STATIONARY-ENERGY SECTOR GREENHOUSE GAS EMISSIONS PROJECTIONS FOR AUSTRALIA

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Abstract

This paper contains updated projections for greenhouse gas emissions from stationary energy sources in Australia. The projections were generated using MMRF-Green, a bottom-up CGE model of the economies of Australia's six states and two territories. MMRF-Green models each region as an economy in its own right, with region-specific prices, region-specific consumers, region-specific industries, and so on. This theoretical structure is supported by a database containing explicit representations of intra-regional, inter-regional and international trade flows, and detailed information on greenhouse gas emissions by fuel, fuel-source, user and user-region.

The current MMRF-Green database recognises 52 commodities produced by 46 industries. Of the 52 commodities, 26 are related to energy and transport. There are four primary sources of energy and six refinery products. The refinery products are produced by a single industry. There are six electricity industries and nine transport sectors. For each transport mode, the provision of freight services is treated separately from the provision of passenger services.

Each solution of MMRF-Green produces pictures of Australia's regions at a high level of detail for a particular year. The model can also produce a sequence of annual solutions, linked together by ensuring, for example, that the quantities of opening capital stocks in any year equal the quantities of closing stocks in the previous year. This allows the model to make forecasts at a high level of detail over periods of policy relevance (say up to 10 years).

The forecasts of emissions reported in this paper have been made for the Australian Greenhouse Office (AGO), the sponsor of our work. The sponsored work involved the modelling of five scenarios. However, for the sake of brevity, in this paper we focus on just one – the "With measures" case. This scenario includes the impacts of federal and state government measures designed to reduce emissions over the medium term. These measures operate on the supply side (e.g., measures designed to improve the fuel efficiency of coal generation) and on the demand side (e.g., measures designed to improve the electricity efficiency of residential appliances). Careful modelling of these measures is the key to producing believable long-term forecasts for stationary-energy emissions.

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1. Introduction

The Centre of Policy Studies (CoPS) was commissioned by the Australian Greenhouse Office (AGO) in 2004 to conduct and report on projections of greenhouse gas emissions for the stationary energy sector to 2020. The analysis was undertaken using MMRF-Green, a multi-sector dynamic model of Australia's six states and two territories.

The sponsored work involved the modelling of five scenarios. However, for the sake of brevity, in this paper we focus on just one – the "With Measures" case. This scenario includes the impacts of federal and state government measures designed to reduce emissions over the medium term. These measures operate on the supply side (e.g., measures designed to improve the fuel efficiency of coal generation) and on the demand side (e.g., measures designed to improve the electricity efficiency of residential appliances.

Underlying assumptions for the With Measures scenario are given in Section 2, before a discussion of the results in Section 3. Section 4 contains concluding remarks. MMRF-Green is described in Appendix A.

2. With Measures Scenario: Underlying Assumptions

2.1. Preamble

In forecasting with MMRF-Green, we impose on the model a large amount of information from specialist external forecasting agencies. The model is then used to trace out the implications of the external forecasts at a level of industrial (Table A) and regional detail consistent with the requirements of the user.

In generating the With-measures forecasts, we use:

- State/territory macroeconomic forecasts from Access Economics to 2010 (see Access, 2003);
- National-level assumptions for changes in industry production technologies and in household preferences from the Centre of Policy Studies (CoPS);
- Estimates of the net impacts of energy-related measures from CoPS (see Appendix B); and
- Forecasts through to 2008 for the quantities of agricultural and mineral exports from the Australian Bureau of Agricultural and Resource Economics (ABARE) (see ABARE, 2003a), and estimates of capital expenditure on major minerals and energy projects from various sources, such as state government agencies, ABARE (see ABARE, 2003b) and the National Electricity Market Management Company (NEMCO).

2.2 Inputs

2.2.1 Macroeconomic variables (Table B)

The first panel of numbers in Table B shows our assumptions for selected macroeconomic variables in the With Measures scenario between 2002 and 2020.[1] Forecasts from Access Economics underlie the assumptions for the first half of the projection period. For the second

[1] *MMRF-Green* is an annual model which uses year-to-year inputs to produce year-to-year forecasts. In this report we generally report the inputs and outputs (i.e., projections) in terms of average annual changes between 2002 and 2010, between 2010 and 2020, and between 2002 and 2020.

half we incorporate ideas from the federal government's *Intergenerational Report* (IGR)[2], supplemented by extrapolations of first-half trends.

The following are some features of our macroeconomic assumptions.

- Growth in real national GDP at an average annual rate of 3.0 per cent in the first half of the projection period, falling to an average annual rate of 2.6 per cent in the second half of the period. Average annual growth over the full projection period is 2.8 per cent, somewhat slower than the average rate of growth over the past ten years. The slowdown is in line with projections from the IGR, which are based on a marked slowing in the rate of growth of the working-age population and hence of employment and real GDP.
- The fastest growing states in terms of real GSP through the projection period are Queensland and Western Australia, with both Territories expected to grow faster than the national average. The slowest growing states are Tasmania and South Australia. NSW and Victoria are in between. In line with national real GDP, growth in all regions slows in the second half of the projection period.
- The growth rates of employment and real private consumption across regions and across time follow the national pattern for real GDP. In other words, the fastest growth occurs in Queensland and Western Australia, the slowest growth in Tasmania and South Australia, and growth in all regions is slower in the second half of the projection period.

Note on Population

Perhaps a surprising omission from the list of macro variables in Table B is population. This suggests, correctly, that population is endogenously determined. We assume that over the projection period, state/territory unemployment rates converge to long-run values, with SA and TAS having slightly higher long-term rates than QLD and WA. These assumptions, along with the assumed rates of growth for employment, drive our projections for the labour force in each state. These in turn drive our population projections, with allowance for pro-cyclical movements in the participation rate (i.e., in the ratio of labour force to population). In general our forecasts for population in the With Measures scenario are in line with the central scenarios projected by the ABS.

2.2.2 Assumptions for Changes in Technology and Tastes (Tables C.1, C.2 and D)

Tables C.1 and C.2 show our assumptions for changes in the preferences of households (i.e., household tastes) and for changes in the production technologies of industries that are imposed in the With Measures projections. These are applied uniformly across regions. The numbers are based on:

- (for non-energy commodities and industries) extrapolated trends calculated from a MONASH simulation for the period 1986-87 to 1997-98 (see Dixon and Rimmer, 2002 Chapter 5); and
- (for energy commodities and industries) extrapolated MONASH trends supplemented by simulated changes in technologies and tastes necessary to incorporate the energy measures into our forecasts (see Appendix B).

Our assumptions for household tastes are summarised in the first panel of numbers in Table C.1. A positive (negative) number indicates that we are assuming the household usage of the relevant commodity will increase (decrease) relative to the movements that are implied in the forecasts by changes in household aggregate expenditure and by changes in relative prices.

[2] See http://www.budget.gov.au/2002-03/bp5/html/index.html

For example, we assume that consumption of Financial and business services will increase at a rate 1.4 per cent a year faster than can be explained on the basis of changes in prices and changes in the average budget of households.

The second panel of numbers in Table C.1 shows our initial assumptions for the average annual rates of change in the usage of commodities as intermediate inputs per unit of production in industries, and as inputs per unit of capital creation. Negative numbers indicate that technological change is commodity saving. Positive numbers indicate that it is commodity using. For example, we assume initially that in each year industries will increase their usage of Communication services by 3.6 per cent more than their outputs.

The exogenous shocks to produced-input technologies impose a cost/saving on the industries that use the inputs. For example, industries that utilise communication services will suffer a cost increase when forced to use 3.6 per cent more of those services per unit of output. To offset these cost effects, we make a simultaneous uniform adjustment to the technology coefficients applying to the entire user's inputs (produced and primary) so that there is no net effect on the user's costs.

Our initial assumptions for each industry concerning average annual changes in primary-factor usage per unit of output are shown in Table C.2. Primary-factor inputs in MMRF-Green comprise labour, capital and agricultural land. For example, our initial assumption for Electricity generation – black coal is that output will increase on average by 1.5 per cent a year relative to the industry's overall usage of primary factors.

The changes in household tastes indicated in Table C.1 hide, to some extent, many of the interesting more detailed trends in household tastes underlying our forecasts. For example, the strongest trend within the Textiles, clothing and footwear sector is against clothing, representing a shift towards less formal modes of dress. In Food, beverages and tobacco, there are strong trends against both tobacco and alcoholic beverages in favour of fruit and vegetable products. The shift towards communication services reflects the rapid adoption of new communication products. Our assumptions for energy products consumed by households other than for transport (i.e., for natural gas, electricity supply and other petroleum products) are strongly influenced by the shifts necessary to incorporate demand-side energy measures (e.g., MEPS) into our forecasts (see Appendix B). The end results are household taste changes against natural gas at an average rate of 0.8 per cent per annum over the full projection period, against the use of electricity at an average rate of 0.5 per cent per annum, and against liquid fuel (mainly for heating) at an average rate of 1.9 per cent per annum.

The shifts in industry technologies indicated in Table C.1 favour the use of high technology products as inputs to industries. These include inputs of Communication services and of electronic and other specialist equipment (part of the Other manufacturing sector). Also favoured strongly are inputs of Motor vehicles and parts and Finance and business services. The trend towards the latter reflects, in part, the increasing use of outside (rather than in-house) financial and business services. Shifts in industry technologies relating to energy products are, like the corresponding changes in household tastes, strongly influenced by the shifts necessary to incorporate energy measures into the scenario. These result in shifts against the use of black coal in all customer industries (end users and electricity generation) at an average annual rate of 0.5 per cent over the full projection period, against the use of brown coal (brown coal is only used by the Electricity- brown coal industry) at an average annual rate of less than 0.1 per cent, against natural gas at an average annual rate of 0.3 per cent, and against electricity in end use demand at an average annual rate of 0.7 per cent.

Our assumptions for all-factor-using technological change in Table C.2 point to large productivity gains in the communications and electricity sectors. This reflects the continued impact of reforms (including EMR) which started in the late 1980s. Substantial gains are also assumed for Agriculture, some parts of mining and transport services, and Communication services.

The numbers in Table D summarise our technical assumptions for the usage of fuels per unit of industrial output and for the usage of fuels per unit of electricity generation in terms of two commonly used measures of efficiency – energy technical efficiency and supply efficiency. These are weighted averages of numbers relating to fuels in Table C.1. We define energy technical efficiency as minus a weighted average of the use of primary and derived fuels per unit of output in all industries using those fuels other than the electricity generators. We define supply efficiency as minus a weighted average of the use of primary fuels per unit of electricity generation. As indicated in Table D, our detailed assumptions for industry technologies yield energy technical efficiency improvements at an average annual rate of 0.5 per cent over the full projection period and improvements in supply efficiency at an average annual rate of 0.4 per cent.

2.2.3 Assumptions for Exports (Table E),

The first panel of numbers in Table E shows our assumptions for the quantities of agricultural and mineral exports in the With Measures scenario. These reflect ABARE projections to 2008, and exogenously imposed long-term trends for the remaining years to 2020.

2.2.4 Natural Gas Supply and Large Resource and Electricity Projects

In the With-measures scenario we impose supply restrictions on the production of natural gas in each state, reflecting current estimates of reserves and “normal” rates of depletion. We assume that supply constraints begin to affect gas production from the Cooper/Eromanga Basin in SA/QLD by 2017, and gas production from the Gippsland/Bass Straight field in Victoria by 2019. Replacement gas is assumed to come from WA and PNG, with some allowance for production from coal methane fields in QLD. Throughout the projection period we assume that gas from the Otway basin in Victoria supplies all of the gas required in Tasmania and some of the gas required in SA.

MMRF-Green’s theory of investment relates year-to-year changes in capital expenditure to year-to-year changes in rates of return. The relationship is a smooth one, such that even the smallest changes in rate of return yield changes in investment and capital. For industries in the resource and electricity sectors, however, investment is seldom smooth. Accordingly, in forecasting we complement the standard MMRF-Green investment theory with extraneous information relating to incremental changes in investment in the resource and electricity industries. Currently, our primary source of information for planned projects in the resource sector is ABARE (2003b). Our primary source of information for future electricity investments is NEMCO, which provides data via personal communication.

Notable projects accommodated in our With-measures scenario are:

- the Victoria-Tasmania natural gas interconnection, which is assumed to start operation in 2004;
- the Victoria-Tasmania electricity connection (Basslink), which is assumed to begin in 2006;
- the PNG-QLD natural gas pipeline, which is assumed to begin shipment after 2012; and
- expansions of both aluminium smelting and alumina refining capacity in QLD, WA and the NT;

We model the opening up of Victoria-Tasmania gas and electricity connections by imposing exogenously increases in demand in Tasmania for Victorian electricity and gas in line with projections by McLennan, Magasanik and Associates (MMA). The projected rate of uptake of PNG gas in QLD is driven by growth in overall demand for gas in QLD, taking into account the assumed reductions in local gas production. The expansions in aluminium/alumina capacity are imposed in the model via exogenous shifts in the supply schedules of the relevant state industries. The shifts are calibrated using projections for production of aluminium/alumina by state supplied by ABARE.

Information on large projects covers the years through to about 2007. Thereafter, we assume that there will be no new inter-state/international connections for electricity and gas. For smelting/refining capacity and for electricity capacity we revert to the standard MMRF-Green treatment of investment, with investment and capital responding smoothly to changes in rates of return.

3. With Measures Scenario: Projections

We report four tables of detailed projections:

Table F: Australia wide industry output (percentage annual growth rates)

Table G: Emissions by major source category and state (levels and growth rates);

Table H: Emissions from stationary energy by fuel and state (levels and growth rates); and

Table I: Electricity generation by generator type and state (levels and growth rates).

3.1 National industry output (Table F)

Table F gives With-measures projections for the 49 industries distinguished in the model (see Appendix A). Here we concentrate on the numbers in the final column which show average annual growth rates between 2002 and 2020.

Electricity – wind (industry 29) is the fastest growing industry with a projected average annual growth rate of 16.8 per cent. Prospects for this industry are heavily influenced by the MRET scheme (see Appendix B). MRET, which is assumed to finish in 2010, also stimulates growth in other non-hydro sources of renewable generation: Electricity – biomass (industry 26), Electricity – biogas (27) and Electricity – solar (28). Other measures such as the QLD cleaner energy strategy and the NSW greenhouse benchmarks scheme account for the strong growth prospects of gas generation (industry 23).

Growth prospects for coal generation (industries 21 and 22) are restricted by relatively fast growth in other forms of generation and by relatively slow growth in end-use demand for electricity (industry 30). Slow growth in end-use demand reflects, in the main, the effectiveness of demand-side measures, especially MEPS. We assume that production of Electricity-oil prods (industry 24) does not change through the projection period[3], and that production of Electricity-hydro (industry 25) is severely constrained by environmental factors.

The fastest growing industry outside of the electricity sector is Communication services (industry 44). Rapid growth in communication services reflects our assumption that changes in technology through the projection period will favour intermediate usage of these services strongly (second panel of Table C.1) and that rapid productivity growth (Table C.1) will reduce their price relative to consumer prices in general. Similar factors explain the relatively strong growth forecast for Financial and business services (industry 45).

Other industries with relatively strong growth forecasts include:

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[3] Generation from oil products mainly occurs in rural areas which are generally outside the main city grids. Thus the model’s treatment of electricity, which’s allows for substitution between generation from different fuels within each state, does not readily apply – there is no substitute for oil-fired electricity in most rural areas. So we turn off the endogenous demand explanation for oil-fired electricity, preferring, instead, to assume that generation of this type is fixed.

- Food, beverages and tobacco (industry 9) and Chemical products (excluding petroleum) (12) which are favoured strongly by projected strong growth in exports, enabling them to grow strongly in the presence of increased import penetration in local markets;
- Iron and steel (industry 16), Other metal products (18), and Other manufacturing (20) which benefit from favourable technological trends (Table C.1) that increase the use of their product per unit of output of customer industries;
- Alumina and aluminium (industry 17) which benefits from a combination of favourable technological trends and strong export growth (see the first panel of Table E);
- Natural gas (industry 7) which is favoured by relatively strong growth in exports (first panel of Table E), even though growth in domestic final use is projected to be a little below that of real GDP;
- Road transport services – freight (industry 36) which is stimulated by rapid growth in its main customer industries; and
- Air transport services – passenger (industry 41) which benefits from the strong growth forecast for international tourism.

Forecasts for Agriculture (industry 1) and for the non-energy mining industries (industries 3 and 4) are, in the main, based on extrapolations of the current views of the ABARE (see first panel of Table E). The prospects of Black coal (industry 5) reflect the prospects for coal exports (Table E) combined with prospects for growth in domestic energy demand which is dominated by electricity generation. Production of oil (industry 6) is expected to decline slightly, reflecting the run down of Bass Straight reserves. The prospects for Brown coal (industry 8) are in line with growth in brown-coal electricity generation (industry 22) with an allowance for changes in efficiency of fuel use.

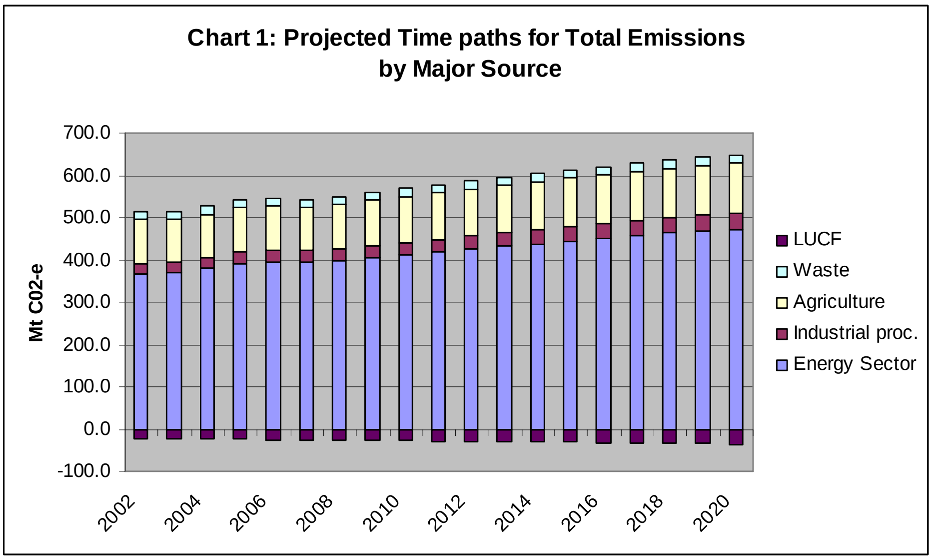
The manufacturing industries with the weakest growth prospects are Textiles, clothing and footwear (industry 10), Petroleum products (13), and Cement (15). Textiles, clothing and footwear production suffers from continued increases in import penetration, while the Petroleum industry is restricted by import competition, weak growth in exports and supply constraints affecting its primary source of supply. The prospects for cement manufacture are poor due to adverse shifts in technology in the construction sector (see the second panel of Table C.1).

Three other notable manufacturing industries have below-average growth prospects: Wood and paper products (industry 11), Building products (not cement and metal) (14) and Motor vehicles and parts (19). The growth prospects of industries 11 and 19 are affected by two offsetting forces - strong export growth and increasing import competition, while the prospects for industry 14 are hampered by adverse technological shifts in the construction industry.

Most of the remaining industries have close to average growth prospects. The prospects for Forestry (industry 2) are quite good, due to strong growth in exports which offset relatively weak growth in domestic demand from the wood and paper industry. The prospects for Construction services (33) reflect our macro assumptions for investment. The trade services industry (industry 34) sells widely throughout the economy. Its growth rate, though, is below that of real GDP because of adverse taste and technology shifts against its products (Table C.1). Dwelling ownership (46), Public services (47), Other services (48) and Private motor vehicle ownership (49) are very consumption oriented. Accordingly, their prospects are explained by appropriate weighted averages of the growth rates assumed for private and public consumption (Table B).

3.2 Projections for Total Emissions by Major Source Category (Table G)

Table G presents With-measures projections for total CO2-e emissions by state and major source category (excluding land clearing). The table includes the average annual growth rate of emissions from 2002 to 2020 and the levels of emissions (Mt) in 2002, 2010 and 2020. Chart 1 shows projections by major category through time.



The national total for all emissions (excluding land clearing) is projected to grow from 493.2 Mt CO2-e in 2002 to 542.4 Mt CO2-e in 2010 and to 613.7 Mt CO2-e in 2020. This implies an average annual growth rate of 1.2 per cent, 1.6 percentage points less than the average annual growth rate projected for real GDP. The main reasons why aggregate emissions are forecast to fall relative to GDP are:

- forecast growth rates for non-combustion emissions from agriculture and waste dumps which are well below the growth rates in economic output of agriculture and waste services reflecting extensive take up of abatement technologies; and
- relatively slow growth in energy-sector emissions.

Within the energy sector, emissions from fuel combustion are forecast to grow at an average annual rate of 1.4 per cent, while fugitive emissions are forecast to grow at an average annual rate of 1.3 per cent. Growth in fugitive emissions is well below growth in real GDP because of below-average growth in coal production (see Table F), which contributes around 85 per cent of total fugitive emissions.

Over 50 per cent of emissions from fuel combustion come from electricity generation, while the remainder is divided fairly equally between transport and non-generation stationary energy. Transport emissions are forecast to grow at an average annual rate of 1.8 per cent. This is somewhat faster than growth in emissions from the energy sector generally, reflecting, in part, the good growth prospects for transport industries, which offset to some extent the assumed rates of improvement in fuel efficiencies within the transport sector.[4]

At the state/territory level, we find that aggregate emissions are projected to grow fastest in the states/territories with the highest projected growth rates - NT, WA and QLD. Emissions in TAS are projected to fall. The reason is clear when we compare the level values of

[4] The rates of improvement in fuel efficiency in transport can be gauged by looking at the second panel of Table C.1 and the rows corresponding to the petroleum products: Petrol, Aviation gasoline, Aviation turbine fuel, Diesel, LPG and Other petroleum products.

emissions in 2002 and 2020. TAS has a large forest sector and uses hydroelectricity, which emits nothing. The bulk of TAS's emissions come from Agriculture. In 2002, the large forestry sink in TAS outweighed emissions from agriculture. Through the projection period, the increase in the forestry sink is larger than the increase in emissions from agriculture. This causes the fall in emissions in TAS.

3.3 Projections for Emissions from the Stationary Energy Sector (Table H)

Table H gives With-measures projections for emissions from the stationary energy sector. As in Table G, Table H includes average annual growth rates and levels in 2002, 2010 and 2020. Projections are provided by fuel and state.

In aggregate, emissions from stationary energy are projected to grow at an average annual rate of 1.3 per cent, 0.1 percentage points more than growth in total emissions (Table G), and 1.5 percentage points less than growth in real GDP (Table B). Emissions from black coal combustion are forecast to grow at an average annual rate of 0.8 per cent, while emissions from brown coal are forecast to grow by 1.2 per cent. Emissions from stationary-energy combustion of gas are projected to grow at an average annual rate of around 2.0 per cent, while those from liquid fuel are expected to grow by 1.9 per cent.[5]

Electricity generation contributes around 70 per cent of emissions from the stationary energy sector. Table G shows that emissions from electricity are forecast to increase at an average annual rate of 1.1 per cent, rising from 180.4 Mt CO2-e in 2002 to 192.7 Mt CO2-e in 2010 and to 218.4 Mt CO2-e in 2020. Total generation is forecast to increase over the forecast period at an average annual rate of 1.7 per cent (see Table I). The difference between this growth rate and the growth rate in emissions from generation (i.e., 1.7 – 1.1 = 0.6 percentage points) is due, in the main, to the operation of supply- and demand-side measures that encourage non-hydro renewable generation (see Table I and Section 3.4) and improved fuel efficiencies in fossil-fuel generation.

Outside of electricity generation, the main sources of stationary-energy emissions are industries producing metals (industries 16, 17 and 18) and chemicals (industries12 and 13). These industry-groups have generally very good prospects for growth in our forecasts (see Table F and Section 3.1). This is the main reason why stationary-energy emissions from "other" sources are forecast to increase at an average annual rate of 1.7 per cent (see Table G), somewhat faster than projected growth in emissions from electricity generation.

What explains the 1.5 percentage point gap between projected growth in real GDP and projected growth in stationary energy emissions? Part of the difference can be explained by the net impact of the energy-related measures included in the With-measures scenario. Appendix B Table 2 shows that the net impact of all measures (other than EMR) is -43.1 Mt CO2-e in 2020. This is 11.6 per cent of the projected level of total stationary energy emissions in 2020 excluding the impact of measures. An 11.6 per cent fall is equivalent to a lowering of the average annual growth rate for stationary energy emissions of around 0.7 percentage points between 2002 and 2020. Thus the measures (other than EMR) contribute about 0.7 percentage points to the overall projected gap of 1.5 percentage points between growth in real GDP and growth in stationary energy emissions. Another 0.3 of a percentage point comes from underlying basecase growth in energy efficiency in the stationary energy sector, leaving 0.4 percentage points to be explained.

We attribute the unexplained residual to stru*ctural effects* which operate when there are low-emitting sectors growing at a faster rate than high-emitting sectors. In our forecasts a large proportion of the *structural effect* is contributed by a small number of service industries:

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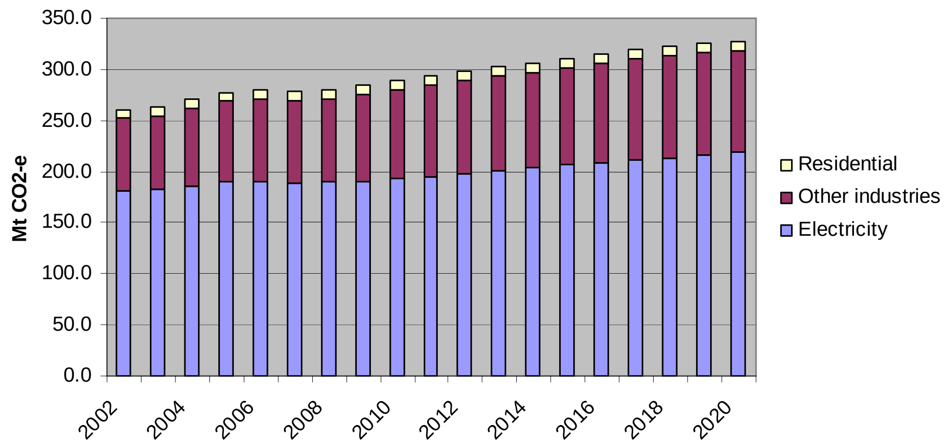
[5] All of the growth in stationary energy emissions from the combustion of liquid fuel occurs outside of electricity generation. Recall from our discussion of Table F that electricity generation from liquid fuel is held fixed through the projection period.

Communication services (industry 44), Financial and business services (45), Dwelling ownership (46) and Other Services (48). Though small in number these are very large industries in economic terms (together they contribute around 35 per cent of real GDP). They emit relatively little (directly and indirectly via their use of electricity) per unit of output, and they are projected to grow faster than real GDP. Metal producers (industries 16 to 18) make a negative contribution to the *structural effect*. These are high-emitting industries with above-average growth prospects (Table F). However, in terms of real GDP they are small compared to the group of fast-growing service industries. Thus their negative contribution to the *structural effect* is more than offset by the positive contribution made by the service sectors.

To complete this section we show in Chart 2 the projected time paths for stationary energy emissions between 2002 and 2020 by major user.

Chart 2: Projected Time Paths for Stationary Energy Emissions by Major User



The chart shows that in all years other than 2007 total emissions increase, rising from around 260 Mt CO2-e in 2002 to around 325 Mt CO2-e in 2020. The very small decline in 2007 reflects an assumed downturn in economic growth. As shown in Table H, the average annual growth rate for stationary energy emissions between 2002 and 2010 is 1.3 per cent, which is the same as the growth rate between 2010 and 2020.

The chart clearly shows the slow growth in emissions from electricity relative to growth in emissions from other industries. The growth rates of the components in each of the two periods, though, are quite different. Between 2002 and 2010, emissions from electricity generation rise at an average annual rate of 0.8 per cent, while between 2010 and 2020 the average annual growth rate is 1.3 per cent. For emissions from other industries, the pattern is reversed, with growth in the first period (2.3 per cent per annum) faster than growth in the second period (1.4 per cent). Electricity emissions grow at a slower rate initially, reflecting the impact of most energy-related measures which cease operation between 2010 and 2012. Emissions from other industries grow at a slower rate in the second period, reflecting the slow down in general economic growth during that period.

3.4 Projections for Electricity Generation (Table I)

Table I presents projections for electricity generation by fuel and state. As in Tables G and H, Table I includes average annual growth rates between 2002 and 2020 and levels (Pj) in 2002, 2010 and 2020.

The projected growth rates in generation shown in the first part of Table I correspond fairly closely to the projected growth rates in output of the electricity generation industries shown in Table F and discussed in Section 3.1. Any difference between national growth rates of generation and output is due to changes across states in the price of generation. The percentage change in national output (Table F) is a weighted average of percentage changes in state outputs, with weights based on the value of output in each state. The percentage change in generation (Table I) is a quantity (Pj)-weighted average of percentage changes in state output. If there are significant differences in growth rates of generation prices across states then the percentage change in the value-weighted national output measure may differ from the percentage change in the quantity-weighted measure. This is the case for black coal generation between 2002 and 2010. In this period national black-coal generation is projected to increase at an average annual rate of 0.6 per cent (Table I), while national output increases at an average annual rate of 1.0 per cent (Table F). In our projections the price of coal generation in QLD increases relative to the national average reflecting, in part, increases in the price of QLD coal due to buoyant overseas demand. The quantity of QLD generation also increases relative to the national average due to strong general growth in the QLD economy. These factors combined are enough to increase the value-weighted rate of growth in national output relative to the quantity-weighted rate of growth in national generation.

From the data in Table I we can deduce the time paths of generation shares at the national level. These are shown below for 2002, 2010 and 2020.

Shares in National Generation by Generator type

Generation type	2002 (%)	2010 (%)	2020 (%)
Black coal	56.4	50.9	49.8
Brown coal	23.6	22.0	21.3
Gas	10.4	16.0	19.2
Oil	0.5	0.4	0.3
Hydro	8.0	7.1	6.2
Biomass	0.8	2.1	1.8
Biogas	0.2	0.3	0.3
Solar	0.1	0.3	0.3
Wind	0.1	0.9	0.8
Total	100.0	100.0	100.0

As can be seen, the national share of gas generation is projected to increase from 10.4 per cent in 2002 to 16.0 per cent in 2010 and to 19.2 per cent in 2020, while the total renewable share increases from 9.1 per cent in 2002 to 10.7 per cent in 2010, before falling back to 9.4 per cent in 2020. Over the projection period the share of coal generation falls from 80 per cent in 2002 to 72.9 per cent in 2010 and to 71.1 per cent in 2020.

4. Concluding remarks

In this paper we have described a method for producing detailed forecasts of greenhouse gas emissions. The vehicle for the forecasting is the MMRF-Green dynamic CGE model. The forecasts include input from specialist macro forecasters and experts in commodity markets, as well as detailed scenarios on changes in technology and household tastes. The role of MMRF-Green is to translate all these inputs into forecasts for variables that are relevant to the sponsor of this work, the Australian Greenhouse Office.

In our central case – the With-measures scenario – we find that the national total for all emissions (excluding land clearing) will grow from 493.2 Mt CO2-e in 2002 to 542 Mt CO2-e in 2010 and to 613.7 Mt CO2-e in 2020. This implies an average annual growth rate of 1.2 per cent, 1.6 percentage points less than the average-annual growth rate projected for real

GDP. At the state/territory level, we find that aggregate emissions are projected to grow fastest in the states/territories with the highest projected economic growth rates - NT, WA and QLD. Emissions in TAS are projected to fall: TAS has a large and growing forest sector and uses hydroelectricity, which emits nothing.

What explains the 1.6 percentage point gap between projected growth in real GDP and projected growth in emissions? Most of the difference can be explained by the net impact of the energy-related measures included in the With-measures scenario (see Appendix B). These measures contribute about 0.7 percentage points to the overall projected gap of 1.6 percentage points. Another 0.3 percentage points comes from underlying basecase growth in energy efficiency in the stationary energy sector. The remaining 0.4 percentage points is explained by structural changes in the economy that favour low-emitting services industries.

The results cited behalf highlight that careful modelling of energy and greenhouse measures is the key to producing believable long-term forecasts for stationary-energy emissions. Incorporated into our With-measures projection are the net impacts of ten current energy-related measures. Our estimates of the net impact of each measure on the national level of stationary energy emissions in 2010 and 2020 are shown below.

Net Impacts of Measures (Mt CO2-e)

Measure	Net impact, 2010	Net impact, 2020
Supply side measures		
QLD cleaner energy strategy	-1.0	-0.8
Generator Efficiency Standards (GES), Greenhouse Challenge (GCP)-supply	-2.8	-3.7
Mandatory Renewable Energy Targets (MRET) and Green Power	-8.5	-9.1
Greenhouse Gas Abatement Program (GGAP)	-1.7	-2.8
NSW electricity retailer scheme	-4.3	-3.9
Demand side measures		
GCP-demand	-1.5	-1.6
Energy efficiency standards for residential and commercial buildings	-1.1	-2.2
Mandatory Energy Performance Standards (MEPS)	-6.1	-15.4
Energy efficiency best practice program	-0.2	-0.2
Reducing government energy use	-0.4	-0.5
Other state and territory action under the National Greenhouse Strategy	-1.6	-2.9
Total	-29.2	-43.1

The table shows that the combined impact of measures in the stationary energy sector is 29.2 Mt CO2-e in 2010 and 43.1 Mt CO2-e in 2020. Demand-side measures provide a net 10.6 Mt CO2-e of abatement in 2010 and a net 22.5 Mt CO2-e of abatement in 2020. Supply-side measures provide a net 18.7 Mt CO2-e of abatement in 2010 and a net 10.6 Mt CO2-e of abatement in 2020.

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Appendix A: The MMRF-Green forecasting model

MMRF-Green is a very detailed dynamic, multi-sectoral, multi-regional model of Australia. The current version of the model distinguishes 49 industries, 54 products, 8 states/territories and 56 sub-state regions. The industries are described in Table A.

MMRF-Green is founded on the Monash Multi-Regional (MMR) model.[6], and was built in four stages. In the first stage, MMR was transformed into a dynamic system through the inclusion of dynamic mechanisms. These were added as self-contained blocks, allowing MMRF-Green to include MMR as a special case. The second stage involved a range of developments designed to enhance the model's capacity for environmental analysis. In the third stage, a regional disaggregation facility was added, which allows state-level results to be disaggregated down to sub-state regions. The fourth stage focused on improvements to the model’s treatment of renewable electricity generation.

A1 Overview of MMR

MMR divides Australia into the six states and two territories. There are five types of agents in the model: industries, capital creators, households, governments, and foreigners. The number of industries is limited by computational constraints. For each industry in each region there is an associated capital creator. The sectors each produce a single commodity and the capital creators each produce units of capital that are specific to the associated sector. Each region in MMR has a single household and a regional government. There is also a federal government. Finally, there are foreigners, whose behaviour is summarised by export demand curves for the products of each region and by supply curves for international imports to each region.

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

The specifications of supply and demand behaviour coordinated through market clearing equations comprise the general equilibrium (GE) core of the model. There are two blocks of equations in addition to the core. They describe regional and federal government finances and regional labour markets.

A1.1 Data requirements for MMR

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

The Australian Bureau of Statistics (ABS) publishes suitable regional data for the government finance and labour market blocks. However, it does not compile multi-regional input-output (IO) tables. Disaggregating the national IO table used in the national GE model, MONASH, created IO data for the GE core. The regional disaggregation of the national IO table involved three steps: (i) splitting of columns using regional proportions of industry outputs and final demands; (ii) splitting of rows using inter-regional trade data available

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

from published sources (e.g., Quinlan, 1991); and (iii) application of mathematical re-balancing procedures to ensure equality in the multi-regional input-output table between the outputs and sales of regional sectors.

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

A1.2 Computing solutions for MMR

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

A2 From MMR to MMRF-Green: dynamics

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

A2.1 Physical capital accumulation

It is assumed that investment undertaken in year t becomes operational at the start of year t+1. Thus, given a starting point value for capital in t=0, and with a mechanism for explaining investment through time, the model can be used to trace out the time paths of industry capital stocks.

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

A2.2 Lagged adjustment processes

One lagged adjustment processes is included in MMRF-Green. This relates to the operation of the labour market in year-to-year policy simulations.

In comparative static analysis, one of the following two assumptions is made about the national real wage rate and national employment:

1. the national real wage rate adjusts so that any policy shock has no effect on aggregate employment; or

2. the national real wage rate is unaffected by the shock and employment adjusts.

MMRF-Green’s treatment of the labour market allows for a third, intermediate position, in which real wages can be sticky in the short run but flexible in the long-run and employment can be flexible in the short-run but sticky in the long-run. For year-to-year policy simulations, it is assumed that the deviation in the national real wage rate increases through time in proportion to the deviation in aggregate employment from its basecase-forecast level.

The coefficient of adjustment is chosen so that the employment effects of a shock are largely eliminated after about ten years. This is consistent with macroeconomic modelling in which the NAIRU is exogenous.

A3 MMRF-Green: Environmental enhancements

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

1. an energy and gas emission accounting module, which accounts explicitly for each of the 49 industries and eight regions recognised in the model;
2. equations that allow for inter-fuel substitution in electricity generation by region; and
3. mechanisms that allow for the endogenous take-up of abatement measures in response to greenhouse policy measures.

A3.1 Emissions accounting

MMRF-Green tracks emissions of greenhouse gases at a detailed level. It breaks down emissions according to:

- emitting agent (49 industries and residential);
- emitting state or territory (8); and
- emitting activity (5).

Most of the emitting activities are the burning of fuels (black coal, natural gas, brown coal or petroleum products[7]). A residual category, named Activity, covers emissions such as fugitives and agricultural emissions not arising from fuel burning.

The resulting 49 x 8 x 5 matrix of emissions is designed to include all emissions except those arising from land clearing. Emissions are measured in terms of carbon dioxide equivalents, $C0_2$-e. The main source of data for the matrix of emissions is the 1999 National Greenhouse Gas Inventory published by AGO.

A3.2 Inter-fuel substitution

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

For other energy-intensive commodities used in industry, MMRF-Green allows for substitution possibilities by including a weak form of input-substitution specification. If the price of say, Cement, rises by 10 per cent relative to other inputs to construction, the Construction industry will use 1 per cent less Cement and, to compensate, a little more of labour, capital and other materials. In most cases, as in the Cement example, we have imposed a substitution elasticity of 0.1. For important energy goods, Petroleum products,

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[7] Each of these fuels is identified as a separate commodity within the model.

Electricity supply, and Urban gas distribution, the substitution elasticity in industrial use is 0.25. This input substitution is driven by price changes, and so is especially important in emission-policy scenarios, which makes outputs of emitting industries more expensive.

A4 MMRF-Green: Disaggregation to sub-state regions

Few multi-regional models of the Australian economy have the level of sectoral detail supported by MMRF-Green. This detail is usually more than adequate for contributions to public discussions on the effects of changes in policies concerning taxes, trade and the environment. However, people wanting to use MMRF-Green in business and public sector planning are often frustrated by the lack of relevant regional detail. This applies especially to people interested in regional adjustment issues.

It is with these people in mind that we have incorporated into MMRF-Green a tops-down method that enables disaggregation of state-level results for output, employment and greenhouse-gas emissions down to projections for 56 sub-state regions (Figure A). The method is an adaptation of the regional disaggregation method first devised by Leontief *et al*. (1965).

These regions are based on the Statistical divisions defined in the Australian Standard Geographical Classification (ABS catalogue number 1216.0). Our division structure differs slightly from that of the ABS. We combine the ABS's Darwin and *Northern Territory - balance* divisions into one division, Northern Territory. Similarly, Canberra and *ACT - balance* are combined into one division, Australian Capital Territory. Note that both territories are distinguished as separate regions in MMRF-Green. Hence, the tops-down disaggregation facility provides no additional detail for them. We also adopt a slightly different regional classification for WA than that defined by the ABS. Our WA regions are based on the classification used by the WA department of Commerce. Finally, we identify the energy intensive La Trobe Valley in Victoria as a separate region (region 24), with 23 Gippsland defined to include all areas in the ABS statistical division *Gippsland* other than the La Trobe Valley.

A4.1 Methodology

The methodology for tops-down regional disaggregation involves firstly classifying each of MMRF-Green's industries (Table 1) into one of two categories: state and local. State industries produce commodities that are readily traded across sub-state regional boundaries. Examples are most agricultural and mining industries. The regional outputs of industries producing state commodities are assumed to move in line with the state-wide percentage rates of change calculated by MMRF-Green.

Local industries produce commodities for which demand within each sub-state region is satisfied mainly from production in that region. Examples include perishable items and services like wholesale and retail trade. The outputs in each region of industries producing local commodities are modelled as depending mainly on demand within the region. In calculating the local demand for the output of local industry j, MMRF-Green takes account of:

- intermediate and investment demands both by local industries and by state industries located in the sub-state region;
- the region's household demands, which are a function of population and employment changes and of the change in consumption at the state level;
- government demand; and
- (if industry j's output is a margin commodity like transport) the usage of industry j's product in facilitating the flow of local and state commodities within the sub-state region and international export flows out of the region.

This gives our regional calculations a multiplier property: the effect on a sub-state region's overall level of activity of a favourable mix of state industries is multiplied through induced effects on the output and employment of the region's local industries.

In the regional disaggregation we allow for the possibility of some demand for local commodities outside the region of their production, but not from outside the state in which the region is located. This is because our data imply that for almost all commodities there is at least some imbalance at the sub-state regional level between demand and supply.

A5 MMRF-Green: Enhanced treatment of renewables

Prior to this stage, MMRF-Green recognised just one renewable generating industry in each state. The cost structure of this generic industry was modelled on the cost structure of the average hydro plant. Sales of this industry were concentrated in the states in which hydro generation was present (TAS, VIC, NSW and to a small extent QLD).

Now we have incorporated a more detailed treatment of renewable technologies. Instead of one industry, we have created five separate industries each producing electricity from a specific renewable source. The five sources are hydro, biomass, biogas, solar (does not include solar hot water systems) and wind. In broad terms, the production technologies for biomass and biogas generation are more labour intensive than for solar and wind generation, and less intensive in the usage of machinery and equipment. The production technology for hydro generation is about halfway between each of these extremes.

Appendix A References

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Appendix B: Impacts of Energy-related Measures

B1 Introduction

In this appendix we report estimated impacts of the energy-related measures identified in the AGO's background paper, *Measures Summary for the 2004 Stationary Energy Sector Projections*, dated 16 February 2004. These estimates come from simulations of the MMRF-Green model and are used as input to the model based "with measures" projections detailed in the main body of this report.

We deal explicitly with all of the measures listed in the AGO paper, other than Energy Market Reform (EMR), the Renewable Energy Commercialisation Program and the Renewable Remote Power Generation Program (outside of MRET). The last two omitted-measures have not been modelled, while EMR is part of our Business-as-Usual basecase, against which the impacts of the other measures are assessed.

The measures described in the AGO document are listed in Section B2, along with explanations of how each were modelled.

B2 The measures

Supply-side

I. *Energy Market Reform*. Included in our basecase. No separate impacts are reported.

II. *QLD Cleaner Energy Strategy*. Via its Queensland Cleaner energy Strategy (QLD CES) the Queensland government is pursuing a number of actions to reduce greenhouse gas emissions. Specifically, under the 13 per cent gas scheme new retail licences require electricity retailers to source 13% of electricity sold in Queensland from gas-fired generators from 1 Janaury 2005. The 13% scheme is modelled via autonomous annual shifts towards gas-fired electricity generation and away from coal-fired generation in QLD. The annual switches are calibrated to increase the share of gas-fired generation in total QLD generation in line with the schedule provided by the Queensland government. According to this schedule, the gas share in QLD generation in 2010 will be 12.5 per cent. Thereafter, the share falls slightly to 12.3 per cent in 2020.

III. *Generator Efficiency Standards (GES) and Greenhouse Challenge Electricity Supply*. These measures effectively work to increase generator efficiencies for different fossil fuels. In our modelling we assume that the measures will result in improved efficiency of fuel use in coal and gas generation. The improvements in efficiency are calibrated to initially[8] achieve by 2010 the following reductions in emissions (relative to basecase levels): 1.5 Mt C02-e (black coal generation), 1.5 Mt C02-e (brown coal generation), and 0.6 Mt C02-e (gas generation). These initial reductions may differ from the final reductions due to second-round (or rebound) effects.

IV. *Mandatory Renewable Energy Targets (MRET)*. The MRET target obliges wholesale purchasers of electricity to proportionately contribute towards the generation of an additional 9.500 GWh of renewable energy per year by 2010. This translates to an additional 34.2 PJ of generated electricity. We implement the scheme via autonomous annual shifts towards renewable electricity generation and away from fossil-fuel

[8] For this measure and most others listed below, the exogenously imposed changes necessary to implement the measure within the model are calibrated so that they achieve, with all else unchanged, a targeted change in emissions. The final outcome for emissions, however, may differ from the initial target change due to second round CGE (or rebound) effects.

generation, sufficient to hit the renewable target in 2010. We assume that the amount of renewable generation remains at its 2010-level through to 2020.

V. *Green Power*. We include Green Power in our modelling of MRET. Thus the simulated impacts of MRET include the impacts of Green Power.

VI. Renewable Energy Commercialisation Program and Renewable Remote Power Generation Program (outside of MRET). This combined measure has not been modelled. The AGO estimates that the combined impact of the two programs in the stationary energy sector (outside of MRET) is 0.5 Mt CO2-e in 2010.

VII. *Greenhouse Gas Abatement Program (GGAP) and Greenhouse Friendly Certification Program*. These programs provide support to activities that are likely to result in substantial emission reductions or substantial sink enhancement up to 2012. We assume that the GGAP will reduce emissions in line with the estimates in Table A.7.2 of the AGO's *Measures Summary for the 2004 Stationary Energy Sector Projections.* According to the AGO, the combined impacts of existing GGAP and Greenhouse Friendly projects in the stationary energy sector will be 2.0 Mt C02-e in 2010. We model these programs via cost-neutral shifts in industry technologies against the use of electricity and gas.[9] These shifts are calibrated to *initially* achieve by 2010 the targeted reductions in emissions.

VIII. *NSW electricity retailer benchmark scheme*. Under the benchmarks, NSW electricity retailers are required to reduce per capita C02-e emissions to 8.65 tonnes in 2003, to 8.31 tonnes in 2004, to 7.96 tonnes in 2005 and to 7.27 tonnes in 2006. We assume that the scheme maintains the per-capita target of 7.27 tonnes through to 2012. The scheme allows NSW electricity retailers to comply with their benchmark obligations by: reducing the greenhouse intensity of electricity purchased from generators; improving the energy efficiency of their customers through the promotion of demand management; and offsetting emissions through the purchase of forest sequestration credits. We assume that improved demand management and the purchases of sequestration credits must occur in NSW. However, credit for reduced greenhouse intensity of generation can be claimed from actions anywhere in the four NEMCO states.

In our modelling we use population projections from the ABS to deduce absolute targets from the per-capita benchmarks. To the annual absolute targets we add an allowance for forestry sequestration and abatement associated with new landfill and sewage projects in NSW. Currently, we assume abatement of 2.0 Mt CO2-e from these sources, making the effective annual target equal to the annual absolute target plus 2.0 Mt. We assume that the effective target is met from a combination of: (1) abatement in NSW associated with existing measures - MRET, GES and demand side programs (MEPS, etc); and (2) abatement from autonomous annual shifts towards gas-fired electricity generation and away from coal generation in each NEMCO state. The necessary shifts towards gas generation are calibrated as follows (using numbers for 2012):

(1) Absolute target = 7.27 × 7.5 = 54.6 Mt C02-e.

(2) Effective target = 54.6 + 2 = 56.6 Mt C02-e.

(3) Basecase level of emissions (NSW electricity sector) 69.6 Mt C02-e.

(4) Abatement task = 69.6 – 56.6 = 13.0 Mt C02-e.

(5) Credit for existing measures in NSW 9.0 Mt C02-e.

[9] A shift in and industry's technology against the use of energy leads to a reduction in the overall unit cost for that industry. However, this ignores the cost of installing the technology in that industry. In our modelling, we assume that the unit cost of installation just matches the unit cost reduction due to more efficient usage of energy. Thus the increased efficiency has no effect on overall unit cost – it is cost neutral.

(6) Required reduction in greenhouse intensity of electricity generation across NEMCO = 13.0 – 9.0 = 4.0 Mt C02-e.

Demand-side

IX. *Greenhouse Challenge Program (GCP).* This is described as a co-operative program between industry and government whereby companies undertake action to abate their greenhouse gas emissions through no regrets energy efficiency and other measures. It is modelled as a combination of improved (relative to baseline levels) generation efficiency and improved energy efficiency in industrial usage targeted *initially* to achieve an Australia-wide reduction in emissions of 1.8 Mt C02-e by 2010.

X. Energy efficiency standards for residential and commercial buildings. This measure has a technical effect that increases the energy efficiency of residential and commercial building. The technological change is modelled as a cost-neutral increase in the efficiency with which energy is used in buildings. The annual increases are targeted to *initially* reduce emissions (relative to basecase levels) by 2010 by 1.4 Mt C02-e.

XI. *Mandatory Energy Performance Standards (MEPS) - Energy performance codes and standards for domestic appliances and commercial and industrial equipment.* This measure increases the effectiveness of existing energy labelling by developing minimum energy performance standards for a broad range of new appliances and equipment. The AGO estimates that the measure will reduce total emissions by 6.9 Mt in 2010. The measure is modelled as a combination of cost-neutral annual shifts in industry technologies and consumer tastes against the usage of electricity and gas. These shifts are targeted *initially* to achieve the AGO estimated reduction in 2010. We assume that the measure remains in place through to 2020. For the years after 2010, we assume rates of change in technologies and tastes equal to the averages achieved between 1999 and 2010.

XII. *Energy Efficiency Best Practice Program*. This measure encourages industries to become more efficient in the use of energy via innovative investments and changes in technologies. The AGO estimates that the measure will, by 2010, reduce total emissions relative to basecase levels by 0.2 Mt C02-e. The program is modelled via cost-neutral annual shifts in industry technologies against the usage of electricity and gas. These shifts are calibrated to *initially* achieve the reduction of 0.2 Mt by 2010.

XIII. *Reducing greenhouse gas emissions from government operations + local government and household greenhouse action*. This measure encourages government industries to become more efficient in the use of energy by implementing plans to reduce emissions via improvements in energy efficiency. The AGO estimates that this measure will reduce stationary energy emissions relative to basecase levels by 0.5 Mt in 2010. The program is modelled via cost-neutral annual shifts in industry technologies against the usage of electricity and gas. These shifts are calibrated to *initially* achieve the reduction of 0.5 Mt by 2010.

XIV. *Additional state and territory action under the National Greenhouse Strategy (NGS)*. This covers all states and territories and includes those actions taken under the NGS for the stationary energy sector and not captured by the measures listed above. The AGO estimates that together the actions will reduce residential, commercial and government energy use in 2010 by 1.9 Mt C02-e. The actions are modelled via cost-neutral annual shifts against the usage of electricity and gas on the part of residential and industry (private plus government) users. These shifts are calibrated to *initially* achieve the reduction of 1.9 Mt by 2010.

Appendix B Table 1 summaries our modelling methodology for each measure in terms of target variables, instruments and allowance for second-round CGE (i.e. rebound) effects on the variables targeted and on emissions from the stationary energy sector in general.

B3 Impacts

Appendix B Table 2 shows the gross impact of each measure on Australia-wide stationary energy emissions (Mt CO2-e). The numbers in the final row are totals, calculated as the sum of the individual gross impacts. Appendix B Table 3 shows the net impact of each measure. Net impact equals gross impact (Appendix B Table 2) less any overlap between individual measures. Adding the individual net impacts yields the combined impact of all measures shown in the final row of Appendix B Table 2.

According to our modelling, the combined impact of measures in the stationary energy sector (with the exclusions noted in Section B2) is 29.2 Mt CO2-e in 2010 and 43.1 Mt CO2-e in 2020. Demand-side measures (IX to XIV) provide a net 10.6 Mt CO2-e of abatement in 2010 and a net 22.5 Mt CO2-e of abatement in 2020. Supply-side measures (II-V, VII and VIII) provide a net 18.7 Mt CO2-e of abatement in 2010 and a net 10.6 Mt CO2-e of abatement in 2020.

Appendix B Table 4 compares our estimates of the net impacts of measures with those from the AGO in 2010 and 2020. [10] For comparison purposes, we exclude from the AGO numbers their estimates of the impacts of EMR (measure I), and of the Renewable Energy Commercialisation Program and the Renewable Remote Power Generation Program (outside of MRET) (measure VI). According to the AGO, the combined impact of measures (excluding I and VI) in the stationary energy sector is 31.9 Mt CO2-e in 2010 and 38.2 Mt CO2-e in 2020.

Focussing on 2020, we see that the most significant disparities between estimated impacts of individual measures are for the QLD cleaner energy strategy (measure II), MRET plus Green Power (IV,V) the NSW electricity retailer benchmark scheme (VIII), and MEPS (XI).

AGO's estimate of the net impact of the QLD strategy (measure II) in 2020 is zero. In the AGO's BAU, QLD's gas share reaches the thirteen per cent target before 2020. In our no-measures case, QLD's gas share remains below ten per cent through to 2020.

Our estimate for the net impact of MRET (plus Green Power) in 2020 is –9.1 Mt CO2-e. This compares to AGO's estimate of –7.4 Mt CO2-e. Most of the difference can be accounted for by differences in second-round impacts. Our simulations suggest that the MRET scheme has a significant negative impact on demand for electricity via an increase in average generation cost which flows through to an increased retail price. According to our modelling, this second-round reduction in demand for electricity reduces generation from fossil fuels yielding an overall reduction in emissions from the stationary energy sector of around 1.5 Mt CO2-e in 2020. Deducting this second-round effect from our net impact estimate yields a number very close to the AGO's estimate of net impact.[11]

At any point in time, the size of the net impact of the NSW scheme (measure VIII) depends critically on the underlying no-measures path of emissions. Differences in the no-measures path, therefore, probably account for the disparity in the alternative estimates of net impact

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[10] Source for the AGO estimates is an unpublished spreadsheet provided by the AGO.

[11] Interestingly, our simulations show rising savings from MRET after 2010. In our modelling we assume that after 2010 there will be no more new non-hydro renewable generation, but the capital put in place up to 2010 must be maintained and, if necessary, replaced. Prior to 2010 the cost of installing and maintaining renewable capacity falls due to significant technological improvement associated primarily with "learning-by-doing". After 2010 the rate of technological improvement drops away. So in the post-MRET world replacing and updating existing renewable generation capacity becomes steadily more costly. The increase in cost directly reduces GDP, directly reducing final demand for electricity and causing emissions from generation to slowly decline.

for the NSW scheme. Differences in the underlying path may also account for the different estimates of net impact for the MEPS (measure XI). Our estimate for 2010 is in line with the AGO number. However, after 2010, our estimate rises steadily above the AGO's estimate, such that there is a gap of over 3 Mt CO2-e in 2020.

Appendix B Table 1: Treatment of Measures

	Measure	Target	Instrument	Second-round effects: Target variable	Second-round: Stationary sector emissions.
I	Energy Market Reform		*Included in basecase*		
II	QLD cleaner energy strategy	QLD gas generation share	Autonomous shifts in electricity-retail demand towards gas, away from coal	No	Yes
III	GES and GCP-supply	Emissions from generation	Autonomous shifts in efficiency in use of fuels by electricity generators	Yes	Yes
IV,V	MRET and Green Power	Renewable generation	Autonomous shifts in electricity retail demand towards gas, away from coal	No	Yes
VI	Renewable energy commercialisation program, etc.		*Not modelled.*		
VII	GGAP and greenhouse friendly certification program	Stationary sector emissions	Cost-neutral shifts in technologies of end-use industries against energy.	Yes	Yes
VIII	NSW electricity retailer scheme	Emissions from electricity generation sector	Non-stationary emissions, Other measures (e.g., MRET), and Autonomous shifts in retail demand towards gas, away from coal in NEMCO states.	No	Yes
IX	GCP-demand	Stationary-sector emissions	Autonomous shifts in end-use demand for electricity	Yes	Yes
X	Energy efficiency for buildings	Stationary sector emissions	Cost-neutral shifts in technologies of end-use industries and in residential buildings, against energy	Yes	Yes
XI	MEPS	Stationary sector emissions	Cost-neutral shifts in technologies of end-use industries, and in residential use, against energy.	Yes	Yes
XII	Energy efficiency best practice	Stationary sector emissions	Cost-neutral shifts in technologies of end-use industries against energy.	Yes	Yes
XIII	Reducing government energy use	Stationary sector emissions	Cost-neutral shifts in technologies of end-use public sector industries against energy.	Yes	Yes
XIV	Other state and territory action	Stationary sector emissions	Cost-neutral shifts in technologies of end-use industries and residential customers against energy.	Yes	Yes

Appendix B Table 2: Gross Impacts of Measures on National Stationary Energy Emissions between 1999 and 2020 (Mt CO2-e)

Measure	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.3	-0.6	-1.1	-1.1
III	0.0	-0.3	-0.4	-0.6	-0.8	-1.1	-1.3	-1.6	-1.9	-2.2	-2.5	-2.8
IV,V	0.0	0.0	-0.3	-0.7	-1.2	-1.7	-2.4	-3.3	-4.4	-5.7	-7.3	-9.2
VII	0.0	-0.1	-0.2	-0.4	-0.5	-0.7	-0.8	-1.0	-1.2	-1.3	-1.5	-1.7
VIII	0.0	0.0	0.0	0.0	-1.6	-3.4	-5.8	-7.6	-9.3	-10.5	-11.7	-12.4
IX	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.8	-0.9	-1.1	-1.3	-1.5
X	0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.9	-1.0	-1.1
XI	0.0	-0.4	-0.7	-1.2	-1.7	-2.3	-2.9	-3.6	-4.4	-5.1	-5.9	-6.7
XII	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2
XIII	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4
XIV	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-0.8	-1.0	-1.2	-1.4	-1.6
Total gross	0.0	-1.1	-2.1	-3.8	-7.0	-10.8	-15.3	-19.6	-24.5	-29.0	-34.2	-38.7
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
II	-1.0	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9		
III	-2.9	-3.0	-3.1	-3.2	-3.3	-3.4	-3.5	-3.6	-3.6	-3.7		
IV,V	-9.4	-9.5	-9.5	-9.6	-9.6	-9.7	-9.7	-9.7	-9.8	-9.8		
VII	-1.9	-2.0	-2.1	-2.2	-2.3	-2.4	-2.5	-2.6	-2.7	-2.8		
VIII	-12.7	-13.0	-13.0	-13.1	-13.1	-13.2	-13.3	-13.4	-13.5	-13.5		
IX	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6		
X	-1.3	-1.3	-1.4	-1.4	-1.6	-1.7	-1.8	-1.9	-2.0	-2.2		
XI	-7.6	-8.5	-9.4	-10.3	-11.2	-12.2	-13.1	-14.1	-15.0	-16.0		
XII	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2		
XIII	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5		
XIV	-1.7	-1.8	-1.8	-2.0	-2.1	-2.3	-2.4	-2.6	-2.8	-2.9		
Total gross	-40.8	-42.3	-43.5	-45	-46.4	-48.1	-49.5	-51.1	-52.6	-54.1		

Appendix B Table 3: Net Impacts of Measures on National Stationary Energy Emissions between 1999 and 2020 (Mt CO2-e)

Measure	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
II	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.5	-1.0	-1.0
III	0.0	-0.3	-0.4	-0.6	-0.8	-1.1	-1.3	-1.6	-1.9	-2.2	-2.5	-2.8
IV,V	0.0	0.0	-0.1	-0.4	-0.8	-1.2	-1.8	-2.6	-3.7	-5.0	-6.6	-8.5
VII	0.0	-0.1	-0.2	-0.4	-0.5	-0.7	-0.8	-1.0	-1.2	-1.3	-1.5	-1.7
VIII	0.0	0.0	0.0	0.0	-0.4	-0.6	-2.2	-3.6	-4.2	-4.1	-5.0	-4.3
IX	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.8	-0.9	-1.1	-1.3	-1.5
X	0.0	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5	-0.6	-0.7	-0.9	-1.0	-1.1
XI	0.0	-0.3	-0.4	-1.0	-1.4	-1.9	-2.4	-3.0	-3.8	-4.5	-5.3	-6.1
XII	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2
XIII	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.4
XIV	0.0	-0.1	-0.2	-0.3	-0.4	-0.5	-0.7	-0.8	-1.0	-1.2	-1.4	-1.6
Total net	0.0	-0.9	-1.6	-3.2	-5.1	-7.1	-10.6	-14.3	-17.9	-21.1	-26.0	-29.2
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020		
II	-0.9	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8	-0.8		
III	-2.9	-3.0	-3.1	-3.2	-3.3	-3.4	-3.5	-3.6	-3.6	-3.7		
IV,V	-8.7	-8.8	-8.8	-8.9	-8.9	-9.0	-9.0	-9.0	-9.1	-9.1		
VII	-1.9	-2.0	-2.1	-2.2	-2.3	-2.4	-2.5	-2.6	-2.7	-2.8		
VIII	-4.0	-4.0	-4.2	-4.2	-4.1	-4.1	-4.0	-4.0	-4.0	-3.9		
IX	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6	-1.6		
X	-1.3	-1.3	-1.4	-1.4	-1.6	-1.7	-1.8	-1.9	-2.0	-2.2		
XI	-7.0	-7.9	-8.8	-9.7	-10.6	-11.6	-12.5	-13.5	-14.4	-15.4		
XII	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2		
XIII	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5		
XIV	-1.7	-1.8	-1.8	-2.0	-2.1	-2.3	-2.4	-2.6	-2.8	-2.9		
Total net	-30.7	-31.9	-33.3	-34.5	-35.9	-37.3	-38.7	-40.2	-41.6	-43.1		

Appendix B Table 4: Net Impacts of Measures on National Stationary Energy Emissions between 1999 and 2020 (Mt CO2-e): AGO estimates compared to CoPS estimates

Measure		2010	2020
CoPS estimates from Appendix B Table 3			
II	QLD Cleaner Energy Strategy	-1.0	-0.8
III	GES and GCP-supply	-2.8	-3.7
IV,V	MRET plus Green Power	-8.5	-9.1
VII	GGAP and Greenhouse Friendly Certification Program	-1.7	-2.8
VIII	NSW electricity retailer benchmark scheme	-4.3	-3.9
IX	GCP-demand	-1.5	-1.6
X	Energy efficiency standards fro residential and commercial buildings	-1.1	-2.2
XI	MEPS	-6.1	-15.4
XII	Energy efficiency best practice program	-0.2	-0.2
XIII	Reducing greenhouse gas emissions (federal and local government)	-0.4	-0.5
XIV	Additional state and territory action under the NGS	-1.6	-2.9
Total		29.2	43.1
AGO estimates			
II	QLD Cleaner Energy Strategy	-0.9	0.0
III	GES and GCP-supply	-3.6	-3.6
IV,V	MRET plus Green Power	-7.4	-7.4
VII	GGAP and Greenhouse Friendly Certification Program	-2.0	-2.0
VIII	NSW electricity retailer benchmark scheme	-5.4	-5.4
IX	GCP-demand	-1.8	-1.8
X	Energy efficiency standards fro residential and commercial buildings	-1.4	-2.3
XI	MEPS	-6.9	-12.1
XII	Energy efficiency best practice program	-0.2	-0.2
XIII	Reducing greenhouse gas emissions (federal and local government)	-0.5	-0.5
XIV	Additional state and territory action under the NGS	-1.9	-3.0
Total		-31.9	-38.2

*Table A: Industries in MMRF-Green**

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

* For most of the products identified in this table there is an obvious correspondence to one or more standard categories in the Australian and New Zealand Standard Industrial Classification (ANZSIC). The exceptions are: industries 21 to 30, which together comprise ANZSIC 3610 *Electricity Supply*; industry 46, which is equivalent to the *Ownership of dwellings* industry in the industrial classification of the official Input/Output statistics; and industry 49 which is unique to MMRF-Green. Industry 49 produces the services of the stock of private motor vehicles. It is analogous to industry 46, which produces the services of the stock of dwellings

Table B: Macroeconomic Assumptions (average annual percentage growth rates)

Variable	With Measures		
	2002-10	2010-20	2002-20
Real private consumption			
National	3.0	2.6	2.8
NSW	2.9	2.5	2.7
VIC	2.7	2.4	2.5
QLD	3.8	2.9	3.3
SA	1.9	1.9	1.9
WA	3.6	3.3	3.4
TAS	1.9	1.6	1.7
NT	4.9	4.2	4.5
ACT	5.3	3.2	4.1
Real GDP/GSP			
National	3.0	2.6	2.8
NSW	2.9	2.5	2.7
VIC	2.6	2.4	2.5
QLD	3.5	2.9	3.2
SA	2.0	1.9	2.0
WA	4.2	3.3	3.7
TAS	1.6	1.6	1.6
NT	5.0	4.2	4.6
ACT	4.6	2.8	3.6
Employment			
National	1.4	1.1	1.3
NSW	1.2	1.0	1.1
VIC	1.1	0.9	1.0
QLD	1.8	1.4	1.6
SA	1.1	0.4	0.7
WA	2.0	1.8	1.9
TAS	1.0	0.1	0.5
NT	4.3	3.3	3.7
ACT	3.4	1.9	2.6

Table C.1: Initial Industry Technology and Household Taste Assumptions (average annual percentage changes)*

Commodities	Household Preferences[(a)]			Intermediate input-using[(b)]		
	2002-10	2010-20	2002-20	2002-10	2010-20	2002-20
Agriculture	#	#	#	0.0	0.0	0.0
Forestry	#	#	#	1.3	1.2	1.3
Iron ore	#	#	#	-0.2	-0.2	-0.2
Non-iron ore	#	#	#	0.0	0.0	0.0
Black coal	#	#	#	-0.5	-0.4	-0.5
Crude oil	#	#	#	0.0	0.0	0.0
Natural gas	-0.6	-0.9	-0.8	-0.5	-0.2	-0.3
Brown coal	#	#	#	-0.1	0.0	-0.1
Food, beverages and tobacco	0.4	0.4	0.4	0.2	0.2	0.2
Textiles, clothing and footwear	-2.1	-1.9	-2.0	-0.3	-0.3	-0.3
Wood and paper products	0.1	0.1	0.1	0.1	0.1	0.1
Chemical products excl. Petrol	1.6	1.4	1.5	1.9	1.8	1.8
Petrol	0.0	0.0	0.0	-0.6	-0.5	-0.5
Aviation gasoline	0.0	0.0	0.0	-0.6	-0.5	-0.5
Aviation turbine fuel	0.0	0.0	0.0	-0.6	-0.5	-0.5
Diesel	0.0	0.0	0.0	-0.6	-0.5	-0.5
LPG	0.0	0.0	0.0	0.5	0.5	0.5
Other petroleum products	-2.0	-1.9	-1.9	-0.5	-0.5	-0.5
Building prods (not cement & metal)	0.1	0.1	0.1	0.4	0.3	0.3
Cement	#	#	#	-0.9	-0.8	-0.8
Iron and steel	#	#	#	1.0	0.9	1.0
Alumina and aluminium	#	#	#	1.5	1.4	1.4
Other metal products	-1.0	-0.9	-1.0	1.0	0.9	0.9
Motor vehicles and parts	0.0	0.0	0.0	1.9	1.7	1.8
Other manufacturing	0.6	0.5	0.5	2.8	2.6	2.7
Electricity – black coal	#	#	#	0.0	0.0	0.0
Electricity – brown coal	#	#	#	0.0	0.0	0.0
Electricity – gas	#	#	#	0.0	0.0	0.0
Electricity – oil prods.	#	#	#	0.0	0.0	0.0
Electricity – hydro	#	#	#	0.0	0.0	0.0
Electricity – biomass	#	#	#	0.0	0.0	0.0
Electricity – biogas	#	#	#	0.0	0.0	0.0
Electricity – solar	#	#	#	0.0	0.0	0.0
Electricity - wind	#	#	#	0.0	0.0	0.0
Electricity supply	-0.5	-0.4	-0.5	-0.8	-0.7	-0.7
Urban gas distribution	0.2	0.2	0.2	0.4	0.4	0.4
Water and sewerage services	-0.4	-0.4	-0.4	-0.1	-0.1	-0.1
Construction services	0.0	0.0	0.0	1.3	1.2	1.3
Wholesale + retail trade, accommodation	-1.6	-1.5	-1.5	-1.3	-1.2	-1.3
Road transport services – passenger	-1.2	-1.1	-1.2	0.4	0.4	0.4
Road transport services – freight	#	#	#	0.0	0.0	0.0
Rail transport services – passenger	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Rail transport services – freight	#	#	#	0.0	0.0	0.0
Water transport services – passenger	-4.6	-4.3	-4.4	-1.9	-1.7	-1.8
Water transport services – freight	#	#	#	0.0	0.0	0.0
Air transport services – passenger	1.2	1.2	1.2	-1.6	-1.5	-1.5
Air transport services – freight	#	#	#	0.0	0.0	0.0
Other transport services	-0.2	-0.2	-0.2	0.6	0.6	0.6
Communication services	0.0	0.0	0.0	3.8	3.5	3.6
Financial and business services	1.4	1.3	1.4	2.5	2.3	2.3
Dwelling ownership	0.0	0.0	0.0	0.0	0.0	0.0
Public services	0.1	0.1	0.1	0.0	0.0	0.0
Other services	0.9	0.8	0.9	1.2	1.1	1.1
Private motor vehicle ownership	-0.7	-0.6	-0.7	0.0	0.0	0.0

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

a) Annual rate of shift of consumption function.

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

*Table C.2: Initial Industry Technology and Household Taste Assumptions (average annual percentage changes)**

Industry	Primary-factor using (c)		
	2002-10	2010-20	2002-20
Agriculture	-1.2	-1.1	-1.1
Forestry	0.0	0.0	0.0
Iron ore	-2.0	-1.9	-1.9
Non-iron ore	-1.2	-1.1	-1.1
Black coal	0.0	0.0	0.0
Crude oil	0.0	0.0	0.0
Natural gas	0.0	0.0	0.0
Brown coal	0.0	0.0	0.0
Food, beverages and tobacco	-0.6	-0.6	-0.6
Textiles, clothing and footwear	-0.9	-0.8	-0.8
Wood and paper products	-0.1	-0.1	-0.1
Chemical products excl. Petrol	0.0	0.0	0.0
Petroleum products	0.0	0.0	0.0
Building prods (not cement & metal)	-0.6	-0.5	-0.5
Cement	-0.2	-0.2	-0.2
Iron and steel	-0.7	-0.6	-0.7
Alumina and aluminium	-1.2	-1.2	-1.2
Other metal products	0.0	0.0	0.0
Motor vehicles and parts	-0.2	-0.2	-0.2
Other manufacturing	-0.9	-0.8	-0.9
Electricity – black coal	-1.5	-1.4	-1.5
Electricity – brown coal	-1.5	-1.4	-1.5
Electricity – gas	0.0	0.0	0.0
Electricity – oil prods.	0.0	0.0	0.0
Electricity – hydro	1.9	0.7	1.2
Electricity – biomass	-1.5	-1.4	-1.5
Electricity – biogas	-1.5	-1.4	-1.5
Electricity – solar	-1.5	-1.4	-1.5
Electricity – wind	-1.5	-1.4	-1.5
Electricity – supply	0.1	-1.1	-0.6
Urban gas distribution	-1.4	-1.3	-1.3
Water and sewerage services	-1.2	-1.1	-1.2
Construction services	0.0	0.0	0.0
Wholesale trade, retail trade, accommodation	0.0	0.0	0.0
Road transport services – passenger	-0.4	-0.4	-0.4
Road transport services – freight	-0.4	-0.4	-0.4
Rail transport services – passenger	-1.1	-1.0	-1.1
Rail transport services – freight	-1.1	-1.0	-1.1
Water transport services – passenger	-0.6	-0.5	-0.6
Water transport services – freight	-0.6	-0.5	-0.6
Air transport services – passenger	-1.8	-1.7	-1.8
Air transport services – freight	-1.8	-1.7	-1.8
Other transport services	0.0	0.0	0.0
Communication services	-2.2	-2.1	-2.1
Financial and business services	-0.9	-0.8	-0.8
Dwelling ownership	0.0	-0.3	-0.2
Public services	-0.2	-0.2	-0.2
Other services	0.0	0.0	0.0
Private motor vehicle ownership	0.0	0.0	0.0

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

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

	2002-10	2010-20	2002-20
With Measures			
Energy technical efficiency improvement[(a)]	0.6	0.5	0.5
Supply efficiency improvement[(b)]	0.5	0.3	0.4

(a) We define energy technical efficiency as minus a weighted average of the use of primary and derived fuels per unit of output in all industries using those fuels other than electricity. Thus a value of 0.6 per cent per annum implies that industries other than electricity use annually 0.6 per cent less fuels (primary and derived) per unit of output.

(b) We define supply efficiency as minus a weighted average of the use of primary fuels per unit of electricity generation. Thus a value of 0.5 per cent per annum implies that electricity-generating industries use annually 0.5 per cent less primary fuels per unit of output.

Table E: Assumptions for National Exports (average annual percentage changes)

Export volume:	With Measures		
	2002-10	2010-20	2002-20
Agriculture	-2.1	2.6	0.5
Iron ore	3.0	3.0	3.0
Non-iron ore	3.0	3.0	3.0
Black coal	2.2	1.7	2.0
Natural gas	4.9	5.0	5.0
Petroleum products	0.0	0.0	0.0
Alumina/aluminium	3.8	3.4	3.6

Table F: Output by Industry
(average annual percentage growth rates)

Industry	2002-2010	2010-2020	2002-2020
1. Agriculture	2.5	2.8	2.6
2. Forestry	2.9	2.6	2.8
3. Iron ore	2.6	2.5	2.6
4. Non-iron ore	2.9	2.5	2.7
5. Black coal	2.0	1.6	1.8
6. Crude oil	-0.1	0.0	-0.1
7. Natural gas	3.7	3.4	3.5
8. Brown coal	1.0	1.4	1.2
9. Food, beverages and tobacco	5.0	3.9	4.4
10. Textiles, clothing and footwear	-0.5	-0.2	-0.3
11. Wood and paper products	2.1	1.7	1.9
12. Chemical products excl. Petrol	3.3	2.9	3.1
13. Petroleum products	1.6	1.2	1.3
14. Building prods (not cement & metal)	2.5	1.9	2.2
15. Cement	1.3	0.6	0.9
16. Iron and steel	4.4	3.2	3.8
17. Alumina and aluminium	3.9	3.3	3.6
18. Other metal products	5.5	4.0	4.7
19. Motor vehicles and parts	1.3	1.5	1.4
20. Other manufacturing	4.2	3.6	3.9
21. Electricity – black coal	1.0	1.4	1.2
22. Electricity – brown coal	1.0	1.2	1.1
23. Electricity – gas	7.0	3.3	4.9
24. Electricity – oil prods.	0.0	0.0	0.0
25. Electricity – hydro	0.3	0.1	0.2
26. Electricity – biomass	15.1	0.0	6.5
27. Electricity – biogas	12.2	0.0	5.3
28. Electricity – solar	13.0	0.0	5.6
29. Electricity - wind	41.7	0.0	16.8
30. Electricity supply	2.0	1.6	1.8
31. Urban gas distribution	3.7	3.4	3.5
32. Water and sewerage services	2.9	2.5	2.7
33. Construction services	3.3	2.6	2.9
34. Wholesale + retail trade, accommodation	2.3	2.0	2.1
35. Road transport services – passenger	2.3	2.0	2.2
36. Road transport services – freight	4.1	3.5	3.8
37. Rail transport services – passenger	2.5	2.3	2.4
38. Rail transport services – freight	2.7	2.5	2.6
39. Water transport services – passenger	0.4	1.5	1.0
40. Water transport services – freight	1.8	1.3	1.5
41. Air transport services – passenger	3.3	4.0	3.7
42. Air transport services – freight	2.9	2.4	2.7
43. Other transport services	3.3	2.8	3.0
44. Communication services	6.7	6.1	6.3
45. Financial and business services	5.0	4.3	4.7
46. Dwelling ownership	3.4	3.1	3.2
47. Public services	3.0	2.6	2.7
48. Other services	3.4	3.0	3.2
49. Private motor vehicle ownership	2.3	1.4	1.8

Table G: $C0_2$-e Emissions by Major Source Category for Australia
(Average annual percentage growth rates)

	2002-2010	2010-2020	2002-2020
Energy sector, total	1.4	1.4	1.4
Fuel combustion	1.4	1.4	1.4
Stationary	1.3	1.3	1.3
Electricity generation	0.8	1.3	1.1
Other	2.2	1.3	1.7
Transport	2.0	1.7	1.8
Fugitive emissions from fuels	1.1	1.4	1.3
Industrial processes	3.0	2.8	2.9
Agriculture	0.4	0.8	0.6
Waste	0.9	0.5	0.7
LUCF	2.9	2.5	2.7
Total	1.2	1.2	1.2

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Table G (continued) Emissions by Major Source Category (Mt $C0_2$-e)

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Levels(Mt CO2-e) (2002)									
Energy sector, total	114.8	118.1	64.7	20.2	42.2	2.3	3.9	2.2	368.2
Fuel combustion	109.1	104.5	58.6	19.9	38.3	2.3	3.3	2.2	338.0
Stationary	81.5	85.0	44.7	15.2	30.4	1.0	2.3	0.8	260.9
Electricity generation	58.3	60.3	32.0	9.5	19.0	0.0	1.4	0.0	180.4
Other	23.2	24.6	12.7	5.7	11.4	1.0	0.9	0.8	80.5
Transport	27.6	19.5	13.9	4.6	7.9	1.3	1.0	1.3	77.1
Fugitive emissions from fuels	5.7	13.6	6.1	0.3	3.9	0.0	0.6	0.0	30.2
Industrial processes	5.4	4.1	5.1	1.2	5.2	0.8	1.8	0.0	23.6
Agriculture	32.6	19.5	25.6	8.2	15.5	3.0	1.2	0.1	105.6
Waste	5.7	5.3	2.5	1.6	1.3	0.4	0.3	0.6	17.6
LUCF	-4.5	-4.7	-3.6	-2.0	-2.2	-4.5	0.0	-0.3	-21.8
Total	154.0	142.2	94.3	29.2	62.0	1.9	7.1	2.6	493.2
Levels (Mt CO2-e) (2010)									
Energy sector, total	124.7	130.6	73.9	18.9	52.7	2.8	5.0	2.8	411.5
Fuel combustion	118.4	117.1	66.8	18.6	47.9	2.8	4.4	2.8	378.7
Stationary	87.2	94.5	49.9	13.6	37.7	1.6	3.0	1.1	288.5
Electricity generation	60.7	66.1	34.4	7.1	22.6	0.0	1.8	0.0	192.7
Other	26.5	28.4	15.5	6.5	15.1	1.6	1.2	1.1	95.8
Transport	31.2	22.6	16.9	5.0	10.2	1.2	1.4	1.7	90.2
Fugitive emissions from fuels	6.3	13.6	7.1	0.3	4.9	0.0	0.6	0.0	32.8
Industrial processes	6.2	5.4	6.8	1.2	6.7	1.0	2.6	0.0	29.9
Agriculture	30.2	21.6	27.4	7.9	18.3	2.6	1.4	0.1	109.4
Waste	6.1	5.5	2.8	1.6	1.4	0.4	0.3	0.7	18.9
LUCF	-5.6	-6.0	-4.6	-2.4	-3.0	-5.3	0.0	-0.4	-27.3
Total	161.6	157.1	106.3	27.3	76.1	1.4	9.3	3.2	542.4
Levels (Mt CO2-e) (2020)									
Energy sector, total	140.8	145.5	89.7	17.6	64.6	3.0	6.9	3.4	471.5
Fuel combustion	133.6	132.1	81.3	17.5	56.5	3.0	6.3	3.4	433.8
Stationary	97.6	105.9	60.6	12.1	43.7	1.7	4.1	1.4	326.9
Electricity generation	67.0	76.3	42.1	6.6	24.0	0.0	2.5	0.0	218.4
Other	30.6	29.6	18.5	5.4	19.8	1.7	1.5	1.4	108.5
Transport	36.0	26.3	20.7	5.4	12.8	1.3	2.2	2.0	106.8
Fugitive emissions from fuels	7.2	13.4	8.4	0.1	8.1	0.0	0.6	0.0	37.8
Industrial processes	7.4	6.9	9.3	1.3	9.3	1.1	4.3	0.0	39.5
Agriculture	30.1	23.4	32.1	7.7	20.6	2.4	1.7	0.2	118.0
Waste	6.3	5.7	3.0	1.7	1.5	0.4	0.4	0.8	19.8
LUCF	-7.1	-7.7	-6.2	-2.9	-4.1	-6.7	0.0	-0.6	-35.2
Total	177.5	173.9	127.8	25.3	91.9	0.2	13.3	3.8	613.7

Table H: CO_2-e Stationary Energy Emissions by Fuel
(Average annual percentage growth rates)

	2002-2010	2010-2020	2002-2020
Black coal	0.4	1.1	0.8
Natural gas	3.1	1.1	2.0
Brown coal	1.0	1.4	1.2
Liquid fuel	2.1	1.8	1.9
Automotive petroleum	1.8	1.9	1.9
Aviation gasoline	0.0	0.0	0.0
Aviation turbine fuel	0.0	0.0	0.0
Diesel	1.9	1.7	1.8
LPG	3.8	3.0	3.4
Other petroleum products	1.6	1.3	1.4
Total	1.3	1.3	1.3

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Table H (continued) C02-e Stationary Energy Emissions by Fuel

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Levels(Mt CO2-e) (2002)									
Black coal	63.7	2.1	32.2	7.7	16.2	0.3	0.2	0.0	122.5
Natural gas	8.3	16.4	6.8	5.9	9.3	0.0	1.5	0.3	48.6
Brown coal	0.0	59.4	0.0	0.0	0.0	0.0	0.0	0.0	59.4
Liquid fuel	9.4	7.0	5.8	1.5	4.9	0.7	0.7	0.5	30.5
Automotive petroleum	0.2	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.6
Aviation gasoline	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aviation turbine fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diesel	4.1	3.0	2.6	0.8	2.4	0.4	0.2	0.4	13.8
LPG	1.7	1.4	0.8	0.2	0.6	0.0	0.0	0.0	4.7
Other petroleum products	3.5	2.5	2.4	0.5	1.8	0.2	0.4	0.1	11.4
Total	81.5	85.0	44.7	15.2	30.4	1.0	2.3	0.8	260.9
Levels (Mt CO2-e) (2010)									
Black coal	65.8	2.7	33.7	3.8	19.9	0.3	0.2	0.1	126.4
Natural gas	10.8	19.6	9.3	8.1	11.1	0.6	1.9	0.4	61.9
Brown coal	0.0	64.1	0.0	0.0	0.0	0.0	0.0	0.0	64.1
Liquid fuel	10.6	8.0	6.9	1.7	6.7	0.7	0.8	0.6	36.0
Automotive petroleum	0.2	0.1	0.2	0.1	0.1	0.0	0.0	0.0	0.7
Aviation gasoline	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aviation turbine fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diesel	4.5	3.3	3.0	0.9	3.1	0.4	0.3	0.5	16.1
LPG	2.1	1.7	1.0	0.2	1.1	0.0	0.0	0.0	6.3
Other petroleum products	3.8	2.8	2.7	0.5	2.3	0.2	0.5	0.1	12.9
Total	87.2	94.5	49.9	13.6	37.7	1.6	3.0	1.1	288.5
Levels (Mt CO2-e) (2020)									
Black coal	72.4	3.1	41.5	2.6	21.0	0.3	0.3	0.1	141.2
Natural gas	13.0	20.0	10.6	7.6	14.1	0.6	2.7	0.5	69.2
Brown coal	0.0	73.5	0.0	0.0	0.0	0.0	0.0	0.0	73.5
Liquid fuel	12.1	9.3	8.5	1.8	8.7	0.7	1.1	0.8	43.0
Automotive petroleum	0.2	0.2	0.2	0.1	0.2	0.0	0.0	0.0	0.9
Aviation gasoline	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Aviation turbine fuel	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Diesel	5.1	3.8	3.7	0.9	4.0	0.5	0.3	0.7	19.0
LPG	2.7	2.2	1.5	0.3	1.8	0.1	0.0	0.0	8.5
Other petroleum products	4.1	3.1	3.1	0.6	2.8	0.2	0.7	0.1	14.7
Total	97.6	105.9	60.6	12.1	43.7	1.7	4.1	1.4	326.9

Table I: Electricity Generation (Pj) by Generator Type for Australia
(Average annual percentage growth rates)

	2002-2010	2010-2020	2002-2020
Generation – Black coal	0.6	1.3	1.0
Generation – Brown coal	1.0	1.2	1.1
Generation – Natural gas	7.5	3.4	5.2
Generation – Liquid fuel	0.0	0.0	0.0
Generation – Hydro	0.5	0.1	0.3
Generation – Biomass	15.2	0.0	6.5
Generation – Biogas	12.2	0.0	5.3
Generation – Solar	13.0	0.0	5.6
Generation – Wind	41.7	0.0	16.8
Total	1.9	1.5	1.7

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Table I (continued) Electricity Generation (Pj) by Generator Type

	NSW	VIC	QLD	SA	WA	TAS	NT	ACT	AUS
Levels(Pj) (2002)									
Generation – Black coal	226.7	0.0	119.2	27.6	55.9	0.0	0.0	0.0	429.4
Generation – Brown coal	0.0	179.8	0.0	0.0	0.0	0.0	0.0	0.0	179.8
Generation – Natural gas	5.4	6.1	10.1	16.6	32.6	0.0	8.6	0.0	79.5
Generation – Liquid fuel	0.7	0.1	1.4	0.3	0.5	0.0	0.5	0.0	3.5
Generation – Hydro	23.1	4.0	1.5	0.0	0.0	32.2	0.0	0.0	60.7
Generation – Biomass	2.0	1.4	2.2	0.0	0.0	0.3	0.0	0.0	6.0
Generation – Biogas	0.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Generation – Solar	0.7	0.2	0.2	0.0	0.0	0.0	0.0	0.0	1.1
Generation – Wind	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.5
Total	259.1	192.6	134.6	44.6	89.0	32.5	9.2	0.0	761.6
Levels (Pj) (2010)									
Generation – Black coal	238.8	0.0	129.1	11.5	71.2	0.0	0.0	0.0	450.7
Generation – Brown coal	0.0	194.5	0.0	0.0	0.0	0.0	0.0	0.0	194.5
Generation – Natural gas	17.5	15.0	20.3	33.0	43.8	0.0	12.1	0.0	141.6
Generation – Liquid fuel	0.7	0.1	1.4	0.3	0.5	0.0	0.5	0.0	3.5
Generation – Hydro	21.3	6.6	1.7	0.0	0.0	33.4	0.0	0.0	63.0
Generation – Biomass	6.6	2.9	8.6	0.0	0.0	0.5	0.0	0.0	18.5
Generation – Biogas	1.8	1.1	0.0	0.1	0.0	0.0	0.0	0.0	3.0
Generation – Solar	2.3	0.3	0.3	0.0	0.1	0.0	0.0	0.0	2.9
Generation – Wind	0.2	5.5	0.0	1.4	1.1	0.0	0.0	0.0	8.1
Total	289.1	225.9	161.5	46.3	116.6	33.8	12.6	0.0	885.9
Levels (Pj) (2020)									
Generation – Black coal	267.0	0.0	162.9	6.7	75.8	0.0	0.0	0.0	512.5
Generation – Brown coal	0.0	219.4	0.0	0.0	0.0	0.0	0.0	0.0	219.4
Generation – Natural gas	25.5	22.1	24.3	42.8	65.1	0.0	17.5	0.0	197.3
Generation – Liquid fuel	0.7	0.1	1.4	0.3	0.5	0.0	0.5	0.0	3.5
Generation – Hydro	21.3	6.6	1.7	0.0	0.0	33.9	0.0	0.0	63.6
Generation – Biomass	6.6	2.9	8.6	0.0	0.0	0.5	0.0	0.0	18.5
Generation – Biogas	1.8	1.1	0.0	0.1	0.0	0.0	0.0	0.0	3.0
Generation – Solar	2.3	0.3	0.3	0.0	0.1	0.0	0.0	0.0	2.9
Generation – Wind	0.2	5.5	0.0	1.4	1.1	0.0	0.0	0.0	8.1
Total	325.4	257.9	199.3	51.2	142.5	34.4	18.1	0.0	1028.8