FINAL REPORT

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APPEA

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Implications of a 20 per cent renewable energy target for electricity generation

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TABLE OF CONTENTS

EXECUTIVE SUMMARY 4

1. INTRODUCTION 5

1.1. CONTEXT 5
1.2. SCOPE OF THE STUDY 5

2. ANALYTICAL FRAMEWORK 6

2.1. AE-GEM DESCRIPTION 6
2.2. FEATURES SPECIFIC FOR CLIMATE CHANGE ANALYSIS 8
2.3. REFERENCE CASE SCENARIO 8
2.3.1. Macroeconomic assumptions 8
2.3.2. Electricity generation 9

3. RENEWABLE ENERGY TARGET 12

3.1. SCENARIOS 12
3.2. RESULTS 12
3.2.1. Macroeconomic effects 12
3.2.2. Electricity generation 13
3.2.3. Greenhouse gas emissions 19
3.3. EFFICIENT POLICY 20

REFERENCES 22

APPENDIX A : A BRIEF DESCRIPTION OF AE-GEM 23

A.1 THE REPRESENTATIVE HOUSEHOLD 23
A.1.1 Some detail 24
A.2 PRODUCERS 24
A.2.1 Some detail 25
A.3 INVESTORS 25
A.3.1 Some detail 26
A.4 INTERNATIONAL LINKAGES 26
A.5 DYNAMICS 26

FIGURES

Figure 1: Levelised cost ranges for various technologies 19

TABLES

Table 1: Sectors and Regions in AE-GEM 7

Table 2: Key macroeconomic assumptions, Reference case, 2007- 2020 9

Table 3: Australian electricity generation assumptions – reference case, 2007 and 2020 (%) 10

Table 4: Electricity generation shares by State and Territory, Reference case, 2010 and 2020 (%) 11

Table 5: Macroeconomic effects for Australia at 2020, relative to reference case 12

Table 6: Effects on electricity generation by State at 2020, relative to reference case 14

Table 7: Australian electricity fuel mix in 2020 16

Table 8: Technical assumptions 17

Table 9: Projected levels of electricity generation by technology type, 2020 17

Table 10: Estimated development requirements to meet combined policy target (20% renewables) 17

Table 11: Comparison of macroeconomic effects under alternative policies, at 2020, differences from reference case 21

EXECUTIVE SUMMARY

This paper seeks to examine the costs associated with the proposal by the federal Labor Party to adopt a renewable energy target of 20 per cent of electricity generation from renewable sources by 2020.

It is assumed in this analysis that an Australian domestic emissions trading scheme (ETS) will be put in place by 2010, and that the renewable energy target would be imposed in conjunction with the ETS.

Analysis shows that the combination of an ETS with a 20 per cent renewable energy regulation is significantly **less** efficient than an unadulterated ETS in achieving a given level of emissions abatement.

To reach an emissions abatement target of 67 Mt CO_2e in 2020, the modelling shows that the combined ETS + 20 per cent renewable energy target policy:

- costs Australia $1.8 billion more in 2020 than a pure ETS policy in terms of economic welfare (GNP) losses;
- costs Australia $1.5 billion more in 2020 than the ETS in output (GDP) losses;
- results in the loss of an additional 3,600 full time equivalent jobs (FTE) in 2020;
- causes substantial switching away from gas fired generation compared with an ETS in the order of 12,620GWh per year by 2020;
- results in electricity prices rising at least 6 per cent more than would be the case under an ETS alone - the price of electricity rises 24 per cent under the combined policy approach, and by 18 per cent under an ETS that delivers equivalent emissions abatement.

A mandated renewable energy target is less efficient at achieving a given environmental outcome because it forces higher cost renewable energy into the electricity generation mix at the expense of exploiting lower cost emissions abatement opportunities elsewhere in the economy. Contrary to the popularly held belief that such mandated targets generate jobs, the overall effect on the economy is the generation of less jobs than otherwise would have occurred and a loss of output in the economy as a whole compared to the outcome with a well designed emissions trading scheme.

1. INTRODUCTION

1.1. CONTEXT

The Labor Party recently announced that if it wins government at the upcoming election, it will set a 20 per cent Renewable Energy Target to be reached by 2020. In doing so, Labor believes this would bring Australia in line with most developed nations including Europe, China and several American states.

To achieve the target of at least 20 per cent of Australia's electricity supply generated from renewable sources by 2020, Federal Labor would increase the current Mandatory Renewable Energy Target (MRET) from 30,000 to 45,000 gigawatt hours (GWh) per year by 2010.

Beyond this date, the target would be to increase the total number of gigawatt hours of renewable energy produced in Australia each year to 60,000 gigawatt hours by 2020. Labor has stated that their 20 per cent renewables target is the equivalent of powering Australia's 7.5 million homes for a year and that this would reduce cumulative emissions between 2010 and 2030 by 342 million tonnes.

The policy announcement has been rationalised as a major step in tackling climate change, by significantly expanding the use of non carbon energy. The extension of the MRET scheme implies that these targets include hydro power in the base but given the limited prospects for new large scale hydro projects in Australia, the implication is that by far the largest share of new renewables must come from wind, solar, biomass and/or geothermal energy sources.

1.2. SCOPE OF THE STUDY

APPEA commissioned CRA International to undertake a quantitative assessment of the costs imposed on the Australian economy of a 20 per cent renewable energy target by 2020. In particular, the costs of combining this policy with an Australian domestic ETS is to be examined for the likely impacts on GDP, employment and electricity prices together with an assessment of the likely impacts of the target on gas penetration in the electricity market.

In addition to the quantitative assessment, CRA is to outline the likely impacts of such a target on the electricity sector in terms of the mix of generating technologies that might be used to meet the target, issues around location and number of plants needed to meet the target and reliability of the grid, including requirements for back-up supply.

2. ANALYTICAL FRAMEWORK

The modelling undertaken for this project was outsourced to Access Economics. The modelling simulations were performed using Access Economics' general equilibrium model AE-GEM. General equilibrium models such as AE-GEM are a widely accepted tool for determining the direct and indirect impacts of policy changes or strategic developments.

2.1. AE-GEM DESCRIPTION

The AE-GEM 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. A brief technical description of the model is provided in Appendix A.

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 each others goods and services; and
- indirect linkages through mechanisms such as the collective competition for available resources, such as labour, that operates in an economy-wide or global context.

AE-GEM captures the all important flow-on effects of different scenarios, particularly as they relate to demand for key commodities. This includes positive flow-on effects created by the additional investment and construction activity, as well as any offsetting impacts through 'crowding out' effects arising from increased competition for resources.

The base data of AE-GEM is derived from the Global Trade Analysis Project (GTAP). GTAP produces a global database for general equilibrium modelling used by over 700 researchers worldwide. AE-GEM is based on Version 6.0 of the GTAP database. This version has a 2001 base year with 87 countries and 57 industry sectors. Since not all regions and sectors are relevant to this exercise, the database has been aggregated to the 38 sectors shown in Table 1. The Australian economy is split into each state and territory (with the ACT included in New South Wales).

AE-GEM is a recursive dynamic model that solves year-on-year over a specified timeframe. The model is then used to project the relationship between variables under different scenarios over a predefined period. A typical scenario is comprised of a reference case projection which forms the basis of the analysis. Set against this reference case is the policy scenario under consideration. The impacts of the policy change (the achievement of the strategic targets) are measured by differences between the reference case and policy scenarios at given points in time.

Table 1: Sectors and Regions in AE-GEM

Number	Sectors	Number	Regions
1	Crops	1	New South Wales
2	Livestock	2	Victoria
3	Other agriculture	3	Queensland
4	Forestry	4	South Australia
5	Brown coal	5	Western Australia
6	Coal mining	6	Tasmania
7	Coking coal	7	Northern Territory
8	Crude oil	8	China
9	Condensate	9	Japan
10	Natural gas	10	South Korea
11	LNG	11	India
12	Bauxite mining	12	North America
13	Other minerals mining	13	Europe
14	Processed food	14	Rest of World
15	Wood products		
16	Petroleum and coal products		
17	Chemicals, rubber and plastics		
18	Non metallic minerals		
19	Iron and steel		
20	Alumina refining		
21	Aluminium manufacture		
22	Other non ferrous metals		
23	Pulp and paper processing		
24	Motor vehicle parts		
25	Other manufacturing		
26	Water		
27	Electricity generation		
28	Electricity distribution		
29	Gas distribution		
30	Construction		
31	Trade		
32	Air transport		
33	Water transport		
34	Land transport		
35	Communications services		
36	Business services		
37	Government services		
38	Other services		

Source: Access Economics AE-GEM

Notes: a) Electricity is generated using coal, gas, oil-fired, nuclear, hydropower and other renewables.

An important feature of the simulation exercise is the specification of the economic environment in which the strategic developments are assumed to take place. In the simulations it is assumed that over the long term, real wages adjust so that the natural rate of unemployment for any economy observed in the base case is maintained. In the short term, employment can vary due to either demand or supply side conditions. For example, the supply of labour can increase in the short term in response to increases in real wages. In addition, the government tax rate is exogenous and the public sector borrowing requirement can vary.

2.2. FEATURES SPECIFIC FOR CLIMATE CHANGE ANALYSIS

AE-GEM has been developed principally for analysing greenhouse 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.

The model has been developed to allow for energy substitution possibilities in response to the pricing of carbon. Critically, the production structure for electricity generation is based on a 'technology bundle' approach developed by ABARE (1996), although modified in AE-GEM. For the electricity sector, the model accounts for 6 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. However, each technology in the bundle uses inputs in fixed proportions to output. Trade in electricity generation between States in the National Electricity Market is also allowed.

2.3. REFERENCE CASE SCENARIO

The reference case is comprised of a set of input assumptions including but not limited to assumptions about economic growth; population and employment growth; and electricity generation fuel mix. From this set of key input assumptions, the model generates a wide range of results from which a subset are relevant for this analysis.

A reference case is necessary in a CGE modelling framework because it is used as the base against which all changes under the new policy settings are quantified and assessed. The reference case scenario for this study runs over the period 2001 to 2020.

2.3.1. Macroeconomic assumptions

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

Table 2: Key macroeconomic assumptions, Reference case, 2007- 2020

Region	Regional output (GSP/GDP)	Population	Employment
	Average annual growth (%)	Average annual growth (%)	Average annual growth (%)
New South Wales	2.7	0.9	0.7
Victoria	3.0	1.1	0.7
Queensland	3.5	2.0	1.6
South Australia	2.1	0.5	-0.2
Western Australia	3.2	1.6	1.3
Tasmania	1.8	0.5	0.3
Northern Territory	3.2	1.5	1.7
Australia	3.0	1.2	1.0

Source: Access Economics forecasts

2.3.2. Electricity generation

ABARE (Cuevas-Cubria and Riwoe, 2006) projects that by 2014-15 under reference case settings, 17.8 per cent of Australia's total electricity generation will be natural gas fired. By 2019-20, this figure will increase to around 19 per cent of total electricity generation. In making this forecast it is assumed that:

- growth in Australian gas fired generation is expected to be particularly strong in the mid term reflecting investment in peak capacity and initiatives such as the Queensland 13 per cent gas policy;

- electricity generation from gas will increase more than 50 per cent in Queensland over the period to 2010-11;

- gas fired generation will account for more than 50 per cent of new generation capacity in NSW in the medium term to 2010-11;

- 76 per cent of Western Australia's projected generation expansion over the period to 2029-30 will be gas fired;

- natural gas use in generation in Tasmania will increase by 75 per cent to 2029-30; and

- almost all growth in generation capacity in the Northern Territory over the period to 2029-30 will be gas fired.

The forecasts demonstrate a gradual displacement of coal fired electricity with gas and other renewables over the projection horizon. Table 3 and Table 4 present the projected reference case generation fuel mix to 2020 for Australia and disaggregated by State and Territory, respectively. The growth in other renewable energy sources is assumed to occur mainly as a consequence of government initiatives such as the mandatory renewable energy target (MRET). The category 'other renewables' consists of a bundle of renewable energy technologies, excluding hydro power and including such options as wind, solar, geothermal and biofuels.

Table 3: Australian electricity generation assumptions – reference case, 2007 and 2020 (%)

(Share of electricity generated by technology, selected years)

Generation technology	2007	2020
	%	%
Brown Coal	20	19
Thermal coal	54	53
Oil fired	1	1
Natural gas	17	19
Nuclear	0	0
Hydropower	6	5
Other renewable	2	3

Source: AE-GEM, ESAA

Table 4: Electricity generation shares by State and Territory, Reference case, 2010 and 2020 (%)

	2010	2020
	%	%
New South Wales		
Brown Coal	0	0
Thermal coal	88	88
Oil fired	0	0
Natural gas	4	5
Hydropower	6	5
Other renewable	2	2
Victoria		
Brown Coal	90	87
Thermal coal	0	0
Oil fired	1	1
Natural gas	5	8
Hydropower	1	1
Other renewable	2	3
Queensland		
Brown Coal	0	0
Thermal coal	85	82
Oil fired	1	1
Natural gas	11	14
Hydropower	1	1
Other renewable	2	3
South Australia		
Brown Coal	0	0
Thermal coal	28	27
Oil fired	1	1
Natural gas	57	57
Hydropower	0	0
Other renewable	14	15
Western Australia		
Brown Coal	0	0
Thermal coal	34	31
Oil fired	2	1
Natural gas	61	65
Hydropower	1	1
Other renewable	3	3
Tasmania		
Brown Coal	0	0
Thermal coal	4	4
Oil fired	0	0
Natural gas	6	7
Hydropower	84	83
Other renewable	6	7
Northern Territory		
Brown Coal	0	0
Thermal coal	0	0
Oil fired	23	19
Natural gas	77	81
Hydropower	0	0

3. RENEWABLE ENERGY TARGET

3.1. SCENARIOS

Aside from the reference case scenario, two separate scenarios were modelled for this analysis:

- Combined policy scenario: an Australian domestic emissions trading scheme covering the electricity generation, transport and fugitive emissions, commencing in 2010 with a carbon price of A$10/t$CO_2$e and rising at a rate of 7 per cent a year over the modelled time horizon to 2020, in combination with a regulated 20 per cent target for renewable energy technology contributions to total electricity generation by 2020; and

- ETS scenario: an Australian domestic emissions trading scheme aimed at achieving the same emissions abatement achieved under scenario 1.

3.2. RESULTS

3.2.1. Macroeconomic effects

The key macroeconomic results for Australia at 2020 are presented in Table 5. Results are measured as percentage deviations from the reference case under each scenario modelled.

Macroeconomic effects are greater under the combined ETS plus renewables target scenario than under the pure ETS scenario. It is more efficient and less economically damaging to employ a pure ETS policy strategy to achieve a given level of emissions abatement than it is to adopt a combined policy approach. In relation to every major macroeconomic indicator, the Australian economy is better off if the abatement task is achieved via an ETS policy rather than via a policy approach that combines an ETS with regulation (see Table 5). This is discussed further in section 3.3.

Table 5: Macroeconomic effects for Australia at 2020, relative to reference case

Scenario	*ETS + 20% renewable*	*ETS equivalent abatement*
	% change relative to reference case	***% change relative to reference case***
GDP	***-1.27***	***-1.17***
Real consumption	***-1.22***	***-1.15***
Real investment	***-3.45***	***-3.49***
Imports	***-2.63***	***-2.53***
Exports	***-1.02***	***-0.73***
Employment	***-0.65***	***-0.62***
Real wages	***-1.80***	***-1.82***

Source: AE-GEM

3.2.2. Electricity generation

The effects of the different policy scenarios on electricity generation are outlined in Table 6 for Australia and for each State and Territory.

Clearly, generation falls relative to the reference case whenever abatement is sought. Under the combined scenario (ETS + 20 per cent renewables), generation declines around 6.2 per cent or 25,000GWh relative to the 2020 generation level under the reference case. Under the pure ETS, electricity generation declines around 5.7 per cent.

The overall effect on electricity generation is less under an ETS than it is under an ETS combined with a mandated renewables target because the abatement task is spread more evenly across the economy under an ETS. With a mandated renewables target the electricity sector takes on a disproportionate abatement burden (given the marginal cost of abatement in the sector compared with marginal costs elsewhere in the economy) for a given abatement task.

Victoria suffers the largest reduction in electricity output under the ETS scenario, reflecting its heavy reliance on brown coal fired electricity generation. Under an ETS, the price on carbon raises the relative price of brown coal generation faster than the less carbon intensive black coal and hence brown coal is removed preferentially from the mix.

Interestingly, Victoria has a higher generation level under the combined policy scenario than under the ETS policy scenario. The reason for this again lies in the fact that Victoria's generation is heavily weighted toward brown coal. Since brown coal is lower on the generation cost curve than black coal in the absence of carbon pricing it therefore suffers proportionately less under a regulatory scenario than under a carbon tax. This is explained in more detail in the electricity fuel mix section below.

All other States experience lower electricity generation under the combined policy scenario than under the ETS scenario, reflecting the additional costs imposed by the renewables regulation on the electricity sector. Under a pure ETS approach, the burden of achieving the fixed abatement target is spread across the entire economy, including transport. This allows a wider range of sources with low marginal abatement costs to provide abatement, and hence the higher marginal cost abatement sources in electricity are not burdened with the task.

South Australia is significantly worse off under the combined policy than under the ETS which reflects the impact on gas fired generation. Under the ETS scenario, gas generation receives a boost compared to the reference case owing to its relative lower carbon intensity vis-a-vis coal. However, when renewable energy technologies are mandated, this occurs in part at the expense of gas fired generation, which is partly forced out of the mix.

Table 6: Effects on electricity generation by State at 2020, relative to reference case

Scenario	*Reference case*	*ETS + 20 per cent renewable*		*ETS equivalent abatement*	
Region	*GWh*	*% change*	*GWh*	*% change*	*GWh*
NSW	***111,129***	***-3.1***	***107,738***	***-2.3***	***108,574***
Victoria	***86,505***	***-6.4***	***80,976***	***-12.7***	***75,533***
Queensland	***115,299***	***-10.7***	***102,969***	***-6.0***	***108,332***
South Australia	***18,248***	***-1.2***	***18,020***	***4.1***	***19,001***
Western Australia	***50,431***	***-8.8***	***45,974***	***-6.1***	***47,357***
Tasmania	***14,423***	***10.3***	***15,914***	***0.6***	***14,508***
Northern Territory	***4,276***	***-7.2***	***3,969***	***-3.9***	***4,110***
Australia	***400,310***	***-6.2***	***375,561***	***-5.7***	***377,415***

Source: AE-GEM

Electricity fuel mix

The implications of the alternative policies on Australia's electricity fuel mix in 2020 are presented in Table 7. Under the combined renewable energy target + ETS scenario, the outcome for gas fired generation is negative relative to the reference case. The result is that the share of gas fired generation in Australia falls by around 3 per cent relative to the reference case - equivalent to roughly 6,430GWh of generation.

Far more favourable for gas is the outcome in scenario 2, which assumes a pure ETS policy is utilised to achieve the equivalent level of abatement as that achieved under the combined policy approach. Under the ETS scenario, gas fired generation in Australia increases by 4 per cent relative to the reference case at 2020; the equivalent of an additional 2,665GWh of generation. Relative to the combined renewable energy target + ETS scenario, gas fired generation is about 12,620GWh higher under a policy scenario that utilises an ETS alone to achieve the specified abatement target.

As would be expected, the scenarios have significantly different implications for generation from renewable energy sources.

When renewable energy is mandated under the combined policy scenario, this brings online an additional 42,175 GWh from renewable energy sources (excluding hydro). Relative to the 2020 reference case level of generation from renewable energy, this represents more than a four-fold increase.

The results for brown and black coal are also of interest. Under both scenarios, brown coal generation declines substantially relative to the reference case at 2020. Black coal fired generation also declines under the ETS scenario. However, under the combined policy scenario, black coal fired generation suffers disproportionately more relative to the effect on brown coal between the two scenarios.

The reason for this result is that brown coal is lower on the generation cost curve than black coal, so a regulation that displaces coal will remove black coal technology from the system faster than it will remove brown coal technology, in the absence of a high price on carbon. Since the renewable energy target is a regulation that favours renewable energies but does not affect the relative prices of brown versus black coal generation (over and above that already resulting from the underlying ETS), the renewables regulation displaces black coal at a faster rate than brown coal.

This effect differs significantly from that which occurs under an ETS, because an ETS generates abatement from the sources with the lowest marginal costs of abatement first. Since brown coal is more emissions intensive than black coal, an ETS will always remove brown coal faster/earlier than black coal from the generation mix. The interesting outcome here is that the regulatory effect associated with the renewable energy target outweighs the pricing effect of the ETS with respect to its impact on black coal use in generation.

Table 7: Australian electricity fuel mix in 2020

% changes are expressed relative to reference case

Scenario	***Ref case***	***ETS + 20% renewable***		***ETS equivalent abatement***	
Generation technology	*GWh*	*% ch*	*GWh*	*% ch*	*GWh*
Brown coal	***75,649***	***-22%***	***58,821***	***-18%***	***61,736***
Black coal	***212,971***	***-19%***	***172,972***	***-7%***	***198,252***
Oil	***4,327***	***-3%***	***4,185***	***12%***	***4,825***
Gas	***75,529***	***-13%***	***65,576***	***4%***	***78,194***
Hydro	***19,043***	***0%***	***19,043***	***0%***	***19,043***
Other renewable	***12,791***	***330%***	***54,965***	***20%***	***15,365***
Total	***400,310***	***-6%***	***375,561***	***-6%***	***377,415***

Source: AE-GEM

Increased penetration of renewables into the grid will impose a number of technical challenges for electricity transmission and distribution infrastructure. Some renewable electricity generation (for example, wind power) is intermittent and less predictable than coal or gas fired power. It also typically has a lower capacity factor, which means that more infrastructure is required per GWh of generation produced. This additional infrastructure is of course associated with higher costs of production using these technologies in order for them to be reliable sources of power to the grid. These additional costs have not been estimated in this study.

Given the AE-GEM model does not disaggregate 'other renewables' into individual technologies, assumptions were adopted for this analysis regarding the growth rates of various renewable generation technologies (see Table 8). Notably, wave/tidal energy has been excluded from this analysis owing to its relative immaturity and significantly higher cost as an alternative renewable energy option.

Table 8: Technical assumptions

	% share of mix in 2020	capacity factor /efficiency	Energy yield
Wind	80	2.5 MW turbines at 20%	4.38GWh pa
Solar	15	300 W per module at 15% (5 cells per module)	0.394MWh/module
Geothermal	5	420 MW phase I Cooper Basin at 20%	735GWh
		1740 MW phase II by 2012	3050GWh

Sources: Schmid (2005), Blakers et al. (2006), CIE (2006).

It is assumed in Table 8 that the solar technology is based on Sliver Cells technology and that the geothermal technology utilised is hot dry rocks, consistent with Australia's natural resource base.

The assumptions about the renewable fuel mix presented in Table 8 were used to determine the levels in GWh of electricity generated by each type of renewable electricity generation technology in Table 9. Technical assumptions about each technology type (Table 8) were then used to estimate the development or number of devices required to generate that amount of electricity in 2020 to meet the mandated target (Table 10).

Table 9: Projected levels of electricity generation by technology type, 2020

GWh	Reference case	Combined policy	Difference
Hydro	19,043	19,043	0
Wind	10,233	43,972	33,739
Solar	1,919	8,245	6,325
Geothermal	640	2,748	2,108
Total other renew	**12,791**	**54,965**	**42,174**
Total Renewables	31,834	74,008	42,174

Source: CRAI calculations

Table 10: Estimated development requirements to meet combined policy target (20% renewables)

2020	Total	Additional
Wind	10,040 turbines	7703 turbines
Solar	20.9 million modules	16.1 million modules
Geothermal	large scale Cooper Basin development phase II	large scale Cooper Basin development phase II

Source: CRAI calculations

As can be seen in Table 10, the developments required to meet the renewable energy target are substantial. Over and above the reference case addition by 2020 of 4.8 million solar panel modules, the 20 per cent renewable energy target in combination with the domestic ETS requires a further 16.1 million solar panel modules to be installed. This equates to an additional 80.5 million solar cells (16.1x5). The policy also mandates the addition of a further 7700 wind turbines over and above the reference case addition of 2,340 turbines by 2020. To achieve 5 per cent of the target from geothermal energy sources would require the successful implementation of the Cooper Basin geothermal resource to at least Phase II of the project.

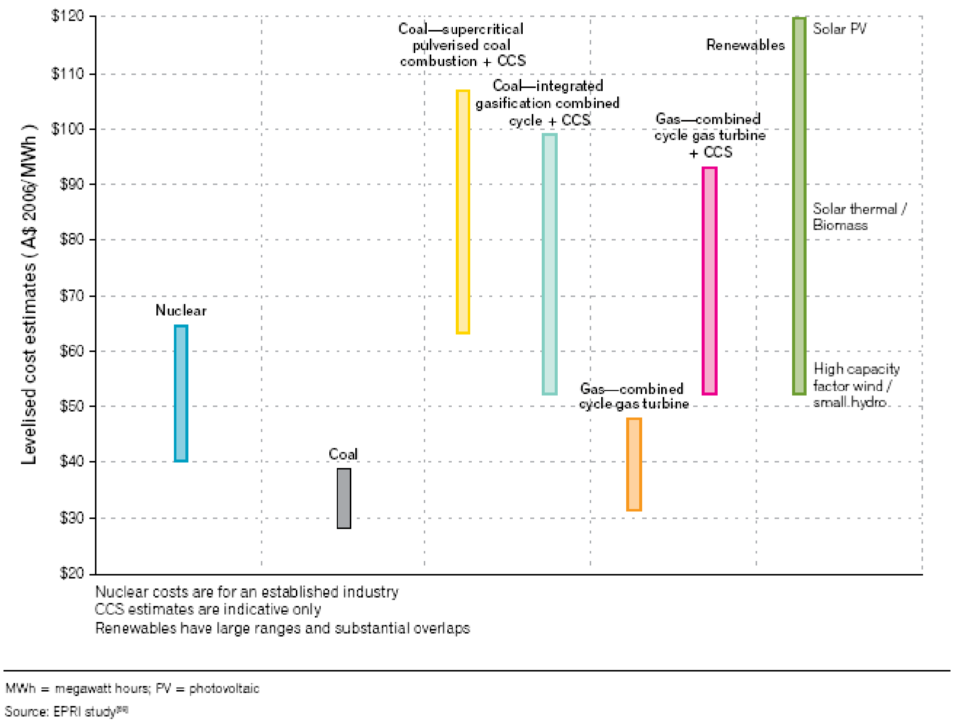
Electricity prices

The price of wholesale electricity is estimated to rise 18 per cent under the domestic ETS scenario modelled here compared with what it otherwise would have been. By contrast, electricity prices would rise around 24 per cent under the combined ETS plus 20% renewable energy target. This again reflects the additional costs associated with imposing a renewable energy regulation on top of the pricing signal generated by the ETS.

As can be seen from Figure 1, the average cost of renewable generation technologies is roughly twice that of coal or gas fired generation. Given that the 20 per cent renewable energy target would increase the contribution of renewable power by around 10 per cent relative to what otherwise would have occurred (ie from 10 per cent of the generation mix in the reference case to 20 per cent in the policy scenario), this electricity price increase is in line with *a priori* expectations.

However, the modelled price increase for electricity generation should be considered a lower bound estimate. This is because it reflects only generation costs and omits any additional costs of integrating larger amounts of intermittent renewable electricity into the grid. These additional costs will be associated with expenses such as back-up gas plant, or the need for more installed capacity to account for the much lower capacity factors of wind and solar technologies compared with gas or coal fired generation.

Figure 1: Levelised cost ranges for various technologies



Source: DPMC (2006)

3.2.3. Greenhouse gas emissions

Both scenarios generate the same emissions abatement for Australia, achieving a 67Mt reduction relative to the reference case at 2020. These emissions reductions will take place relative to a reference case emissions level of about 610Mt (excluding land use change and forestry) thus representing an 11 per cent reduction relative to the reference case at 2020.

Under the ETS scenario, abatement is obtained at least cost as a result of the inclusion of a broad range of sectors across the economy and an efficient price signal that allows reductions to be made wherever it is cheapest to do so. The renewables regulation policy on the other hand imposes a renewable energy target for the electricity sector on top of the existing economy wide carbon price, thereby distorting that price signal. The requirement for a certain proportion of electricity to be generated from renewable sources distorts resource allocation by requiring a disproportionate amount of abatement to be obtained from the electricity generation sector and moreover, from more expensive sources.

3.3. EFFICIENT POLICY

Given that the environmental outcome is identical under both policy scenarios modelled here, the policies may be directly compared on the basis of the economic efficiency with which they achieve that outcome. The key macroeconomic effects of the two policies are shown in Table 11.

We find that the combination of an ETS + 20% renewable energy regulation policy is significantly **less** efficient than a pure ETS policy approach in achieving the specified level of abatement.

At 2020, for the same level of abatement, the combined ETS + 20% renewable energy target policy costs Australians:

- $1.8 billion more than a pure ETS policy in terms of economic welfare (GNP) losses;
- $1.5 billion more than the ETS in output (GDP) losses; and
- The loss of an additional 3,600 full time equivalent jobs (FTE).

In addition, the price of electricity rises 24 per cent under the combined policy approach compared with an 18 per cent increase under the ETS policy that delivers equivalent emissions abatement relative to what it otherwise would have been.

Moreover, the combined policy approach, which mandates that 20 per cent of electricity generation must come from renewable energy sources, pushes natural gas from the generation mix. This is a highly inefficient way of reducing emissions from the Australian economy.

Table 11: Comparison of macroeconomic effects under alternative policies, at 2020, differences from reference case

	Units	*ETS + 20% renewable*	*ETS equivalent abatement*	*Difference*
Real GNP	***$m***	***-16,239***	***-14,436***	***-1,803***
Real GDP	***$m***	***-19,332***	***-17,827***	***-1,505***
Employment	***000 FTE***	***-67***	***-64***	***-3.56***
Real investment	***$m***	***-14,071***	***-14,237***	***166***
Export volumes	***$m***	***-2,091***	***-1,488***	***-603***
Import volumes	***$m***	***-6,729***	***-6,483***	***-246***
Emissions	***%***	***-11***	***-11***	***0***
Emissions	***Mt CO_2***	***-67***	***-67***	***0***
Carbon price	***A$ (real 2010)***	***20***	***25***	***-5***
Electricity prices	***(% difference from reference case)***	***23.5***	***18.2***	***5.3***

Source: AE-GEM

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APPENDIX A: A BRIEF DESCRIPTION OF AE-GEM

AE-GEM is a large scale, dynamic, multi-region, multi-commodity computable general equilibrium model of the world economy. The model solves for the equilibrium quantities of commodities and factors of production by equating their demand and supply as determined by the behaviour of the agents represented in the model. These agents optimise their behaviour in each region of the model.

AE-GEM is based on a substantial body of accepted microeconomic theory. The model projects changes in macroeconomic aggregates such as GDP, employment, export volumes, investment and private consumption. At the sectoral level, the model provides detailed results such as production, exports, imports and employment.

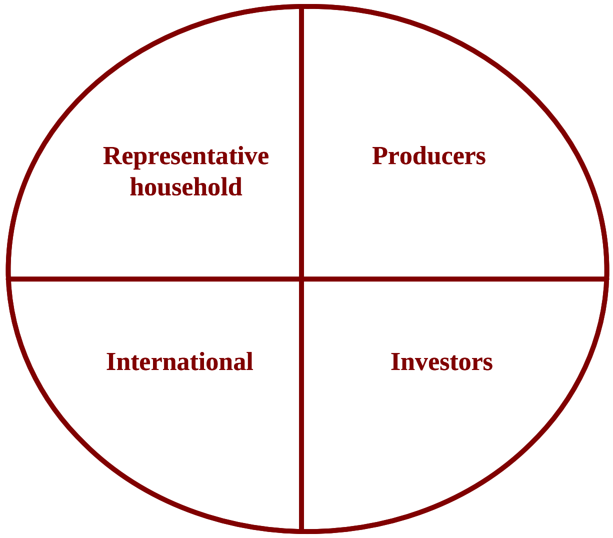
The model is based on set of key underlying relationships between the various *components* of the model. These relationships are solved simultaneously. Appendix Figure 1 shows the key components of the model for an individual country. The components include a representative household, producers, investors in the country of interest and international linkages with the other countries or regions. Below is a description of each component of the model and the key linkages between components. Some additional, somewhat technical, detail is also provided.

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 Appendix Figure 1, the representative household interacts with producers in two ways. First, in allocating expenditure across household and government consumption, demand for production is sustained. Second, the representative household owns and 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.

Appendix Figure 1: Key components of AE-GEM



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 is determined to maximise utility (through a Constant Difference in Elasticity (CDE) of substitution function) and minimise cost by substituting domestic and imported commodities (through a Constant Elasticity of Substitution (CES) aggregator).
- Government consumption is determined to maximise utility (through a Cobb-Douglas function) and minimise cost by substituting domestic and imported commodities (through a Constant Elasticity of Substitution (CES) aggregator).
- All savings generated in each region are 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 private households and government, producers sell products to each other (for intermediate usage) and to investors.

Intermediate usage is where one producer supplies inputs into another's production. For example, airlines supply transport services to many sectors in the economy.

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 private and government expenditure by 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 abroad 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.

To minimise costs, producers substitute between domestic and imported intermediate inputs 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 levels of employment and the wage rate. This is a typical labour market specification for a dynamic model such as AE-GEM. There are other labour market 'settings' that can be used. First, the labour market can 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 can take on short-run characteristics with fixed wages and flexible employment levels.

A.3 INVESTORS

Investment takes place in a global market where different regions are allowed to have different rates of return reflecting different risk profiles and severities of policy impediments to investment. The global investor ranks countries as desirable investment destinations 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, the investor is assumed to consume composite investment commodities in fixed proportions, and minimise costs by substituting domestic for imported commodities (CES).

A.4 International Linkages

Each of the components outlined above are operating, 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 producers, consumers and investors optimising their behaviour. Of course, this implies some global conditions must be met such as global exports and global imports being the same and global debt repayments equalling global debt receipts each year.

A.5 Dynamics

AE-GEM is a recursive dynamic model that solves year-on-year over a specified timeframe. The model is then used to project the relationship between variables under different scenarios, or states, over a predefined period. This is illustrated in Appendix Figure 2. This shows the BAU or reference case scenario that forms the basis of the analysis undertaken using AE-GEM. 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). In this case, the reference case in this example is a state of the world where only existing greenhouse policies and measures operate.

The 'Variable' represented in the figure could be one of the hundreds of thousands represented in the model ranging from macroeconomic indicators such as real GDP to sectoral variables such as the consumption of iron and steel in the construction sector. In the figure, the percentage changes in the variables have been converted to an index (= 1.0 in 2005) and is projected to increase by 2030.

Set against this reference case scenario is, in Appendix Figure 2 a 'Scenario projection'. This scenario represents the impacts of imposing a carbon price say on electricity. That results in a new projection of the path of the variable over the simulation time period. The impacts of the policy change are reflected in the differences in the variable at time T. It is important to note that the differences between the reference case and policy intervention scenario are tracked over the entire timeframe of the simulation.

Appendix Figure 2: Dynamic simulation using AE-GEM