Report to

The Australian Treasury

Model Development and Scenario Design:

MMRF Modelling to Support a Study of the Economic Impacts of Climate Change Mitigation

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1 INTRODUCTION

The Australian Treasury is investigating the potential economic impacts of the introduction of a carbon price on the Australian economy within policy frameworks outlined in the Government's *Carbon Pollution Reduction Scheme Green Paper* and the Garnaut Climate Change Review. To do so, it has engaged the Centre of Policy Studies (CoPS) to assist in the modelling of a number of scenarios using the Monash Multi-Regional Forecasting (MMRF) model.

The first scenario is a Reference case, or 'business as usual', projection for the Australian economy and its states and territories. The reference case 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 Reference case shows what might be expected to happen if the policy frameworks being considered by the Treasury had not been introduced and there had been no change in current greenhouse policies. The policy scenarios consider the impact of emissions pricing imposed with different design features and different trajectories for emissions and prices.

In this report we first describe changes and additions to the model that facilitate the Treasury simulations. Aspects of scenario design are then discussed. Simulation results and explanations are provided in detail in the Treasury's main report, and so are not repeated in this supplementary paper.

2 MMRF

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, 8 states/territories and 56 sub-state regions[1]. 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

[1] Of the 58 industries, 3 produce primary fuels (coal, oil and gas), 1 produces refined fuel (petroleum products), 6 generate electricity and 1 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 a small amount of biofuel. The petroleum products industry produces 5 products – gasoline, diesel, LPG, aviation fuel, and other refinery products. Thus, in total 63 products are produced by the 58 industries.

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 Treasury project is given in Adams *et al.* (2008). A brief overview of the greenhouse gas enhancements that existed before the Treasury work is given in Section 2.2. The changes undertaken for the Treasury modelling are outlined in Section 2.3.

2.2 Existing environmental enhancements

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

- An energy and gas emission accounting module, which accounts explicitly for each industry and region recognised in the model;
- Equations that allow for inter-fuel substitution;
- Mechanisms that allow for abatement of non-combustion emissions;
- Allowance for the operations of the National Electricity Market (NEM); and
- 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[2]). A residual category, named Activity, covers emissions such as fugitives and agricultural emissions not arising from fuel burning.

The resulting $58 \times 8 \times 9$ 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] 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.

2.2.2 Inter-fuel substitution

Inter-fuel substitution in electricity generated is handled using the "technology bundle" approach[3]. 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 WA and NT or indirectly via the NEM for NSW, VIC, QLD, SA and 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 WA 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 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-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

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

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 NEM. The NEM covers electricity supply in the NEM-regions: NSW, VIC, QLD, SA, TAS and the 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 Additions for the Treasury modelling

A large number of additions to MMRF have been made for the Treasury modelling. Some changes are mundane, involving the definition of variables and coefficients for reporting or for the purpose of facilitating simulations. These are not discussed here. Of relevance for this section are the changes that significantly affect the modelling of the Reference case and/or the policy scenarios. These changes cover:

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

2.3.1 Database

First, the industry structure of the model was reconfigured to better meet the detailed modelling requirements of the policy scenarios. In particular:

- The commodity petroleum and coal products was split into five commodities — gasoline, diesel, LPG, aviation fuel (aviation turbine fuel and aviation gasoline) and a residual *other petroleum products* — produced by the petroleum and coal products industry to enable more accurate measurement of transport emissions within the MMRF model.
- The industry and commodity livestock was split into high emissions livestock (sheep & beef), low emissions livestock (chicken & pork) and dairy cattle.
- A latent nuclear energy industry was added that could be triggered, if desired, at a specified threshold price.
- The pipeline transport was combined with the water and transport services industries and commodities.
- Biofuels was modelled as an output of the agriculture cropping industries.

Then, the emissions component of the database was uprated to the year 2005-06, in line with the year-of-record for the economic input/output data.[4] The main sources of data for the 2005 matrix of emissions are the 2005 National Greenhouse Gas Inventory published by the Australian Greenhouse Office (now part of the Department of Climate Change) and the 2006

[4] The 2005-06 input/output data were generated in a separate exercise, in which official ABS statistics for 2001-02 were updated to 2005-06 via model simulation. In the update simulation, data for observable variables covering the period 2001-02 to 2005-06 were imposed on the model, with the model producing estimates for unobservable variables over the four year period. Typical observable variables include macroeconomic aggregates, industry output and prices, and commodity exports. Typical unobservable variables include industry technological change indicators and indicators of household tastes.

Fuel Energy Survey produced by ABARE. A summary of the emissions data is given in Table B.

2.3.2 Revised mechanisms for the abatement of non-combustion emissions

The original 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, allows for lagged adjustment and employs more up-to-date data. The data and theoretical antecedents come from the GTEM model.

The key theoretical idea is the targeted level of non-combustion emissions per unit of output (or targeted emissions intensity). For a specific industry, it is assumed that:

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

where:

LAMBDAT is the targeted emissions intensity;

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

ALPHA is the no regret level of abatement; and

GAMMA is the speed of adjustment to the tax rate.

Typical values of ALPHA and GAMMA 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)).

The ordinary-change form of equation (1) is:

$$\text{d\_LAMBDAT} = -\text{LAMBDAT}\times\text{ALPHA}\times\text{GAMMA}\times(1+T)^{\text{GAMMA}-1}\times\text{d\_T} \qquad (2)$$

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 using a conditional IF statement which effectively sets d_LAMBDAT to zero when the level of LABMDAT moves below a specified level as the price of emissions rises.

The actual level of non-combustion emissions per unit of output is determined via a partial adjustment mechanism. This is required to ensure that the emissions intensities of industries do not respond too vigorously to changes in emissions price, especially at the start of a simulation when the price rises immediately to values like $25-$50 per tonne. The partial adjustment mechanism is simply:

$$\text{LAMBDA} = -\text{LAMBDA\_L} + \text{ADJUSTMENT}\times(\text{LAMBDAT} - \text{LAMBDA\_L}) \qquad (3)$$

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

ADJUSTMENT is a parameter with a typical value of 0.3.

The ordinary change form of (3) is written as:

$$d\_LAMBDA = (1 - ADJUSTMENT) \times d\_LAMBDA\_L + ADJUSTMENT \times d\_LAMBDAT \quad (4).$$

It is assumed that the abatement implied by (2) and (4) is not costless. 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. This is defined as 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.

2.3.3 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 the pre-Project version 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 Treasury modelling by including abatement response functions analogous to equation (1). 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.

2.3.4 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 segments over the 2000-threshold. The other class contains segments in the 1500-

2000 category. 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:

$$\text{SHIELDING(dir)} = -\text{COVER} \times \text{T} \times \left[\frac{\text{QGAS}}{\text{OUTPUT}}\right]_{\text{INIT}} \times \text{OUTPUT} \qquad (5)$$

where:

SHIELDING(dir) (a minus number) is the necessary reduction in average cost;

COVER is the rate of coverage;

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

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

According to equation (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) level of emissions intensity.

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

$$\text{SHIELDING(ind)} = -\text{COVER} \times [\text{Pets} - \text{Pref}] \times \left[\frac{\text{ELECTRICITY}}{\text{OUTPUT}}\right]_{\text{INIT}} \times \text{OUTPUT} \qquad (6)$$

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

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

Equation (6) is similar in structure to equation (5), with the emissions price-induced increase in the electricity price in (6) analogous to the permit price in (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*[5]. 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.

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

2.3.5 Global linkages

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 Treasury 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 Treasury 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 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.

2.3.6 Regional sourcing of natural gas

The Treasury simulations for the Garnaut Climate Change Review extend to 2100. Before then, on present indications, a number of gas fields will have ceased production. The most important of these are the SA and Queensland fields in and around the Cooper/Eromanga Basins. Because MMRF is a regional model, it is important that allowance is made for the closure of these fields and opening up of new supplies to cover the demand which would otherwise not be met.

In the Reference case we assume that SA production steadily falls away after 2020, to be replaced by increased production from Victoria and QLD. Production from QLD is assumed to be from newly constructed mines extracting methane gas from coal-seam deposits. Production from Victoria starts to decline after 2030 and is replaced partly by production from QLD and partly from WA/NT. QLD production starts to decline after 2050, leaving WA/NT as the source of all of Australia's domestic needs.

Closing down industries in MMRF requires substantial intervention by the model user. To facilitate this, a number of new technological change variables have been introduced into the model which allow for industries in state r to re-direct their usage of gas produced in state s to state q. Thus, for example, in shutting down SA production after 2020, the exogenous technological-change variable for SA gas used in region r by user j is shocked by a number like -50 per cent and the corresponding variable for QLD gas used in region r by user j is increased by an amount that would leave the value of gas purchases by j in r unchanged.

2.3.7 Land-land substitution

In MMRF, land is an input to production for the agricultural industries and forestry. The standard treatment of land before the Treasury 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 Treasury 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.

3 SIMULATION DESIGN

In Section 3.1 we describe the key assumptions underlying the Reference-case scenario. Key aspects of simulation design for the policy scenarios are discussed in Section 3.2. Section 3.3 describes important assumptions for the macro-economy that applies in all of the policy simulations.

3.1 Reference case

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 Reference case scenario, the external inputs are detailed in Annex B of the modelling report. Some of the key inputs are:

- Population projections, based upon the framework used to develop the second *Intergenerational Report* — although the Australian Treasury has updated input assumptions since the reports release in 2007;
- National real GDP growth, based on estimates from the Australian Treasury;
- National-level assumptions for changes in industry production technologies and in household preferences compiled by the Australian Treasury, in conjunction with CoPS;
- Estimates of the net impacts of existing energy-related measures from groups such as McLennan, Magasanik and Associates (MMA);
- Forecasts for the foreign-currency prices of imports and for the positions of export demand schedules from modelling undertaken with GTEM;
- Estimates of changes in generation mix, emissions and energy use, and prices of generation, from MMA; and
- Forecasts for changes in fuel used and emissions from road transport industries by the BITRE and CSIRO; and
- Forecasts for land used for forestry and the associated forestry sequestration from land-use experts at ABARE.

To accommodate this information, numerous naturally endogenous variables in the model are made exogenous. These include, for example, real GDP, the production of electricity generation industries, and the use of gasoline in road transport. 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 real GDP, economy-wide all-industry labour saving technological change is made endogenous. To accommodate forecasts for electricity generation from coal, price-responsive demand mechanisms for the NEM are turned off by making endogenous demand-twists for generation from coal-based technologies. To accommodate forecasts for the use of gasoline in road transport, demand-shift (technological change) variables in industry usage of gasoline are made-endogenous.

3.2 Policy scenarios

The policy scenarios are modelled as deviations away from the Reference case projection. The main differences in the domestic policy frameworks between the scenarios relate to:

- Coverage;
- Levels and coverage of shielding; and
- Scheme cap.

Differences in coverage are handled by having a permit price with energy-user and regional dimensions. In most simulations, the permit price is the same for all energy users in all regions. However, if a sector/region is excluded from the emissions trading scheme, then that sector/region will simply face a zero permit price. This applies, for example, in some simulations where non-combustion emissions from agriculture are excluded for the first few years.

Differences in the level and coverage of shielding are handled via the mechanisms described in Section 2.3.3. Coverage changes are implemented via changes to the sets identifying category 1 and category 2 industries. Differences in shielding levels are imposed by exogenously changing the coefficient COVER.

Scheme caps for Australia are determined by the Australian Treasury and imposed exogenously in the MMRF modelling.

Inputs to the policy simulations are sourced primarily from:

- Projected electricity market outcomes, as modelled by MMA using their suite of bottom up electricity sector models;
- Projected outcomes for road transport, as modelled by the BITRE and CSIRO;
- Assumptions for forestry sequestration and plantation use of land from land-use experts at ABARE;
- Estimated changes in foreign currency import prices and in the positions of foreign export demand schedules from the GTEM model; and
- Projections of the global emissions price and Australia's scheme cap.

In the remainder of this section we explain how these inputs are implemented.

3.2.1 Electricity inputs from MMA

For each scenario, for each year, MMA provides data for:

- Changes in the mix of generation by technology class and region;
- Changes in emissions and energy-use by technology class and region; and
- The wholesale price of electricity.

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.

The MMA emission numbers are imposed via technological shifts in emissions per unit of fuel used for each technology class in each region. These shifts are calibrated year-by-year to achieve the levels of emissions as estimated by MMA. Similarly, changes in energy (or fuel) use are imposed via technological shift variables that change the amount of fuel used per unit of generation by technology class and region.

Wholesale electricity prices are defined in MMRF as the producer prices received by the electricity generation industries. These are fixed to MMA estimates via endogenous shifts in the price of the miscellaneous *other costs* item.

3.2.2 Road transport inputs from the BITRE and CSIRO

For each scenario, the BITRE and CSIRO provides data for changes in fuel and emissions by region. To accommodate projections for the use of gasoline, diesel and LPG in road transport, demand-shift (technological change) variables in industry usage of each fuel type are made-endogenous. Emissions from road transport are made exogenous and shocked to BITRE and CSIRO settings via endogenous shifts in technological change variables for emissions per unit of fuel used.

3.2.3 Forestry land and sequestration

Changes in land under forestry are imposed by effectively shifting the land-land substitution mechanism described in Section 2.3.6, so that land under forestry changes by the desired amount. Total land availability by region is still held fixed, so that if land under forestry rises land available for agriculture must fall. Land price continues to be the mechanism to ensure that total land supply does not change.

Forestry sequestration is made exogenous and shocked to external estimates of response to the emissions price via endogenous shifts in technological change variables for emissions per unit of forestry output.

3.2.4 Trade variables from GTEM

Changes in foreign-currency import prices and in the positions of foreign export demand schedules for Australia in response to a global emissions price are sourced from GTEM modelling. GTEM has a more aggregated commodity classification than does MMRF, so the GTEM information must first be mapped to MMRF commodities. After mapping, the import and export stories are imposed directly; foreign-currency import prices and the positions of foreign-currency export schedules are naturally exogenous variables in a single-country model like MMRF.

3.3 Assumptions for the Macroeconomy in the policy scenarios

In applying inputs from MMA to MMRF, the following key assumptions are made for key aspects of the economy.

Labour markets

At the national level, initially the real-wage is assumed to be sticky and so employment can deviate from its Reference case value in response to the emissions price. Over time, though, it is assumed that real wage adjustment steadily eliminates most, if not all, of the short-run employment consequences. This means that in the long run the costs of emissions pricing 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 emissions price.

At the regional level, labour is assumed to be mobile between state economies. Labour is assumed to move between regions so as to maintain inter-state wage differentials at their levels in the reference-case projection. Accordingly, regions that are relatively favourably affected by emissions pricing will experience relative increases in employment at the expense of regions that are relatively less favourably affected.

MMRF lacks the necessary demographic detail to allow for a full explanation of changes in population and labour supply in response to emissions pricing. Accordingly, in the policy simulations, population and participation rates are exogenously set at Reference-Case levels.

Private consumption and investment

Consumption expenditure of the regional household is determined by Household Disposable Income (HDI). HDI is the sum of payments to domestic labour and capital and government transfer payments net of direct taxation. Included in government transfer payments is the lump-sum return of permit income.

Investment in all but a few industries is allowed to deviate from its value in the Reference-Case scenario in line with deviations 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.

For some industries, mainly the electricity generation sectors, investment is lumpy. This is at odds with the MMRF investment theory which assumes that investment responds smoothly to changes in rates of return, even very small changes. Accordingly, for the policy

simulations, changes in investment from Reference-case levels for the "lumpy-investment" industries are exogenously imposed.

Rates of return on capital

Under the policy scenarios, MMRF allows for short-run divergences in rates of return on industry capital stocks from their levels in the Reference-Case 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.

Government budget balances

The budget balances as a share of nominal GDP of all governments, state and Federal, are fixed at their values in the reference case. Budget balances are constrained via endogenous movements in lump-sum payments to households.

Production technologies and household tastes

MMRF contains many types of technical change variables. Under the policy scenarios, it is assumed that all technology variables, other than those used in the implementation of shocks, have the same values as in the reference-case projection.

Land for agriculture and forestry

As outlined earlier, it is assumed that land is mobile between forestry and agriculture in each region. It is also assumed for each region that the total supply of land available for agricultural and forestry use is fixed Thus, if the demand for land by the forestry industry increases, then the price of land will be bid up causing land to shift from agricultural use to forestry use.

Gas reserves and gas prices

The regional sourcing of gas in the policy simulations changes in line with changes in the Reference Case (see Section 2.3.6). Thus, for example, in the policy simulation gas production from SA fields closes down in the same year as in the Reference Case.

In the Reference Case and policy simulations gas reserves in the East of Australia gradually close down and are replaced by supply from WA and NT. WA and NT gas is produced for export as well as for local users and its price is set in line with the global price of gas. Gas from Eastern sources is produced for local demand and its price is determined, in the main, by domestic factors. As Eastern fields are replaced by WA and NT gas, so the price paid by customers in the Eastern states moves to international parity. In the Reference Case and policy simulations, it is assumed that Eastern gas prices rise gradually to reach full international parity by 2030.

4 REFERENCES

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Table A: Industries in MMRF*

Name	Description of major activity
1. Sheep & beef cattle	Primary agricultural activities related to sheep and cattle production
2. Dairy cattle	Primary agricultural activities associated with dairy cattle
3. Other livestock	Primary agricultural activities associated with other animals
4. Grains	Grains production
5. Other agriculture	Other primary agricultural production
6. Agricultural services, fishing and hunting	Provision of agricultural services, fishing and hunting
7. Forestry	Logging and forestry services
8. Coal mining	Mining of coal
9. Oil mining	Mining of oil
10. Gas mining	Production of natural gas at well
11. Iron ore mining	Mining of iron ore
12. Non-ferrous ore mining	Mining of ore other than iron
13. Other mining	Other mining activity
14. Meat & meat products	Processed food related to animal
15. Other food, beverages & tobacco	Other food and drink products
16. Textiles, clothing & footwear	Textiles, clothing and footwear
17. Wood products	Manufacture of wood (including pulp) products
18. Paper products	Manufacture of paper products
19. Printing and publishing	Printing and publishing
20. Petroleum products	Manufacture of petroleum (refinery) products
21. Basic chemicals	Manufacture of basic chemicals and paints
22. Rubber & plastic products	Manufacture of plastic and rubber products
23. Non-metal construction products	Manufacture of non-metallic building products excl. cement
24. Cement	Manufacture of cement
25. Iron & steel	Manufacture of primary iron and steel.
26. Alumina	Manufacture of alumina
27. Aluminium	Manufacture of aluminium
28. Other non-ferrous metals	Manufacture of other non-ferrous metals
29. Metal products	Manufacture of metal products
30. Motor vehicles and parts	Manufacture of motor vehicles and parts
31. Other manufacturing	Manufacturing non elsewhere classified
32. Electricity generation - coal	Electricity generation from coal (black and brown) thermal plants
33. Electricity generation - gas	Electricity generation from natural gas thermal plants
34. Electricity generation – oil products	Electricity generation from oil products thermal plants
35. Electricity generation - nuclear	Electricity generation from nuclear plants
36. Electricity generation – hydro	Electricity generation from renewable sources – hydro
37. Electricity generation – other	Electricity generation from all other renewable sources
38. Electricity supply	Distribution of electricity from generator to user
39. Gas supply	Urban distribution of natural gas
40. Water supply	Provision of water and sewerage services
41. Construction services	Residential building and other construction services
42. Trade services	Provision of wholesale and retail trade services
43. Accommodation, hotels & cafes	Provisions of services relating to accommodation, meals and drinks
44. Road passenger transport	Provision of road transport services – passenger
45. Road freight transport	Provision of road transport services - freight
46. Rail passenger transport	Provision of rail transport services – passenger
47. Rail freight transport	Provision of rail transport services - freight
48. Water, pipeline & transport services	Provision of water transport services
49. Air transport	Provision of air transport services
50. Communication services	Provision of communication services
51. Financial services	Provision of financial services
52. Business services	Provision of business services
53. Dwelling services	Provision of dwelling services
54. Public services	Provision of government and community services
55. Other services	Provision of services not elsewhere classified
56. Private transport services	Provision of services to households from the stock of motor vehicles
57. Private electricity equipment services	Provision of services to households from the stock of electrical equipment
58. Private heating services	Provision of services to households from the stock of heating equipment

* For most of the industries 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 32 to 38, which together comprise ANZSIC 26 *Electricity Supply*; industry 53, which is equivalent to the *Ownership of dwellings* industry in the industrial classification of the official Input/Output statistics; and industries 56 to 58 which relate to the provision of services from the private stocks of motor vehicles, electrical equipment (not heating) and heating equipment.

Table B: Summary of MMRF Emissions Data for 2005-06: Australia (Kt of CO2-e)

Fuel User:	Source of Emissions (fuel combustion and non-combustion)				
	Coal	Gas	Petroleum	Non-fuel	Total
1. Sheep & beef cattle	0.0	1.3	1,179.7	70,179.0	71,360.0
2. Dairy cattle	0.0	0.4	483.9	9,297.0	9,781.3
3. Other livestock	0.0	0.7	192.4	2,983.0	3,176.1
4. Grains	0.0	0.8	1,650.2	2,399.0	4,049.9
5. Other agriculture	0.0	0.7	1,248.3	3,085.0	4,333.9
6. Agricultural services, fishing and hunting	0.0	1.2	1,231.2	13.0	1,245.5
7. Forestry	0.0	0.0	473.6	-19,610.0	-19,136.4
8. Coal mining	0.0	0.0	2,761.5	21,610.0	24,371.5
9. Oil mining	0.0	0.0	136.3	818.0	954.3
10. Gas mining	0.0	8,991.0	263.2	6,360.0	15,614.2
11. Iron ore mining	37.1	312.0	321.8	0.0	670.9
12. Non-ferrous ore mining	699.9	660.0	3,699.8	1,634.0	6,693.7
13. Other mining	0.0	0.0	926.4	0.0	926.4
14. Meat & meat products	78.7	83.2	21.1	0.0	182.9
15. Other food, beverages & tobacco	718.4	1,529.8	124.8	0.0	2,373.0
16. Textiles, clothing & footwear	2.8	350.3	12.8	0.0	365.9
17. Wood products	371.1	96.1	14.1	0.0	481.4
18. Paper products	606.7	682.3	17.2	704.0	2,010.3
19. Printing and publishing	13.0	174.0	32.6	0.0	219.6
20. Petroleum products	0.0	1,255.1	4,740.4	490.0	6,485.5
21. Basic chemicals	507.0	1,332.2	2,073.1	2,513.0	6,425.2
22. Rubber & plastic products	27.0	982.9	398.0	0.0	1,407.9
23. Non-metal construction products	404.2	1,814.1	156.4	1,499.0	3,873.7
24. Cement	2,004.8	1,011.9	406.4	4,738.0	8,161.2
25. Iron & steel	3,532.0	1,295.0	170.5	8,961.0	13,958.5
26. Alumina	3,488.7	3,023.6	1,958.9	0.0	8,471.1
27. Aluminium	0.0	0.0	291.6	4,642.0	4,933.6
28. Other non-ferrous metals	1,778.1	3,380.8	481.1	0.0	5,640.0
29. Metal products	0.0	76.6	25.6	0.0	102.2
30. Motor vehicles and parts	0.0	62.1	20.5	0.0	82.6
31. Other manufacturing	97.1	228.0	73.3	674.0	1,072.4
32. Electricity generation - coal	179,163.0	0.0	0.0	0.0	179,163.0
33. Electricity generation - gas	0.0	14,573.0	0.0	0.0	14,573.0
34. Electricity generation – oil products	0.0	0.0	1,042.3	0.0	1,042.3
35. Electricity generation - nuclear	0.0	0.0	0.0	0.0	0.0
36. Electricity generation – hydro	0.0	0.0	0.0	0.0	0.0
37. Electricity generation – other	0.0	0.0	0.0	0.0	0.0
38. Electricity supply	0.0	0.0	662.6	0.0	662.6
39. Gas supply	0.0	0.0	15.5	2,132.0	2,147.5
40. Water supply	0.0	0.0	307.4	0.0	307.4
41. Construction services	0.0	159.3	1,696.7	0.0	1,856.0
42. Trade services	0.0	1,490.5	5,299.4	361.0	7,150.9
43. Accommodation, hotels & cafes	0.0	232.9	705.2	302.0	1,240.1
44. Road passenger transport	0.0	5.6	2,371.0	728.0	3,104.6
45. Road freight transport	0.0	71.5	22,469.0	0.0	22,540.4
46. Rail passenger transport	0.0	0.0	341.3	0.0	341.3
47. Rail freight transport	0.0	0.0	1,793.6	0.0	1,793.6
48. Water, pipeline & transport services	0.0	4.1	2,657.8	0.0	2,661.8
49. Air transport	0.0	0.0	5,136.3	0.0	5,136.3
50. Communication services	0.0	98.2	1,574.1	0.0	1,672.3
51. Financial services	0.0	2.3	3.3	0.0	5.6
52. Business services	0.0	262.3	1,635.9	0.0	1,898.2
53. Dwelling services	0.0	5.4	18.5	0.0	23.8
54. Public services	0.0	187.4	1,867.9	0.0	2,055.2
55. Other services	0.0	44.1	1,633.9	17,037.0	18,715.0
56. Private transport services	0.0	0.0	36,904.7	1,613.0	38,517.7
57. Private electricity equipment services	0.0	0.0	0.0	835.0	835.0
58. Private heating services	0.0	6,983.6	0.0	0.0	6,983.6
Residential	16.8	0.0	277.9	0.0	294.7
Total	193,546.4	51,466.3	114,000.6	145,997.0	505,010.4