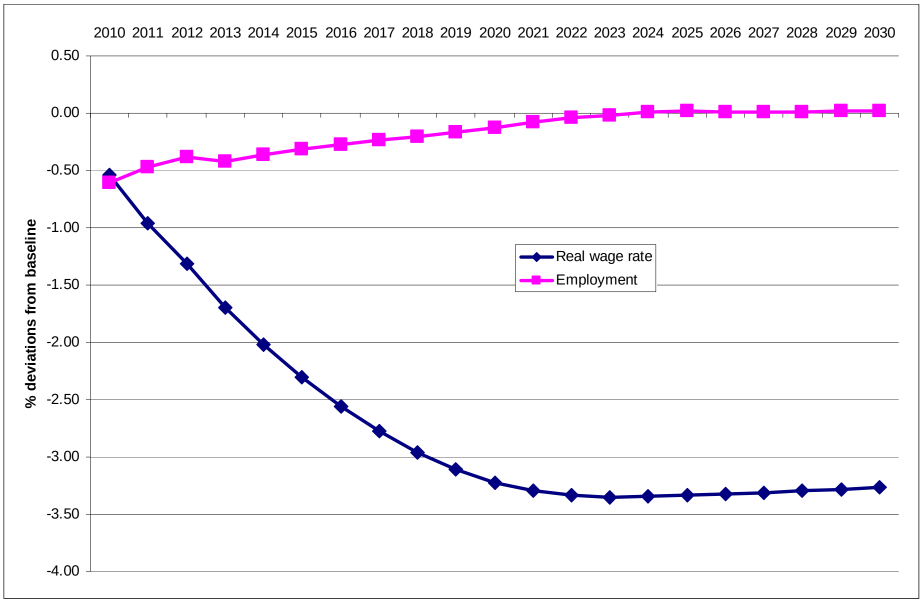
Figure 4: Deviations in Real Consumption



In the short run, the ETS reduces employment slightly relative to baseline values. Over time, employment returns slowly to its baseline level as the real wage rate falls progressively further below its baseline level.

Figure 5 shows percentage deviations in national employment and in the national real wage rate. The impacts of the ETS are small – at most, inducing a 0.6 per cent reduction in employment relative to baseline levels. According to the labour-market specification in MMRF (see Section 4.4), if employment is below its baseline level, employees allow a decrease in their real wage rate. This strengthens producers' incentives to substitute labour for capital. Consequently, employment recovers to baseline levels over time. In 2030, there is no employment deviation, but the real wage rate is down about 3.3 per cent relative to its baseline value. Note that it takes some time before full adjustment occurs; the progressive increase in permit price through most of the period (see Figure 1) requires steadily increasing real wage adjustments to eliminate the deviation in employment.

Figure 5: Deviations in Employment and Real Wage Rate



A final point to make is that even though national employment returns to its baseline level, this does not mean that employment at the individual industry or regional level returns to baseline values. Indeed, in most industries and regions there will be "permanent" employment responses to the ETS, compounding or defusing existing (baseline) pressures for structural change.

Production in some industries increases relative to baseline levels, while output in other industries decreases.

Table 3 gives deviations (% and $m of value added) from baseline values for production by industries nationally in 2030. At the national level, there are a number of industries for which the ETS significantly raises output in percentage terms relative to baseline values. The most favourably affected are the renewable generation industries producing electricity from biomass, biogas and wind (industries 32, 33 and 34). The permit prices causes substitution in favour of these industries at the expense of the high-emissions coal generator (industry 28) in the MMA modelling, and this carries through into the MMRF results. The other favourably affected industry is Forestry (industry 3). Demand for biosequestration offsets pushes up demand for the output of forestry (logging and services associated with plantations). This, in turn, increases forestry's demand for arable land which pushes up the price of land. Increased land prices cause a decline in output from Agriculture-animal (industry 1) relative to baseline values.

Among the industries most adversely affected by the introduction of an ETS is Electricity – coal (industry 28). Coal generation loses share in the national electricity market, especially to non-hydro renewable generation. Another factor influencing the decline – for coal generation and the electricity supply industry (industry 35) is the general reduction in electricity demand due to the increased price of electricity to end-use customers.

Of the remaining electricity generation industries, production of electricity from liquid fuels (industry 30) is, by assumption, fixed at baseline levels, as is hydro generation. Gas generation rises by 2.5 per cent.

Despite the reduction in output of the coal generation sector, overall production of coal (industry 5) falls by only 6.5 per cent relative to its baseline value. The imposition of the ETS adversely affects coal demand for generation, but this is only part of the story. Nationally, coal is mostly sold for export, and while there have been some increases in costs of production the ETS scenarios have had relatively little impact on coal exports[12]. Another positive factor for coal exporters is the compensation that they receive to offset the permit price applied to emissions from underground mines in NSW and QLD.

Activity in the transport services industries 41-44 and 52, and the petroleum products industry (18) fall relative to baseline levels due to the ETS's direct impact on the purchases price of fuels. Of the transport services industries, the most affected is air transport services (industry 44). This is because demand for air transport services is relatively elastic, with a relatively high proportion of sales to exports. It is also a comparatively fuel-intensive industry.

The provision of compensation to the main trade exposed, emissions intensive industries producing metals and metal products (industries 23, 24 and 25) have insulated them against increases in energy costs. Indeed, overall their output has increased against baseline levels due, in the main, to a small depreciation in the real exchange rate, which makes exports more competitive on world markets.

Most of the remaining industries suffer mild contractions in output relative to baseline values in line with the general shrinkage of the economy. This is particularly influential for the service oriented industries. Note that government demand is assumed to be fixed at its baseline level, and hence government-oriented industries (e.g. 50 and 51) experience little change in output.

[12] The modelling considers the impacts of an ETS imposed in Australia only. We are not modelling international action, which would cause world demand for coal to contract.

Table 3: Deviations in National Industry Production in 2030

Name	% deviation from baseline in 2030	$m deviation in real value added in 2030
1. Agriculture – animal	-3.4	-411
2. Agriculture – other	0.0	1
3. Forestry	69.0	516
4. Fishing	-0.4	-8
5. Coal	-6.5	-1033
6. Oil	-0.1	-3
7. Gas	-0.7	-111
8. Iron ore	-0.8	-36
9. Other mineral ore	-4.4	-778
10. Other mining	-1.0	-93
11. Food products – animal	-2.6	-215
12. Food products – other	0.1	8
13. Drink	-0.7	-24
14. TCF	1.4	54
15. Wood products	-0.1	-3
16. Paper products	-0.2	-12
17. Manufacturing nec	0.0	-1
18. Petroleum products	-9.4	-297
19. Chemical prods. excl. petrol	-1.6	-121
20. Plastic and rubber products	-0.4	-15
21. Building prods (not cement & metal)	-0.3	-12
22. Cement	-0.6	-14
23. Iron and steel	1.5	80
24. Alumina and aluminium	-0.1	-11
25. Other metal products	1.4	165
26. Transport equipment	0.6	49
27. Other equipment	0.9	110
28. Electricity – coal	-30.5	-1374
29. Electricity – gas	3.5	52
30. Electricity – oil prods.	0.0	0
31. Electricity – hydro	0.0	0
32. Electricity – biomass	129.2	1843
33. Electricity – biogas	122.7	887
34. Electricity – wind	122.5	973
35. Electricity supply	-12.3	-1429
36. Urban gas distribution	0.8	36
37. Water and sewerage services	-1.2	-83
38. Construction services	-0.7	-618
39. Trade services	-0.5	-604
40. Accommodation and restaurants	-0.5	-137
41. Road transport services	-0.5	-121
42. Rail transport services	-1.0	-97
43. Water transport services	-1.9	-20
44. Air transport services	-6.8	-798
45. Other transport services	-0.9	-331
46. Communication services	-0.6	-323
47. Financial services	-0.4	-528
48. Dwelling ownership	-0.4	-709
49. Business services	-0.3	-546
50. Public services	0.1	138
51. Other services	-0.9	-434
52. Private transport services	-3.8	-1478

Emissions are reduced in all major source categories

Table 4 gives deviations (% and Mt of CO_2-e) from baseline values for national emissions.

Table 4: Deviations in Emissions by Source in 2030

	% deviation from baseline	Mt of CO2-e change from baseline
Energy sector, total	-22.4	-144.5
Fuel combustion	-21.5	-123.6
Stationary	-26.0	-108.1
Electricity generation	-35.5	-98.2
Other	-7.1	-9.9
Transport	-9.7	-15.4
Fugitive emissions from fuels	-29.9	-21.0
Industrial processes	-0.8	-0.4
Agriculture	-3.2	-3.8
Waste	-29.9	-4.1
LUCF	68.8	-16.8
Total	-21.1	-169.6

Relative to baseline levels, as shown in Table 4 the total of all emissions in 2030 falls by 21.1 per cent, or 169.6 Mt of CO_2-e. The bulk of the overall abatement is delivered by the stationary energy and fugitive emissions sectors. Emissions from stationary energy are down 108 Mt relative to their baseline levels, with emissions from electricity generation falling by 98 Mt, and emissions from other forms of direct combustion by 10 Mt. Fugitive emissions fall by 30 per cent (21 Mt) in 2030 relative to their baseline levels. Transport emissions are down 9.7 per cent, which is equivalent to 15 Mt. The fall in emissions from agriculture and waste, and the increase in biosequestration are due, in the main, to the offset provisions in the ETS (see Section 4.3). Overall, offsets contribute around 15 per cent of the total emissions reduction.

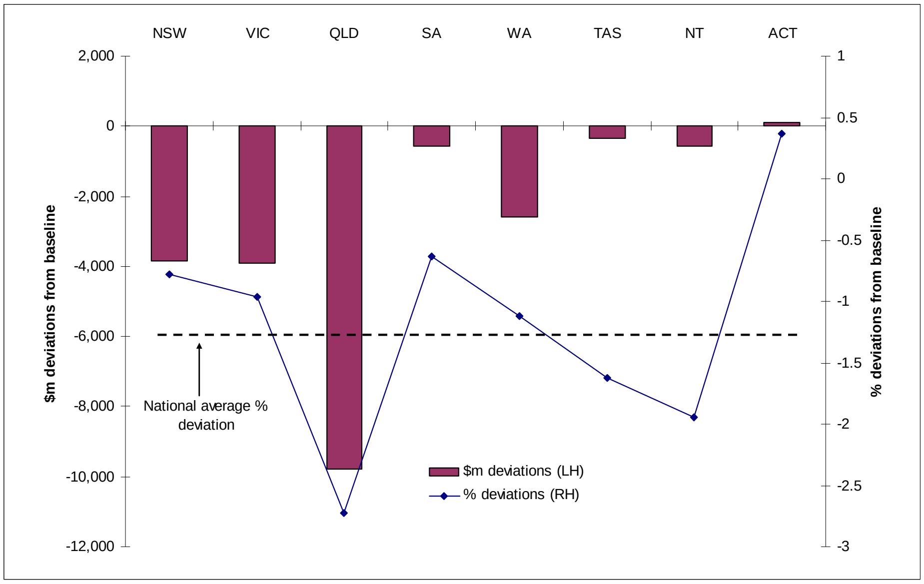
The assumption of unlimited banking plays an important role in determining levels of abatement in 2030. Banking allows covered parties (e.g. electricity generators) to take advantage of relatively cheap abatement options in the first few years, making greater than necessary emissions reductions. Excess emissions permits are then banked for compliance in later years, thereby avoiding higher abatement costs during that period. Without banking, and based on a linear path for the ETS cap, electricity emissions would have fallen to around 130 Mt of CO_2-e, which is 147 Mt of CO_2-e below the baseline level for that year. However, with banking, these emissions reductions have been achieved in earlier years, so in 2030 electricity emissions are 179 Mt (i.e. 98 Mt below their baseline level).

5.1.1 State variables

Real Gross State Product (GSP) falls relative to baseline values in all states/territories, except NT and ACT.

Figure 6 shows projected deviations ($m and %) from baseline values for real GSP in 2030.

Figure 6: Deviations in real GSP in 2030



QLD and NT are projected to experience the largest percentage declines in real GSP relative to baseline levels. The 2.0 per cent fall for SA is equivalent to a reduction of $585 million. TAS's real GSP is down by around 1.6 per cent. WA is projected to lose 1.1 per cent of its GSP in 2030. In contrast to the other regions, ACT is expected to gain real GSP (0.4 per cent).

The impacts of the ETS on real GSP are heavily influenced by the changes in industry output. Without the disparity of industry outcomes (see Table 3), we might expect real GSP in each region to fall by the same percentage amount as real GDP (i.e., by 1.4 per cent). Instead, some industries experience output gains relative to baseline levels, while others experience output losses. This, and different industrial compositions of the states/territories, explains why QLD, TAS and NT lose share in national economic activity in favour of the other regions.

In general a region's share in national GDP will fall if:

- Its economy is over-represented in industries that are expected to lose output relative to baseline levels; and/or
- Its economy is under-represented in industries that are expected to gain output relative to baseline levels.

The QLD economy is over-represented in coal-fired electricity generation (industry 28), which experiences rising costs compared to other fuel sources. This is the main factor which reduces its share in the national economy. NSW experiences less of these impacts, because the share of coal generation in the NSW economy is smaller than in QLD.

TAS does not have coal-fired generation and it is over-represented in forestry (industry 3) for which output expands significantly. So it is somewhat surprising that TAS loses share in the national economy. The reason is twofold. First, as forestry production increases, production of the primary and secondary animal agricultural industries (industries 1 and 11) decreases. For TAS this switch from agriculture into forestry represents a net loss of value added, since in the baseline forestry is less profitable than agriculture. The second main reason for the reduction in real GSP in TAS, is its over-reliance on electricity as a source of energy in final demand. The price of electricity in TAS rises in line with the price of electricity in the other NEM states. With relatively little opportunity to switch towards gas in end-use demand, the increase in electricity price imposes a significant cost penalty on Tasmania's inter-state trade exposed industries.

The main reason why NT loses share in national GDP is the inclusion of transport in the coverage of the ETS. If transport were not included then NT would potentially gain real GSP relative to baseline levels. NT has an economy relatively intensive in the use of transport fuels. Increases in the cost of transport fuels, therefore, tend to increase the general cost of production in NT by more than in other states, with adverse implications for the inter-state and international trade competitiveness of NT industries.

NSW has an industrial composition similar to Australia as a whole; unsurprisingly, its loss in real GSP in percentage terms is similar to that of the nation. WA is favoured by an industrial composition which is over-represented in gas-fired generation, natural gas and the trade exposed, emissions intensive industries that are compensated in the MMRF modelling and therefore experience marginal growth, such as Other mineral ore (industry 9), Alumina and aluminium (24), Other metal products (25).

Finally, it should be noted that no mention has been made of specific regions gaining a competitive advantage by being over-represented in non-hydro forms of renewable generation the sector that expands most relative to baseline levels. This is because this new generation is evenly distributed across Australia, with the amounts going to each state roughly in line with the size of their economies.

6 CONCLUSIONS

The modelling reported in this paper shows that introducing an ETS is likely to have a cost, with the extent of the cost depending on the amount of abatement targeted and the associated permit price. It also shows that the distribution of the cost will be affected by the emissions permit allocation method, and the approach to compensation.

Other key findings include:

- The economy will grow strongly even with stringent ETS emissions targets;
- Free allocation of ETS permits to generators can offset the generators' profit losses that result from an ETS;
- Compensation for increased energy costs as a result of the ETS can maintain global competitiveness of trade exposed, emissions intensive industries, such as aluminium; and
- The impacts on the economic welfare of Australians (as measured by the impact on consumption) can be moderated via targeted recycling of revenue from auctioned permits.

We conclude that a worthwhile reduction in emissions ("risk in the insurance analogy) is possible with a national cost of around 1.3 per cent of income. It seems therefore that the "insurance policy" is the best option.

Section 2 of the paper contains a discussion of features of the MMRF model, particularly those designed to enhance the model's capability for greenhouse-policy analyses. The proposed bottom-up dynamic regional model of China (SIC China Multi-Provincial Forecasting Model, or MPFM) ideally should include similar features: detailed accounting for energy consumption and production, and greenhouse emissions; mechanisms allowing for fuel substitution in electricity production; and a comprehensive representation of energy use in transportation.

While debate in Australia has centred around an ETS, simulations with the China regional CGE model can be used to analyse the effects of many kinds of abatement policies. These include policies designed to reduce greenhouse gas emissions via increasing the share of renewable energy, and by improving energy efficiency through closing down less efficient production capacities.

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APPENDIX

Table A1: Industries in MMRF*

Name	Description of major activity
1. Agriculture – animal	Primary agricultural activities related to animals
2. Agriculture – other	Other primary agriculture
3. Forestry	All forestry activities, including logging and management
4. Fishing	Fishing and hunting
5. Coal	Mining of coal
6. Oil	Mining of oil
7. Gas	Production of natural gas at well
8. Iron ore	Mining of iron ore
9. Other mineral ore	Mining of ore other than iron
10. Other mining	Other mining activity
11. Food products – animal	Processed food related to animal
12. Food products – other	Other food products
13. Drink	Drink products
14. TCF	Textiles, clothing and footwear
15. Wood products	Manufacture of wood (including pulp) products
16. Paper products	Manufacture of paper products
17. Manufacturing nec	Manufacturing products not elsewhere classified
18. Petroleum products	Manufacture of petroleum products
19. Chemical prods. excl. petrol	Manufacture of basic chemicals and paints
20. Plastic and rubber products	Manufacture of plastic and rubber products
21. Building prods (not cement & metal)	Manufacture of non-metallic building products excl. cement
22. Cement	Manufacture of cement
23. Iron and steel	Manufacture of primary iron and steel.
24. Alumina and aluminium	Manufacture of alumina and aluminium
25. Other metal products	Manufacture of other metal products
26. Transport equipment	Manufacture of transport equipment
27. Other equipment	Manufacture of equipment other than transport equipment
28. Electricity – coal	Electricity generation from coal (black and brown) thermal plants
29. Electricity – gas	Electricity generation from natural gas thermal plants
30. Electricity – oil prods.	Electricity generation from oil products thermal plants
31. Electricity – hydro	Electricity generation from renewable sources – hydro
32. Electricity – biomass	Electricity generation from biomass
33. Electricity – biogas	Electricity generation from biogas
34. Electricity – wind	Electricity generation from wind
35. Electricity supply	Distribution of electricity from generator to user
36. Urban gas distribution	Urban distribution of natural gas
37. Water and sewerage services	Provision of water and sewerage services
38. Construction services	Residential building and other construction services
39. Trade services	Provision of wholesale and retail trade services
40. Accommodation and restaurants	Provisions of services relating to accommodation, meals and drinks
41. Road transport services	Provision of road transport services
42. Rail transport services	Provision of rail transport services
43. Water transport services	Provision of water transport services
44. Air transport services	Provision of air transport services
45. Other transport services	Provision of water, air and rail transport services
46. Communication services	Provision of communication services
47. Financial services	Provision of financial services
48. Dwelling ownership	Services of dwellings
49. Business services	Provision of business services
50. Public services	Provision of public services
51. Other services	Provision of all other services
52. Private transport services	Provision of services from the stock of private motor vehicles

* For most of the products identified in this table there is an obvious correspondence to one or more standard categories in the Australian and New Zealand Standard Industrial Classification (ANZSIC, 2006). The exceptions are: industries 28 to 35, which together comprise ANZSIC 26 *Electricity Supply*; industry 48, which is equivalent to the *Ownership of dwellings* industry in the industrial classification of the official Input/Output statistics; and industry 52 which relates to the provision of services from the private transport fleet.

Table A2: Macroeconomic Assumptions: Baseline
(average annual percentage growth rates)

	2004 to 2010	2010 to 2020	2020 to 2030	2004 to 2030
Real GDP/GSP				
NSW	2.3	2.7	2.4	2.5
VIC	3.1	2.8	2.7	2.8
QLD	4.8	3.5	3.7	3.9
SA	1.9	1.9	1.8	1.9
WA	5.0	3.6	3.8	4.0
TAS	1.8	1.6	1.6	1.6
NT	5.5	3.7	4.0	4.2
ACT	3.7	2.2	2.5	2.7
National	3.3	2.9	2.9	3.0
Real Consumption				
National	3.7	2.7	3.0	3.1
International Exports				
National	4.5	4.8	4.4	4.6
International Imports				
National	4.4	4.6	4.3	4.4
Employment				
National	2.1	0.9	1.3	1.3

Table A3: Implied Values for Energy Efficiency: Baseline
(average annual percentage changes)

	2004 to 2010	2010 to 2020	2020 to 2030	2004 to 2030
Energy technical efficiency improvement[(a)]	1.2	1.2	1.0	1.1
Supply efficiency improvement[(b)]	0.8	0.8	0.5	0.7

(a) Energy technical efficiency equals the negative of a weighted average of the use of primary and derived fuels per unit of output in all industries using those fuels other than electricity generation. Thus a value of 1.1 per cent per annum as shown in the table above implies that industries other than electricity generation use annually 1.1 per cent less fuels (primary and derived) per unit of output. Note that the numbers reported in this table are a combination of autonomous energy efficiency and induced energy efficiency arising from the effects of demand-side energy efficiency measures.

(b) Supply efficiency equals the negative of a weighted average of the use of primary fuels per unit of electricity generation. Thus a value of 0.7 per cent per annum as shown in the table above implies that electricity-generating industries use annually 0.7 per cent less primary fuels per unit of output. Note that the numbers reported in this table are a combination of autonomous energy efficiency and induced energy efficiency arising from the effects of demand-side energy efficiency measures.

Table A4: Projections for Industry Output: Baseline (average annual percentage changes)

Industry	2004 to 2010	2010 to 2020	2020 to 2030	2004 to 2030
1. Agriculture – animal	2.2	2.5	2.5	2.4
2. Agriculture – other	2.7	2.4	2.4	2.5
3. Forestry	1.2	1.4	1.6	1.5
4. Fishing	2.1	2.0	2.3	2.2
5. Coal	4.2	2.4	2.4	2.8
6. Oil	-0.9	-0.6	-0.3	-0.6
7. Gas	8.7	6.1	5.1	6.3
8. Iron ore	2.6	2.7	2.7	2.7
9. Other mineral ore	5.0	4.9	5.7	5.2
10. Other mining	2.4	2.6	3.0	2.7
11. Food products – animal	2.6	2.7	2.7	2.7
12. Food products – other	2.1	2.7	2.7	2.5
13. Drink	2.5	1.7	1.7	1.9
14. TCF	0.4	1.5	1.9	1.4
15. Wood products	1.6	1.7	1.5	1.6
16. Paper products	1.5	1.3	1.2	1.3
17. Manufacturing nec	1.4	1.8	1.3	1.5
18. Petroleum products	1.9	1.1	1.4	1.4
19. Chemical prods. excl. petrol	2.2	1.8	1.9	1.9
20. Plastic and rubber products	1.1	0.9	0.8	0.9
21. Building prods (not cement & metal)	1.4	1.4	1.3	1.4
22. Cement	2.2	2.2	2.1	2.2
23. Iron and steel	0.9	2.0	1.7	1.6
24. Alumina and aluminium	2.3	2.1	2.2	2.2
25. Other metal products	2.1	2.8	2.3	2.4
26. Transport equipment	0.9	1.8	1.6	1.5
27. Other equipment	1.2	2.4	1.9	1.9
28. Electricity – coal	0.8	0.6	2.1	1.2
29. Electricity – gas	5.9	3.2	3.7	4.0
30. Electricity – oil prods.	0.0	0.0	0.0	0.0
31. Electricity – hydro	1.6	0.3	0.6	0.7
32. Electricity – biomass	26.1	13.8	0.5	11.1
33. Electricity – biogas	32.1	11.8	1.2	11.8
34. Electricity – wind	32.9	12.2	1.1	12.0
35. Electricity supply	2.4	1.9	2.3	2.2
36. Urban gas distribution	5.6	4.7	4.3	4.8
37. Water and sewerage services	1.9	1.0	1.6	1.4
38. Construction services	2.5	2.4	2.4	2.4
39. Trade services	1.7	2.0	2.0	1.9
40. Accommodation and restaurants	3.0	2.3	2.5	2.5
41. Road transport services	2.9	3.0	2.9	2.9
42. Rail transport services	3.2	2.9	2.8	3.0
43. Water transport services	0.1	1.0	2.0	1.2
44. Air transport services	2.7	2.9	3.2	3.0
45. Other transport services	3.0	2.9	3.0	2.9
46. Communication services	4.5	3.8	3.7	3.9
47. Financial services	5.0	4.2	4.0	4.3
48. Dwelling ownership	4.1	3.8	3.5	3.7
49. Business services	3.6	3.8	3.1	3.5
50. Public services	3.2	2.4	2.6	2.7
51. Other services	3.2	2.3	2.6	2.6
52. Private transport services	4.3	2.9	3.5	3.5

Table A5: $C0_2$-e Emissions by Major Source Category for Australia: Baseline

	2004 to 2010	2010 to 2020	2020 to 2030	2004 to 2030
Average annual percentage growth rates				
Energy sector, total	1.9	1.5	2.3	1.9
Fuel combustion	1.6	1.3	2.2	1.7
Stationary	1.4	1.1	2.1	1.6
Electricity generation	1.0	0.8	2.1	1.4
Other	2.1	1.9	2.1	2.0
Transport	2.5	1.9	2.3	2.2
Fugitive emissions from fuels	5.4	3.6	3.4	3.9
Industrial processes	1.5	1.6	1.6	1.6
Agriculture	0.1	0.9	0.8	0.7
Waste	1.4	0.3	0.6	0.7
LUCF	1.3	1.4	1.7	1.5
Total	1.6	1.4	2.0	1.7

Table A6: Electricity Generation by Generator Type for Australia: Baseline

	2004 to 2010	2010 to 2020	2020 to2030	2004 to 2030
Average annual percentage growth rates				
Generation – Black coal	0.9	1.0	2.4	1.5
Generation – Brown coal	0.2	-0.6	1.6	0.4
Generation – Natural gas	6.3	3.1	3.6	4.0
Generation – Liquid fuel	0.0	0.0	0.0	0.0
Generation – Hydro	1.5	0.3	0.6	0.7
Generation – Biomass	26.4	13.4	0.5	11.0
Generation – Biogas	32.5	11.6	1.2	11.8
Generation – Wind	35.3	10.8	1.5	12.2
Total	2.1	1.6	2.3	2.0