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REPORT

ESTIMATED IMPACTS OF THE PROPOSED DOMESTIC EMISSIONS TRADING SCHEME ON THE OIL AND GAS INDUSTRY

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1. INTRODUCTION

The Australian Petroleum Production & Exploration Association (APPEA) commissioned Concept Economics to undertake analysis of the impact of Australia's proposed emissions trading scheme on the oil and gas industry. The description of the proposed scheme that has been used as the basis for the analysis is that set out in the Department of Climate Change green paper on emissions trading. The modelling reported here was conducted using Access Economics' general equilibrium model. The model is described in the next chapter of the report. An outline of the policy scenarios together with key underlying assumptions is set out in chapter 3. The results of the analysis are presented in chapter 4.

2. ANALYTICAL FRAMEWORK

The quantitative analysis undertaken in this report is based on Access Economics' general equilibrium model called AE-RGEM (Access Economics Regional General Equilibrium Model). General equilibrium models like AE-RGEM are a widely accepted tool for estimating the direct and indirect impacts of policy changes, such as the imposition of an emissions trading scheme. The main benefit of a model such as AE-RGEM is that greenhouse gas emissions arise from a range of activities across the economy and, as such, policies designed to constrain emissions growth will have widespread economic consequences.

Of course, any economic model is highly dependent on its assumptions, parameters and data. This chapter provides a brief overview of the structure of AE-RGEM (with more detail in Appendix A) and describes the reference case assumptions against which the policy changes will be assessed.

2.1. THE MODEL

AE-RGEM is a large-scale, dynamic, multi-region, multi-commodity computable general equilibrium model of the world economy. More detail of the model specification is set out in Appendix A.

The model allows policy analysis in a single, robust, integrated economic framework. The model projects changes in macroeconomic aggregates such as GDP (or GSP at the State level), employment, export and import volumes, investment and private consumption.

AE-RGEM was developed specifically with climate change response policy in mind. It is based on Access Economics' more general model of the global economy AE-GEM. AE-RGEM replaces the treatment of Australia as a single region with multiple regions representing the States and Territories. Each Australian sub-region is treated as a separate economy but operates within national constraints.

2.2. BASE DATA

The base data of the model is derived from the Global Trade Analysis Project (GTAP). GTAP produces a global database for general equilibrium modelling used by over 700 researchers worldwide. The Australian component of the database is provided by the Productivity Commission, and is based on Australian input-output tables produced by the Australian Bureau of Statistics.

The model is primarily based on input-output or social accounting matrices, as a means of describing how economies are linked through production, consumption, trade and investment flows. For example, the model considers:

- Direct linkages between industries and countries through purchases and sales of goods and services; and
- Indirect linkages through mechanisms including the collective competition for available resources, such as labour, that operates in an economy-wide or global context.

AE-RGEM is based on Version 6.0 of the GTAP database that has a 2001 base year with 87 countries and 57 industry sectors. Not all regions and sectors are relevant to this exercise, so the database has been aggregated to the 23 sectors and 18 regions shown in Table 2-1.

AE-RGEM uses the 2000-01 input-output, state and national accounts data from the ABS to calibrate the State-based components of the model. Consistent with the national accounts, the model is commodity- or industry-based rather than characterised at the firm level. A production function is assumed for each sector and commodities or industries are represented in state-wide aggregates, rather than as firm-specific data.

In disaggregating commodities that were not included in the original GTAP database (e.g. brown, thermal and coking coal), various sources besides the ABS were used including ABARE, the International Energy Association (IEA), and the National Electricity Market Management Company (NEMMCO). Further data are sourced from the MMRF-NRA model used by the Productivity Commission in the National Reform Agenda report.[1]

2.3. FEATURES SPECIFIC FOR CLIMATE POLICY ANALYSIS

AE-RGEM has been developed principally for analysing climate change response policy. The industry detail allows for comprehensive accounting for greenhouse gas emissions at the State and Territory levels. These data are calibrated to the latest greenhouse gas inventory numbers across States published by the Australian Greenhouse Office (2004).

Apart from emission accounting, AE-RGEM has been developed to allow for energy substitution possibilities in response to emissions pricing. The energy-factor bundle is a constant elasticity of substitution (CES) combination of the primary factor bundle and the energy bundle, and is combined in fixed proportions with the intermediate input bundle. Depending on the value of the substitution elasticities at the various production nodes for an industry sector, substitution is possible between the four energy inputs and then between the energy and primary factor bundles.

The production structure for electricity generation is based on a ‘technology bundle’ approach developed by ABARE (2006), and modified in AE-RGEM. The model accounts for six generation technologies: brown coal, thermal coal, gas, oil, hydro, nuclear (not in Australia) and other renewables. Electricity generators choose their pattern of technologies by minimising costs in response to changes in relative prices using a CES production function. Trade in electricity across the National Electricity Market is also modelled.

[1] Productivity Commission, 2006, Supplement to *Potential Benefits of the National Reform Agenda*, Productivity Commission Research Paper, December, Canberra.

Table 2-1 Sectoral and regional aggregation in AE-RGEM

No.	Sectors	No.	Regions
1	Primary and processed agriculture	1	Western Australia
2	Coal	2	Rest of Australia
3	Oil	3	China
4	Gas	4	Japan
5	Minerals	5	South Korea
6	Light manufacturing	6	Taiwan
7	Petroleum and coal products	7	India
8	Chemicals, rubber and plastics	8	Rest of Asia
9	Other non-metallic mineral products	9	Canada
10	Iron and steel	10	USA
11	Non-ferrous metals	11	Brazil
12	Fabricated metal products	12	Rest of South America
13	Motor vehicles and parts	13	Mexico
14	Other transport equipment	14	EU27
15	Other machinery and equipment	15	Russian Federation
16	Other manufacturing	16	Rest of Former Soviet Union
17	Electricity generation	17	South Africa
18	Electricity distribution	18	Rest of World
19	Gas and water		
20	Construction		
21	Sea and air transport		
22	Road and rail transport		
23	Other services		

Note: Electricity is generated using brown coal, black coal, gas, oil-fired, nuclear, hydropower and other renewables. Nuclear generation is precluded in Australia.

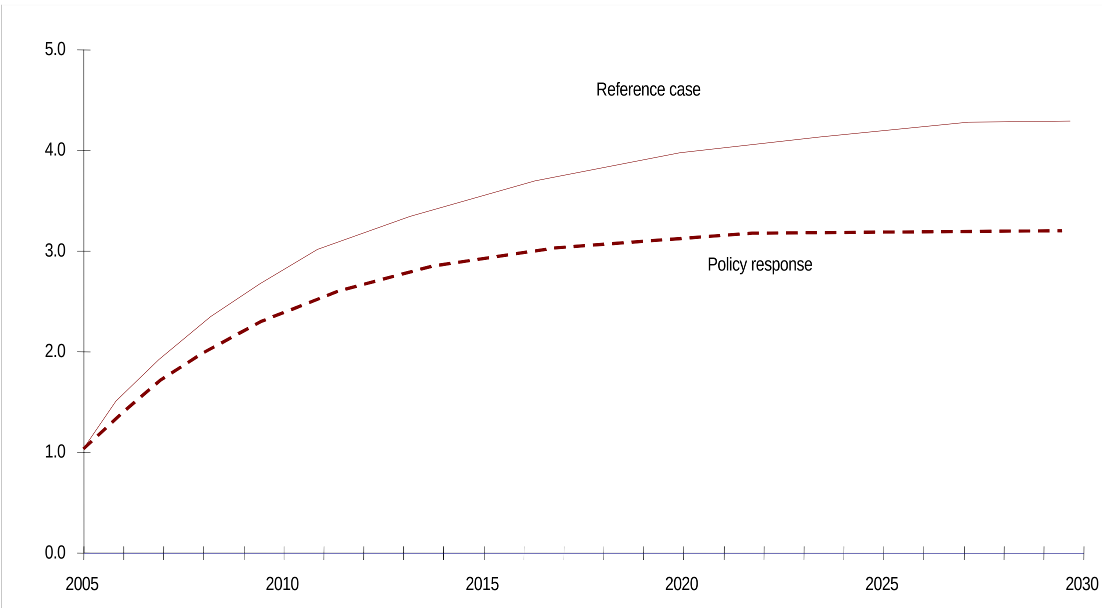
This treatment of electricity is an attempt to bridge the gap between the general equilibrium modelling framework and 'bottom-up' electricity models. 'Bottom-up' models are engineering-based, linear programming models that take energy/electricity demand as given and determine the least-cost technology mix to satisfy a given level of demand. While these 'supply side' models are not suited to estimating the economy-wide impacts of imposing a carbon price they are often used to inform general equilibrium models of the responses to emissions pricing in the electricity sector. In the case of the results reported here the electricity sector in the model was enhanced to reflect specific assumptions supplied by International Power. In particular, the cost of generation from renewable sources was increased to reflect the costs of provision of network backup and enhancement.

2.4. DYNAMICS

AE-RGEM is a dynamic recursive model that solves year-on-year over a specified timeframe. The model is used to project the relationship between variables under different scenarios over a predefined period. The reference case scenario forms the basis of the analysis and the model is solved year-by-year from time 0 (which reflects the base year of the model - 2001), to a predetermined end year (in this case 2030).

The variable represented on the vertical axis of Figure 2-1 could be any one of those represented in the model, ranging from macroeconomic indicators such as real GDP to sectoral variables such as exports of thermal coal. In Figure 2-1, the percentage changes in the variables have been converted to an index (= 1.0 in 2005) and are projected to increase by 2030. Set against the reference case scenario is a policy response projection. The policy response projection represents the impacts of imposing an emissions price, for example on stationary energy. The impact of that policy is a new projection path over the simulation period, with the impacts of the policy change reflected in the differences in the variable at time T. It is important to note that the difference in the manipulated variable between the reference case and policy intervention scenario will also affect other variables in the model.

Figure 2-1 Dynamic simulation using AE-RGEM



2.5. REFERENCE CASE PROJECTIONS

As described above, AE-RGEM requires a reference case projection against which to compare the various climate change response policies. The reference case runs over the period 2001 to 2030 and is based on a set of input assumptions including on:

- economic growth;
- population and employment growth;
- electricity generation;
- energy efficiency; and
- existing implemented policies and measures.

From this set of key input assumptions, the model generates a wide range of results from which a subset are relevant for this analysis.

Key macroeconomic assumptions are shown in Table 2-2 including assumed regional output growth, population and employment growth. These are consistent with Access Economics' March 2007 Business Outlook publication.

Table 2-2 Reference case assumptions 2008-2030

Regions	GSP/GDP	Labour supply	Population
	Average annual % change		
China	5.82	0.28	0.41
Japan	1.04	-0.87	-0.37
South Korea	3.96	0.06	0.23
Taiwan	3.57	0.18	0.25
India	6.61	1.30	1.09
Rest of Asia	5.48	1.72	1.23
Canada	2.49	0.35	0.68
United States	2.62	0.40	0.82
Brazil	3.73	1.00	0.99
Rest of South America	3.60	1.52	1.22
Mexico	3.34	1.34	0.96
EU27	2.05	0.16	0.08
Russian Federation	3.22	-0.57	-0.41
Rest of Former Soviet Union	4.83	-0.05	-0.10
South Africa	4.22	0.75	0.43
Rest of World	5.43	2.06	1.75

A target of reducing emissions below some historic level by a future date requires knowledge of the likely level of emissions into the future. AE-RGEM uses publicly available emissions forecasts released by the Australian Greenhouse Office (AGO) in 2008 to forecast the 'reference case' for annual national emissions out to 2030.

The AGO reports two series of forecasts: business as usual (BAU) estimates of emissions that embody no policy response to climate change, and 'with measures' estimates that account for the effect of policies already in place. To accurately assess the abatement needed from an ETS it is necessary to first include the effect of other measures, leaving only the incremental abatement needed from the emissions trading scheme.

Reference case emissions are based on the 'with measures' forecasts. Table 2-3 reports the effects of measures in terms of the reduction in annual emissions in each of eight sectors. Table 2-4 provides the 'with measures' emissions projections for the Kyoto period and in 2020.

Table 2-3 Impacts of measures on abatement (Mt CO_2e reduction per annum)

Sector	2008-2012	2020
Stationary Energy	*36*	*83*
Transport	1.8	5.0
Fugitive	8.5	9.8
Industrial Processes	7.4	9.1
Agriculture	0.6	1.1
Land Use	24.1	24.1
Waste	9.3	18.7
Reforestation	n.a	n.a
Total	87.7	150.8

Table 2-4 Projected emissions by sector (Mt CO_2e)

Sector	2005	2008-2012	2020
Stationary Energy	*282.0*	*304.0*	*348.5*
Transport	80.6	87.4	103.6
Fugitive	32.3	37.7	52.0
Industrial Processes	25.3	29.6	49.4
Agriculture	89.9	93.1	99.8
Land Use	74.1	44.2	44.2
Waste	15.3	15.1	14.6
Reforestation	-21.8	-20.5	-20.5

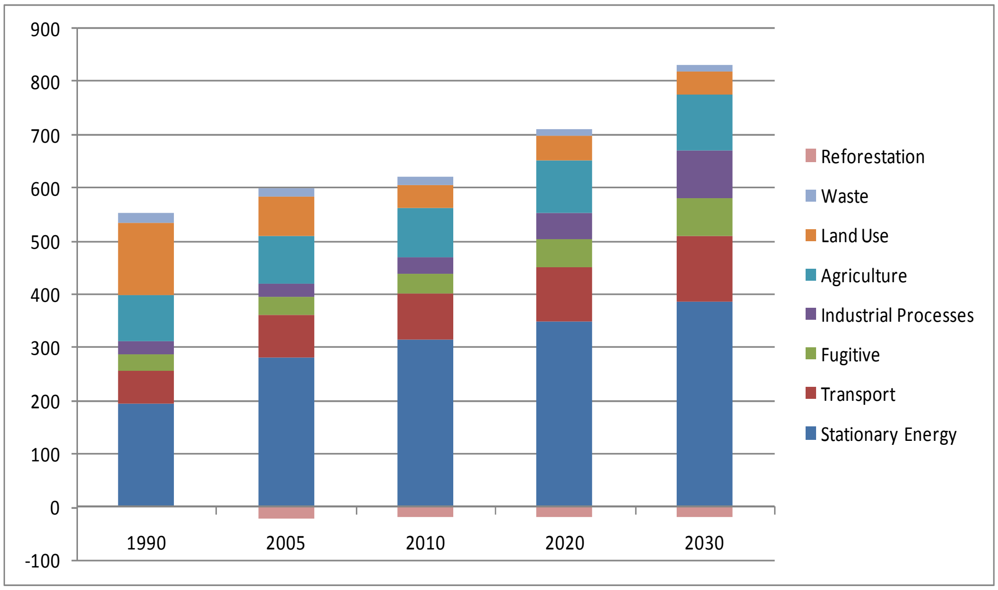
Source: AGO. Note: for modelling purposes the average of the Kyoto period is assumed to occur in 2010.

For input into the model, these projections need to be interpolated between the reported years. Emission forecasts for in-between years are based on the implied average annual growth rates between two dates. The AGO forecasts emissions up to 2020. For the purposes of this report, however, forecasts to 2030 are needed. These were calculated by extending the 2010-20 growth rates to 2030.

The effect on the projections of the major measures in each sector is outlined in Figure 2-2.

Figure 2-2 shows aggregate emissions increasing from 553Mt in 1990 to 813Mt in 2030, an increase of 47 per cent over the period. However, growth in emissions is not evenly spread across the sectors. Large reductions in emissions from land use have already been achieved since 1990, and these are almost solely responsible for Australia being on track to meet the Kyoto target of 108 per cent of 1990 levels for the period 2008-2012. Emissions from other sectors are expected to increase strongly. Stationary energy currently accounts for around half of total national emissions and this is projected to increase by 98 per cent above 1990 levels by 2030 in the reference case. Other sectors are expected to experience stronger growth, albeit off smaller bases, with transport emissions growing 99 per cent, fugitive emissions 148 per cent and industrial processes rising 252 per cent over the 1990 to 2030 period under the reference case.

Figure 2-2 Emissions projections by sector (Mt CO_2e)



3. OUTLINE OF THE POLICY SCENARIOS

The policy scenarios and their underlying assumptions are set out below.

3.1. COMMON ASSUMPTIONS FOR POLICY SCENARIOS

A number of common assumptions were adopted under each policy scenario as follows.

- Carbon capture and storage (CCS) becomes available in 2020 for the electricity generation sector (but CCS is not available as a viable technology for permit prices below \$60/tCO_2e).
- The new renewable energy target is included in all scenarios.
- Forestry offsets are available in Australia at the following levels:
  - 5Mt at \$12/tCO_2e;
  - 12Mt at \$50/tCO_2e; and
  - a maximum of 20Mt at \$100/tCO_2e.
- No international trade in Article 17 permits is permitted until 2015. Five per cent of the target may be achieved using CDM credits from 2010 to 2015. After 2015, 8 per cent of the target may be made up using either CDM or Article 17 international trading.
- Agriculture is included in the ETS in Australia from 2015.
- LNG growth is assumed to be consistent with the Platform for Prosperity target
- Oil production is held at reference case levels in the policy simulations.
- East coast gas prices are internationalised by 2015 and international oil prices are held above US\$80 per barrel (in real 2008 dollars) over the projection period.
- Assistance to emissions intensive trade exposed industries (EITE) is assumed to that outlined in the green paper for activities with emissions intensities above 1500 t CO_2e (according to Appendix D of the green paper). It is assumed that there is no administrative allocation of permits for gas or LNG.
- EITE assistance is phased out smoothly between 2020 and 2025.
- EITE assistance consistent with that assumed for Australia is applied in overseas countries.

3.2. INTERNATIONAL POLICY SETTINGS

The basic assumptions surrounding international action on climate change were as follows.

- All reductions in emissions are taken from a common base year of 2000 with the exception of the existing Kyoto commitments (base year of 1990).

- Annex B countries except Canada and the United States meet their first commitment period Kyoto targets.
- The EU adopts a 20 per cent reduction by 2020 and a 30 per cent reduction by 2030 on the way to a 60 per cent reduction by 2050. It is further assumed that New Zealand adopts the EU target.
- The United States and Canada commence an ETS in 2015 with a target of a 20 per cent reduction by 2030 and a 60 per cent reduction by 2050. The Russian Federation and Japan adopts the same targets.
- Mexico and South Korea commence abatement in 2020 with a goal of a 10 per cent reduction by 2030 and a 30 per cent reduction by 2050.
- Developing countries adopt goal of a 10 per cent reduction by 2050 commencing abatement in 2030.

These targets are assumed to apply in the case where Australia adopts a target of a 20 per cent reduction in emissions relative to the 2000 base year by 2020 with a long term target of a 60 per cent reduction in emissions by 2050. For less stringent targets in Australia the effort in each overseas country/region is reduced proportionately.

3.3. AUSTRALIAN EMISSIONS REDUCTION SCENARIOS

Three emissions reduction trajectories are modelled as follows.

Scenario 1: A 20 per cent reduction in CO_2e emissions relative to 2000 levels by 2020 and a 30 per cent reduction by 2030 (consistent with a 60 per cent reduction by 2050).

Scenario 2: A 10 per cent reduction in CO_2e emissions relative to 2000 levels by 2020 and a 20 per cent reduction by 2030 (followed by a trajectory consistent with a60 per cent reduction by 2050).

Scenario 3: A zero per cent reduction in CO_2e emissions relative to 2000 levels by 2020 followed by a trajectory consistent with a 60 per cent reduction by 2050).

The results for each scenario are reported in the following chapter.

4. RESULTS OF THE ANALYSIS

4.1. PROJECTED IMPACT ON THE AUSTRALIAN ECONOMY

The macroeconomic impacts of the proposed emissions trading scheme in 2020 and 2030 under each policy scenario for Australia as a whole are set out in tables 4-1 and 4-2 respectively. As expected, the results show a consistent pattern of smaller impacts as the emissions reductions trajectory is assumed to become less ambitious under scenarios 1 to 3. This pattern is reflected in the estimated carbon permit prices required to reach each target. For example, in 2020 a permit price of almost \$100/tCO_2e is required to achieve a 20 per cent reduction in emissions whereas a price of \$54/tCO_2e is required in the case of a 10 per cent reduction in that year. It is projected that a carbon price of \$25/tCO_2e is sufficient by 2020 to hold emissions at their 2000 level by 2020 given the assumptions about offsets available and the ability to access credits under the Clean Development Mechanism.

Under scenario 1 real GNP is projected to be 5.4 per cent less than it otherwise would have been by 2030 and real GDP is projected to be 6.1 per cent lower. In 2030 real consumption is projected to be 6.5 per cent less than it otherwise would have been. Under scenario 2 this impact falls to 4.5 per cent and under scenario 3 to about 1 per cent. It can be seen that the assumptions about the emissions reduction trajectory have a major influence on the estimated impact of the scheme that is reflected in both the projected impact on real consumption and the carbon permit prices.

Table 4-1 Macroeconomic results for Australia in 2020 (per cent deviation from the reference case unless stated)

	Scenario 1	Scenario 2	Scenario 3
Real GNP	-3.8	-1.8	-0.6
Real GDP	-3.9	-1.8	-0.7
Investment	-10.4	-4.9	-1.6
Consumption	-4.4	-2.1	-0.5
Employment	-2.3	-1.1	-0.3
Real after-tax wages	-5.4	-2.9	-1.0
Exports	-2.5	-1.7	-0.5
Imports	-8.9	-5.2	-2.2
Emissions	-39	-29	-20
Emissions (Mt)	-236	-177	-119
Carbon price (\$/tCO_2e)	98	54	25

Table 4-2 Macroeconomic results for Australia in 2030 (per cent deviation from the reference case unless stated)

	Scenario 1	Scenario 2	Scenario 3
Real GNP	-5.4	-3.7	-1.0
Real GDP	-6.1	-3.9	-1.1
Investment	-10.5	-7.9	-1.5
Consumption	-6.5	-4.5	-0.9
Employment	-2.0	-1.5	-0.3
Real after-tax wages	-9.1	-6.1	-1.7
Exports	-8.5	-5.2	-2.3
Imports	-11.5	-9.2	-3.5
Emissions	-56	-48	-32
Emissions (Mt)	-418	-359	-241
Carbon price ($/t$CO_2$e)	196	129	47

The projected impacts on output by sector for Australia as a whole in 2020 and 2030 are shown in tables 4-3 and 4-4 respectively. As expected the sectoral impacts are less marked the less ambitious the emissions reduction trajectory. Despite that, the projected impacts on the energy sector remain large under all policy scenarios. By far the largest impact is experienced by the brown coal industry whose output is projected to fall by about 60 per cent compared to what otherwise would have occurred in 2020 under scenario 1 and by almost 39 per cent under scenario 3.

In 2020 the impacts of the proposed scheme on natural gas and thermal coal output are projected to be similar. The output of gas for domestic use is projected to fall below what it would otherwise have been for three reasons. First, electricity output is projected to contract sharply under all scenarios and this reduces the overall demand for all fuels for electricity generation. Second, under the assumptions about the administrative allocation of permits employed in this study, there is an allocation of permits to the coal mining industry whereas there is no allocation to the natural gas industry. Finally, a number of industries that use gas in their production processes, for example, the other non-ferrous metals industry including copper and gold, do not receive an administrative permit allocation and as a consequence their output falls relative to what it otherwise would have done in all scenarios. This in turn reduces the overall demand for gas even further than already experienced as a consequence of the reduction in electricity demand.

The projected impact on the natural gas industry in 2030 is far more severe than that projected for 2020. Even under scenario 3 output is projected to fall by about 30 per cent compared to what it otherwise would have done. This occurs both because of the general contraction in output and therefore fuel demand by the resources sector and because Australia no longer has a comparative advantage in energy intensive fossil fuel based industries.

The large projected impacts of the proposed scheme on the LNG industry arise even though the sector is deemed in the Department of Climate Change green paper to be below the emissions intensity cut off that would attract an administrative allocation of permits. The projected impact occurs for two key reasons. First, both the production of gas and the processes required to produce and transport LNG are emissions intensive. Finally, LNG projects are highly capital intensive and changes in costs, such as those projected to be imposed as a consequence of the introduction of an emissions trading scheme, are enough in the case of many projects to make them unviable. As a consequence project proponents will seek to develop alternative projects in overseas countries where emissions trading regimes do not exist and are unlikely to be introduced in the foreseeable future. In 2030 LNG output is projected to be about half what it otherwise would have been under scenario 1 and to be a third less under scenario 3.

Table 4-3 Impact on output for Australia by sector in 2020 (per cent deviation from the reference case unless stated)

	Scenario 1	Scenario 2	Scenario 3
Crops	4.2	2.4	0.9
Livestock	1.9	1.1	0.5
Other agriculture	3.9	2.3	1.0
Brown coal	-60.4	-51.4	-38.8
Thermal coal	-28.3	-23.9	-16.5
Natural gas	-34.6	-24.1	-15.6
LNG	-37.4	-26.0	-16.4
Other minerals	-3.8	-2.5	-1.8
Processed food	1.9	1.2	0.6
Lumber and wood products	1.5	1.1	0.8
Chemicals, rubber and plastic	2.2	2.5	1.4
Non-ferrous metals other than aluminium	-49.5	-30.0	-10.4
Pulp, paper and printing	-1.4	-0.4	0.0
Motor vehicles and parts	0.4	0.6	0.6
Electrical equipment	2.9	1.8	1.1
Other manufacturing	4.4	4.4	2.1
Water	-6.4	-4.4	-0.9
Electricity generation	-46.3	-37.8	-21.5
Construction	-9.9	-7.4	-1.5
Air transport	-3.1	2.1	5.0
Water transport	0.6	1.9	1.7
Land transport	-6.5	-4.2	-0.8
Communications	-4.7	-3.1	-0.5
Business services	-5.7	-3.8	-0.8
Government services	-2.1	-1.5	0.0
Other services	-4.7	-3.0	-0.3

Table 4-4 Impact on output for Australia by sector in 2030 (per cent deviation from the reference case unless stated)

	Scenario 1	Scenario 2	Scenario 3
Crops	5.6	4.5	1.5
Livestock	2.1	2.1	0.8
Other agriculture	6.3	5.2	2.0
Brown coal	-78.2	-72.5	-57.8
Thermal coal	-63.0	-55.3	-34.2
Natural gas	-53.9	-44.5	-30.1
LNG	-54.4	-45.8	-33.8
Other minerals	-5.2	-3.8	-1.3
Processed food	1.6	2.2	0.9
Lumber and wood products	1.6	2.1	1.0
Chemicals, rubber and plastic	2.3	4.8	3.5
Non-ferrous metals other than aluminium	-67.5	-50.9	-15.7
Pulp, paper and printing	-2.6	-1.0	0.3
Motor vehicles and parts	0.1	0.9	0.9
Electrical equipment	0.1	0.9	0.9
Other manufacturing	4.4	4.4	2.1
Water	-6.4	-4.4	-0.9
Electricity generation	-46.3	-37.8	-21.5
Construction	-9.9	-7.4	-1.5
Air transport	-3.1	2.1	5.0
Water transport	0.6	1.9	1.7
Land transport	-6.5	-4.2	-0.8
Communications	-4.7	-3.1	-0.5
Business services	-5.7	-3.8	-0.8
Government services	-2.1	-1.5	0.0
Other services	-4.7	-3.0	-0.3

The projected carbon prices under each scenario are set out in table 4.5. In 2030 the projected carbon prices range from about \$50/t CO_2e under scenario 3 to about \$200 under scenario 1. The projected carbon prices reported here are higher than those reported in the Garnaut supplementary draft report. These differences are likely to reflect the (as yet undocumented) technological enhancements incorporated in the models employed by the Garnaut Review and differences in assumptions about the level and timing of international action.

Table 4-5 Carbon permit prices under different emissions reduction scenarios (\$/t CO_2e)

	Scenario 1	Scenario 2	Scenario 3
2010	6	4	3
2011	13	9	5
2012	20	13	7
2013	27	18	9
2014	36	23	12
2015	44	27	14
2016	54	33	16
2017	64	38	18
2018	75	43	21
2019	86	49	23
2020	98	54	25
2021	107	61	27
2022	116	69	30
2023	126	76	32
2024	136	83	35
2025	146	91	37
2026	156	98	39
2027	165	105	41
2028	175	113	43
2029	186	121	46
2030	196	129	47

4.2. IMPACTS OF THE SCHEME ON WESTERN AUSTRALIA

The projected macroeconomic impacts of the scheme on Western Australia in 2020 and 2030 are shown in Tables 4-6 and 4-7 respectively. Again, the overall impact on Western Australia follows the same pattern as that for the whole of Australia in the sense that the impacts fall as the size of the emissions reduction target is reduced. The projected overall impacts on output in the Western Australian economy are around the same in magnitude in percentage terms as those for Australia as a whole. Among other things this reflects the fact that much Western Australia’s export income is derived from relatively low emissions intensive mining activities such as the production and export of iron ore. In addition it has been assumed in the modeling that oil output is maintained at reference case levels despite the introduction of the emissions trading scheme. This assumption was made on the basis that real oil prices are projected to remain high over the period to 2030 and therefore oil producers are likely to attempt to maintain their reference case level output.

Table 4-6 Macroeconomic results for Western Australia in 2020 (per cent deviation from the reference case unless stated)

	Scenario 1	Scenario 2	Scenario 3
Real GSP	-4.2	-2.1	-0.5
Investment	-5.1	-2.8	-1.1
Consumption	-3.9	-2.0	-0.5
Employment	-2.4	-1.2	-0.3
Exports	-7.9	-4.2	-1.4
Imports	-12.7	-7.4	-3.0
Emissions	-39.8	-29.1	-18.9
Emissions (Mt)	-42.0	-30.6	-19.9
Carbon price ($/t$CO_2$e)	98	54	25

Table 4-7 Macroeconomic results for Western Australia in 2030 (per cent deviation from the reference case unless stated)

	Scenario 1	Scenario 2	Scenario 3
Real GSP	-5.5	-3.8	-0.9
Investment	-7.9	-5.2	-1.8
Consumption	-5.7	-3.8	-1.0
Employment	-1.5	-1.3	-0.3
Exports	-15.4	-10.1	-4.0
Imports	-14.4	-11.3	-4.4
Emissions	-54.4	-45.7	-29.9
Emissions (Mt)	-64.9	-54.6	-35.8
Carbon price ($/t$CO_2$e)	196	129	47

The projected impacts of the scheme on sectoral output in Western Australia in 2020 and 2030 are shown in Tables 4-8 and 4-9 respectively. The emissions intensive trade exposed industries that are not administratively allocated permits are projected to experience large falls in output compared with what would have otherwise occurred. For example, in 2030 the output from the LNG industry is projected to be about half what it otherwise would have been under scenario 1. Even under scenario 3, output is projected to be one third less than it otherwise would have been. Similar effects can be expected for the other emissions intensive trade exposed industries that fall below the proposed permit allocation cut off of 1500t CO_2e per million dollars of revenue.

Table 4-8 Impact on output in Western Australia by sector in 2020 (per cent deviation from the reference case unless stated)

	Scenario 1	Scenario 2	Scenario 3
Crops	7.1	4.1	1.6
Livestock	5.7	3.3	1.3
Other agriculture	8.9	5.3	2.2
Thermal coal	-28.4	-24.4	-17.2
Natural gas	-36.6	-25.5	-16.3
LNG	-36.7	-25.6	-16.2
Other minerals	-7.4	-4.2	-1.3
Processed food	3.3	2.1	1.0
Lumber and wood products	9.1	5.3	2.4
Chemicals, rubber and plastic	8.9	6.4	3.0
Non-ferrous metals other than aluminium	-41.2	-21.9	-5.5
Pulp, paper and printing	2.0	1.7	1.0
Electrical equipment	8.0	5.0	2.3
Other manufacturing	7.0	4.4	2.0
Water	-2.3	-1.0	-0.2
Electricity generation	-29.6	-18.7	-9.8
Construction	-11.0	-6.1	-2.1
Air transport	-0.5	1.9	1.8
Water transport	0.8	1.3	0.7
Land transport	-4.3	-2.0	-0.4
Communications	-2.4	-1.1	-0.2
Business services	-4.7	-3.2	-0.6
Government services	-0.7	-0.5	0.0
Other services	-3.6	-2.2	-0.5

Table 4-9 Impact on output in Western Australia by sector in 2030 (per cent deviation from the reference case unless stated)

	Scenario 1	Scenario 2	Scenario 3
Crops	8.9	6.7	2.5
Livestock	7.8	6.0	2.4
Other agriculture	13.1	10.1	3.9
Thermal coal	-56.9	-52.2	-33.5
Natural gas	-54.5	-45.7	-32.4
LNG	-52.9	-45.1	-33.6
Other minerals	-11.7	-8.0	-2.0
Processed food	3.2	2.8	1.4
Lumber and wood products	11.3	8.8	3.4
Chemicals, rubber and plastic	11.0	10.7	5.8
Non-ferrous metals other than aluminium	-60.0	-40.2	-6.3
Pulp, paper and printing	3.2	3.0	2.0
Electrical equipment	10.0	8.2	3.7
Other manufacturing	9.5	7.7	3.5
Water	-4.0	-2.6	-0.4
Electricity generation	-42.8	-32.4	-16.0
Construction	-8.0	-7.1	-1.9
Air transport	-1.5	1.8	3.7
Water transport	0.9	1.7	1.3
Land transport	-6.0	-3.8	-0.6
Communications	-3.2	-2.0	-0.2
Business services	-4.2	-2.0	-0.5
Government services	-1.2	-0.5	0.0
Other services	-2.2	-1.0	-0.1

APPENDIX A SOME DETAIL ABOUT AE-RGEM

AE-RGEM is a large scale, dynamic, multi-region, multi-commodity computable general equilibrium model of the world economy. The model allows policy analysis in a single, robust, integrated economic framework. This model projects changes in macroeconomic aggregates such as GDP (or GSP at the State level), employment, export volumes, investment and private consumption. At the sectoral level, detailed results such as output, exports, imports and employment are also produced.

The model is based upon a set of key underlying relationships between the various components of the model, each which represent a different group of agents in the economy. These relationships are solved simultaneously, and so there is no logical start or end point for describing how the model actually works. Figure A1 shows the key components of the model for an individual region (say, Queensland). The components include a representative household, producers, investors and international (or linkages with the other regions in the model, including other Australian States and foreign regions). Below is a description of each component of the model and key linkages between components. Some additional, somewhat technical, detail is also provided.

AE-RGEM is based on a substantial body of accepted microeconomic theory. Key assumptions underpinning the model are:

- The model contains a ‘regional consumer’ that receives all income from factor payments (labour, capital, land and natural resources), taxes and net foreign income from borrowing (lending).
- Income is allocated across household consumption, government consumption and savings so as to maximise a Cobb-Douglas (C-D) utility function.
- Household consumption for composite goods is determined by minimising expenditure via a CDE (Constant Differences of Elasticities) expenditure function. For most regions, households can source consumption goods only from domestic and imported sources. In the Australian regions, households can also source goods from interstate. In all cases, the choice of commodities by source is determined by a CRESH (Constant Ratios of Elasticities Substitution, Homothetic) utility function.
- Government consumption for composite goods, and goods from different sources (domestic, imported and interstate), is determined by maximising utility via a C-D utility function.
- All savings generated in each region are used to purchase bonds whose price movements reflect movements in the price of creating capital.
- Producers supply goods by combining aggregate intermediate inputs and primary factors in fixed proportions (the Leontief assumption). Composite intermediate inputs are also combined in fixed proportions, whereas individual primary factors are combined using a CES production function.
- Producers are cost minimisers, and in doing so choose between domestic, imported and interstate intermediate inputs via a CRESH production function.

   - The model contains a more detailed treatment of the electricity sector that is based on the 'technology bundle' approach for general equilibrium modelling developed by ABARE (1996).[2]

- The supply of labour is positively influenced by movements in the real wage rate governed by an elasticity of supply (assumed to be 0.2).

- Investment takes place in a global market and allows for different regions to have different rates of return that reflect different risk profiles and policy impediments to investment. A global investor ranks countries as investment destinations based on two factors: global investment and rates of return in a given region compared with global rates of return. Once the aggregate investment has been determined for Australia, aggregate investment in each Australian sub-region is determined by an Australian investor based on: Australian investment and rates of return in a given sub-region compared with the national rate of return.

- Once aggregate investment is determined in each region, the regional investor constructs capital goods by combining composite investment goods in fixed proportions, and minimises costs by choosing between domestic, imported and interstate sources for these goods via a CRESH production function.

- Prices are determined via market-clearing conditions that require sectoral output (supply) to equal the amount sold (demand) to final users (households and government), intermediate users (firms and investors), foreigners (international exports), and other Australian regions (interstate exports).

- For internationally-traded goods (imports and exports), the Armington assumption is applied whereby the same goods produced in different countries are treated as imperfect substitutes. But in relative terms imported goods from different regions are treated as closer substitutes than domestically-produced goods and imported composites. Goods traded interstate within the Australian regions are assumed to be closer substitutes again.

- The model accounts for greenhouse gas emissions from fossil fuel combustion. Taxes can be applied to emissions, which are converted to good-specific sales taxes that impact on demand. Emission quotas can be set by region and these can be traded, at a value equal to the carbon tax avoided, where a region's emissions fall below or exceed their quota.

A.1. THE REPRESENTATIVE HOUSEHOLD

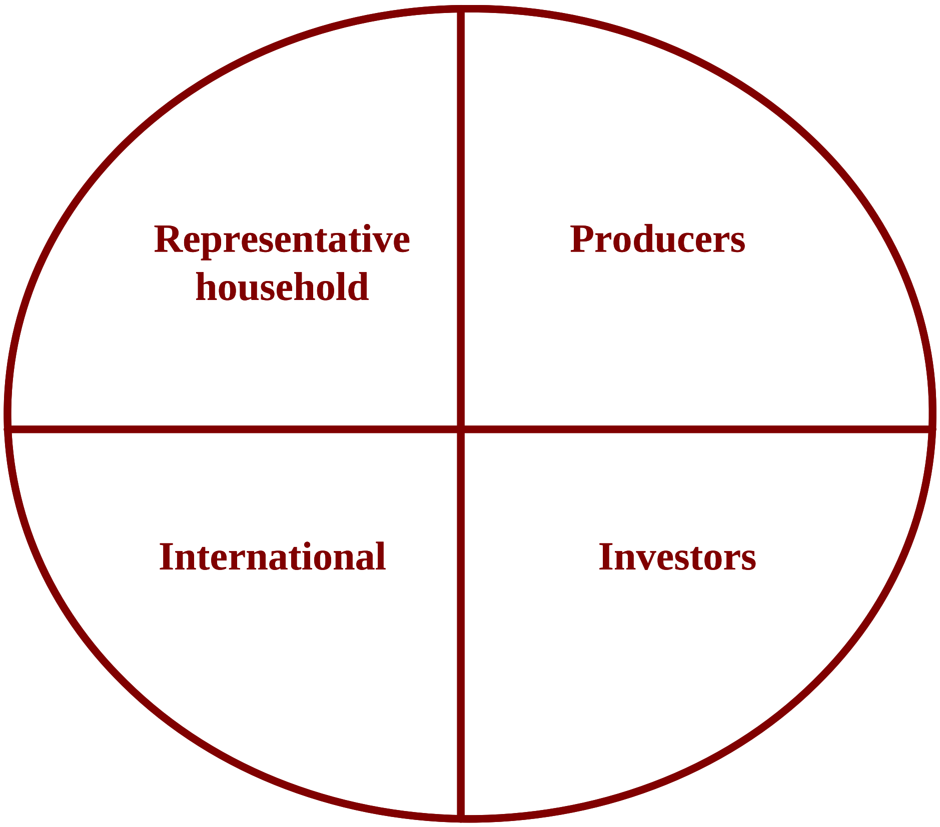
Each region in the model has a so-called *representative household* that receives and spends all income. The *representative household* allocates income across three different *expenditure* areas: private household consumption; government consumption; and savings.

Going clockwise around Figure A1, the representative household interacts with producers in two ways. First, in allocating expenditure across household and government consumption, this sustains demand for production. Second, the representative household owns and

[2] Australian Bureau of Agricultural and Resource Economics (ABARE), 1996, *MEGABARE: Interim Documentation*, Canberra.

receives all income from factor payments (labour, capital, land and natural resources) as well as net taxes. Factors of production are used by producers as *inputs into production* along with intermediate inputs. The level of production, as well as supply of factors, determines the amount of income generated in each region.

Figure A1 Key components of AE-RGEM



The *representative household's* relationship with investors is through the supply of investable funds – savings. The relationship between the representative household and the international sector is twofold. First, importers compete with domestic producers in consumption markets. Second, other regions in the model can lend (borrow) money from each other.

A.1.1. SOME DETAIL

- The representative household allocates income across three different expenditure areas – private household consumption; government consumption; and savings – to maximise a Cobb-Douglas utility function.
- Private household consumption on composite goods is determined by minimising a CDE (Constant Differences of Elasticities) expenditure function. Private household consumption on composite goods from different sources is determined is determined by a CRESH (Constant Ratios of Elasticities Substitution, Homothetic) utility function.
- Government consumption on composite goods, and composite goods from different sources, is determined by maximising a Cobb-Douglas utility function.

- All savings generated in each region is used to purchase bonds whose price movements reflect movements in the price of generating capital.

A.2. PRODUCERS

Apart from selling goods and services to households and government, producers sell products to each other (intermediate usage) and to investors. Intermediate usage is where one producer supplies inputs to another's production. For example, coal producers supply inputs to the electricity sector.

Capital is an input into production. Investors react to the conditions facing producers in a region to determine the amount of investment. Generally, increases in production are accompanied by increased investment. In addition, the production of machinery, construction of buildings and the like that forms the basis of a region's capital stock, is undertaken by producers. In other words, investment demand adds to household and government expenditure from the representative household, to determine the demand for goods and services in a region.

Producers interact with international markets in two main ways. First they compete with producers in overseas regions for export markets, as well as in their own region. Second, they use inputs from overseas in their production.

A.2.1. SOME DETAIL

- Sectoral output equals the amount demanded by consumers (households and government) and intermediate users (firms and investors) as well as exports.
- Intermediate inputs are assumed to be combined in fixed proportions at the composite level. The exception to this is the electricity sector that is able to substitute different technologies (brown coal, black coal, oil, gas, hydropower and other renewables) using the 'technology bundle' approach developed by ABARE (1996).
- To minimise costs, producers substitute between domestic and imported intermediate inputs is governed by the Armington assumption as well as between primary factors of production (through a CES aggregator). Substitution between skilled and unskilled labour is also allowed (again via a CES function).
- The supply of labour is positively influenced by movements in the wage rate governed by an elasticity of supply is (assumed to be 0.2). This implies that changes influencing the demand for labour, positively or negatively, will impact both the level of employment and the wage rate. This is a typical labour market specification for a dynamic model such as AE-RGEM. There are other labour market 'settings' that can be used. First, the labour market could take on long-run characteristics with aggregate employment being fixed and any changes to labour demand changes being absorbed through movements in the wage rate. Second, the labour market could take on short-run characteristics with fixed wages and flexible employment levels.

A.3. INVESTORS

Investment takes place in a global market and allows for different regions to have different rates of return that reflect different risk profiles and policy impediments to investment. The global investor ranks countries as investment destination based on two factors: current economic growth and rates of return in a given region compared with global rates of return.

A.3.1. SOME DETAIL

Once aggregate investment is determined in each region, the regional investor is constructs capital goods by combining composite investment goods in fixed proportions, and minimises costs by choosing between domestic, imported and interstate sources for these goods via a CRESH production function.

A.4. INTERNATIONAL

Each of the components outlined above operate, simultaneously, in each region of the model. That is, for any simulation the model forecasts changes to trade and investment flows within, and between, regions subject to optimising behaviour by producers, consumers and investors. Of course, this implies some global conditions must be met such as global exports and global imports are the same and that global debt repayments equals global debt receipts each year.