Modelling the impact of greenhouse gas mitigation policies on electricity prices

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A range of Government policies can be implemented to reduce greenhouse gas emissions from the electricity generation industry. Two options that are frequently discussed in the Australian context are cap and trade emissions trading schemes and a variant of a baseline and credit scheme, which is currently in place in NSW called the NSW Greenhouse Gas Abatement Scheme. These two types of schemes can have quite different effects on patterns of investment in the electricity industry, patterns of dispatch among generators, the bidding behaviour of different generators, and the wholesale price of electricity. These effects are explored in this paper.

The comparative impact of different greenhouse gas mitigation strategies have been quantitatively estimated using two approaches. The first uses a linear programming approach to assess optimal long-term patterns of investment and dispatch to meet future projected demand growth, given the assumed greenhouse emissions policy constraints and new plant cost and availability assumptions. The second uses a game-theoretic approach to simulate bidding incentives and behaviour in a wholesale market in which standard assumptions of perfect competition are relaxed. Game theory is used to provide a systematic method for determining sustainable and profitable generator bidding strategies and is particularly well suited to analysis of generator bidding behaviour as structural changes occur within a market, such as the commissioning of new generation plant or new interconnection. The model outputs include the costs, revenues and operating profits of individual generators.

The results show that a cap and trade scheme is likely to create much higher pool prices than the business-as-usual case. By contrast, a scheme like the existing NSW scheme applied nationally would tend to reduce wholesale pool prices compared with business-as-usual. This has important distributional effects, which should be taken into account by policy makers.

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Introduction

Governments around the world are experimenting with a range of policies to reduce greenhouse gas emissions from electricity generation. Alternative scheme designs can have radically different impacts on investment, wholesale electricity prices, output, and the profitability of different electricity generators.

In the Australian electricity market, a range of Commonwealth and State-based schemes exist that aim to reduce greenhouse emissions. However, none of these schemes imposes an overall cap on greenhouse emissions. Such a cap could be implemented in two quite different ways: through a cap and trade emissions trading scheme, and a scheme imposed at the retailer level, where certificates must be purchased that each represent a tonne of carbon dioxide equivalent abated. Such a scheme already exists in New South Wales (NSW). We have explored the option of such a scheme being imposed nationally, and compared this with a cap and trade emissions trading scheme.

The National Electricity Market

The Australian National Electricity Market (NEM) encompasses the bulk of electricity sold and consumed in Australia. It currently covers the interconnected grids in New South Wales, Victoria, Queensland, South Australia and the Australian Capital Territory. From 2006, it will also cover Tasmania. The market is designed as a gross pool, and is operated by the National Electricity Market Management Company (NEMMCO). NEMMCO dispatches generators on the basis of competitive bids provided by generators on a half-hourly basis. The models used to conduct the analysis reflect these conditions.

The scenarios

We have modelled the implications of three different sets of arrangements on the NEM operating in Australia. The three scenarios that we examined are:

- business as usual (BAU). A number of greenhouse emission reduction schemes are already in place, which we have included in our analysis. The schemes modelled are the NSW Greenhouse Gas Abatement Scheme, the Queensland 13% Gas Scheme, and the Commonwealth's Mandatory Renewable Energy Target (MRET) scheme. The modelling approach is designed to simultaneously solve for multiple constraints of different types such as these;

- a cap and trade emissions trading scheme. In this scenario, we have assumed that the MRET scheme would continue to operate. The cap and trade scheme imposes a limit on emissions from the NEM, and all generators are required to surrender permits to emit greenhouse gases. (We have assumed no permits are issued for free.) We have assumed that offset credits created through forestry projects are included; and

- a scheme modelled on the NSW greenhouse benchmarks scheme, applied to the whole of the NEM. Information about the NSW scheme – which commenced in 2003, and so was one of the first emissions trading schemes to be implemented in the world – is available at www.greenhousegas.nsw.gov.au. Frontier Economics assisted in the development of this scheme. Liable parties under this scheme are retailers. Retailers must achieve an emissions target by surrendering abatement certificates. The number of certificates surrendered depends on each retailer's market share. The total certificate requirement is designed to give the same emissions outcome as has been assumed under the cap and trade scheme, to allow comparability between the results. In the existing NSW scheme, abatement certificates are known as NSW Greenhouse Abatement Certificates, or NGACs. We have termed the national version of this scheme the NATGACs scheme. Abatement certificates may be created by low emissions generators (those whose emissions rates are lower than a specified level, in this case, we have assumed lower than 0.92 t/MWh), those who undertake energy efficiency projects (in which case credit is gained for avoiding electricity consumption, and the emissions it would have entailed), and through forestry-based carbon sequestration. Existing low-emissions generators are treated differently to new generators. Existing generators are given a baseline, representing their typical levels of output. We have estimated baselines using the same cut-off dates defining new and existing plant as are used in the existing NSW scheme. We have retained the MRET scheme in this scenario also.

Methodology

Two models were used to explore the impact of the different greenhouse schemes, *WHIRLYGIG* and *SPARK*. Both of these models are proprietary software developed by Frontier Economics. *WHIRLYGIG* was used to assess the impact on investment patterns and long term output trends. *SPARK* uses a game theoretic approach to assess generators' optimal bidding strategies under each environment, to determine likely wholesale prices in each region, plus the, output and operating profits of each generator.

WHIRLYGIG

The *WHIRLYGIG* model is a mixed integer linear programming model. The model is used to optimise investment and dispatch decisions in the electricity market over the modelling period (in this case, 10 years). Specifically, it seeks to minimise the net present value (NPV) of meeting electricity demand in Australia, subject to a number of constraints, including:

- supply must exactly meet demand at all demand points;
- minimum reserve requirements in each region must be met;
- generators cannot run more than their physical capacity factors;
- generators that must run for particular periods are taken into account;
- flows over interconnects cannot exceed their capacity; and
- any additional policy constraints (eg the Mandatory Renewable Energy Target (MRET) scheme, the NSW greenhouse benchmarks scheme, a general emissions constraint) must be respected.

The model chooses from an array of investment and dispatch options over time. These include options to run existing plant (whose capital costs are assumed to be irrelevant to future decision-making, and for which only variable costs are taken into account), or to invest in new plant (where capital as well as operating costs are an important element in this decision).

In relation to new plant, assumptions are made regarding:

- committed plant;
- the fixed and variable costs associated with different technologies;
- minimum investment block sizes (for example, the model recognises that a 7 MW black coal-fired plant is not a commercially feasible option to install);
- the timing of when different technologies are available; and
- the lead times for new plant (for example, it is impossible to have a fully operational new coal-fired plant in the market by the start of 2006, unless this plant had been planned and approved some time ago).

SPARK

SPARK is a wholesale market model that replicates real bidding situations faced by generators. The modelling approach is based on game theory. This provides a mathematical and, therefore, systematic process for selecting an optimal or best strategy given that a rival has its own strategy and preferred position.

The basic concepts that underpin the game theoretic model include:

- **Players**: players are generators that are able to make decisions based on the behaviour they know or expect from other players. Strategic players are given a range of different strategies allowing them to respond to changes in the behaviour of other players. For example, non-strategic plant would include any must-run plan;
- **Payoffs**: in every game, players seek to maximise pay-off (i.e., profit) for a given set of strategies; and
- **Equilibrium:** an equilibrium describes a best or optimal set of choices by the players in the game. An equilibrium is an optimum in the sense that if any player makes another choice to improve its own position, this will elicit a strategic response by the other players in a way that will ultimately push the players back to the equilibrium point. *SPARK* employs the concept of a Nash equilibrium to determine optimal bidding behaviour.

Generators bid to maximise operating profit; that is, the pool price minus the variable costs of production (which mostly comprises fuel costs). A generator's best bidding strategy is then the bid that results in the highest operating profit.

An equilibrium set of bids is determined for varying levels of demand from off-peak through to the peak. The equilibrium bids are then used to determine the pool price for each trading interval for each year (as distinct from guessing the bids that generators with market power may submit). The average (time weighted) annual pool price may then be calculated for each year by weighting the outcomes according to the expected hours per year for that demand level.

Some caution must be exercised when interpreting game theoretic results. For example, some generators may never recognise the market power they possess. Also some generators may choose not to use their market power either because they are fearful of retaliation by a regulator or a competitor, or because they are operating against some constraint, such as those created by firm financial contracts.

Assumptions

Space does not permit a full exposition of our assumptions in this paper. However, the main assumptions to note are that:

- details on existing generator capacities and the timing of planned increments and decrements of capacity were taken from the Statement of Opportunities published by NEMMCO, which can be ordered from its website (www.nemmco.com.au);
- costs (fixed and variable) and availabilities of new black coal, brown coal, open cycle gas turbine (OCGT) and closed cycle gas turbine (CCGT) were taken from a report prepared by ACIL Tasman for NEMMCO, which can be found at www.**nem**mco.com.au/transmission_ distribution/419-0008.pdf; and
- interconnect capacities, demand forecasts (medium) and minimum reserve requirements, were taken from NEMMCO's Statement of Opportunities.

It should be noted that these results of this modelling exercise should be regarded as illustrative – a full analysis of available generation, energy efficiency and sequestration options has not been undertaken for the purposes of this paper. However, we believe that the fairly simplified set of assumptions made here are sufficient to illustrate the differences in the types of effects that could be expected under the two different types of greenhouse abatement schemes.

WHIRLYGIG results

The results generated by the *WHIRLYGIG* model include:

- size and type of new investment in each region, in each year;
- output by generator (which can be grouped by type and/or region) in each year;

- flows over interconnects between regions;
- marginal cost of producing electricity in each region, in each period (which can be transformed into an average cost per year). This is not the same as an average pool price, since *WHIRLYGIG* assumes that the generation market is perfectly competitive. The *SPARK* model relaxes this constraint, and hence delivers more realistic pool price outcomes;
- emissions by each generator, and by the NEM as a whole;
- the marginal cost of achieving each of the greenhouse policy constraints. This is equivalent to the estimated certificate price for each of the schemes.

BAU scenario

In our BAU scenario, the results show that almost 8000 MW of new capacity would be required in the NEM. A large proportion of this new capacity is open cycle gas plant, to meet growing peak demand. The mix of new capacity is shown in Figure 1 below.

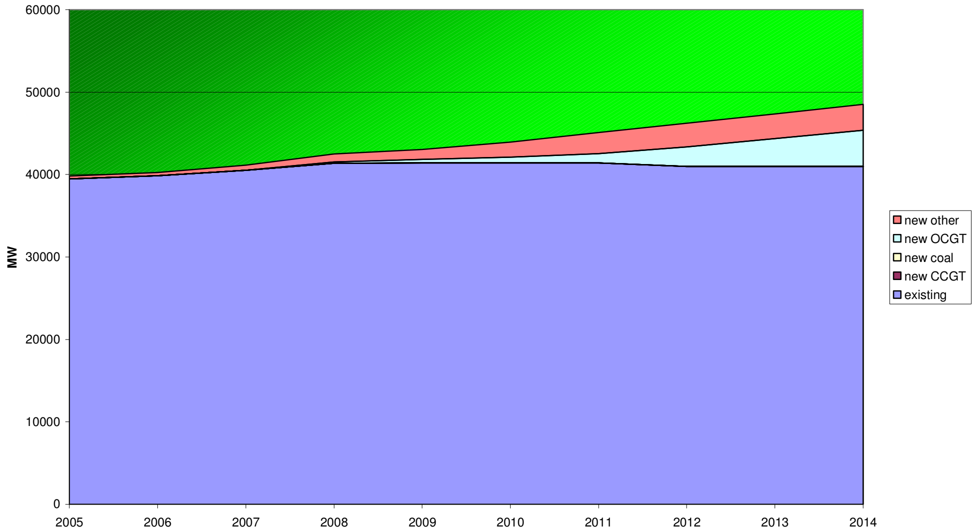

Figure 1: Mix of capacity in the NEM, 2005 to 2014

The output of different types of generators is shown in Figure 2 below. This shows that in the BAU, we would expect to see output to continue to be dominated by coal-fired plant (black and brown). A relatively small proportion of total output would be contributed by gas-fired plant, while the remainder is dominated by existing large-scale hydro plant.

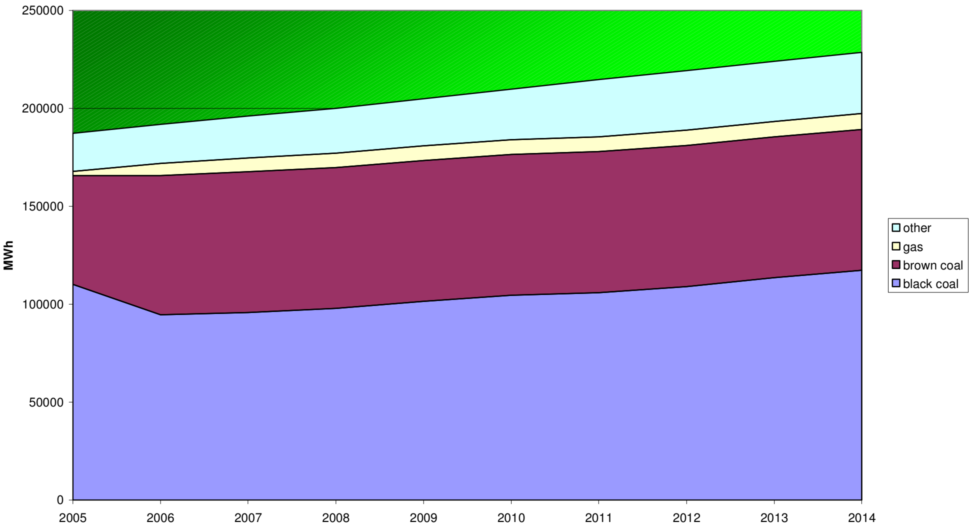

Figure 2: Mix of generation output, by fuel type, 2005-2014

The estimated BAU emissions trajectory of the NEM is shown in Figure 3. This shows that in the absence of any additional government intervention, emissions in the electricity sector would be expected to rise by 18 Mt, or almost 10 per cent.

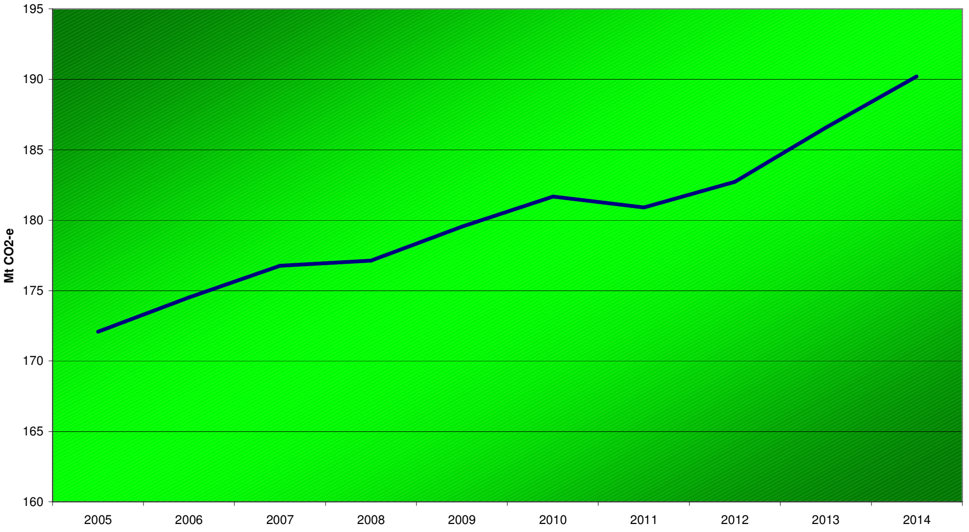

Figure 3: NEM emissions, BAU scenario, 2005-2014 (MtCO$_2$-e)

Emissions constraints used in cap and trade and NATGACs scenario

To contrast the effects of a cap and trade scheme and a NATGACs-type scheme, we have chosen to model a 10 per cent reduction in emissions by 2014 compared with BAU. We have selected emissions targets that step down gradually to meet this target. The emissions constraints used in both the cap and trade scenario and the NATGACs scenario are shown in Figure 4 below. By the end of the modelling period, the abatement schemes are required to reduce greenhouse emissions by 36 Mt compared with BAU.

Figure 4: NEM emissions, BAU compared with constraints in cap and trade and NATGACs scenarios

Cap and trade scenario

Meeting the emissions constraints in the cap and trade scenario significantly changes the expected investment mix in the NEM over the next 10 years. The differences between the BAU investment mix and the cap and trade investment mix is shown in Figure 5.

The main change is that it encourages a change in the mix of gas-fired plant. Under the relatively strict cap and trade targets, it becomes economic to build more CCGT than OCGT plant. Under the BAU, OCGT was installed to meet peak demands, and ran quite rarely. Under the cap and trade scenario, it becomes more sensible to incur the greater capital costs associated with a CCGT plant, because this is outweighed by lower operating costs, over much greater operating volumes. (Changes in output are discussed below.)

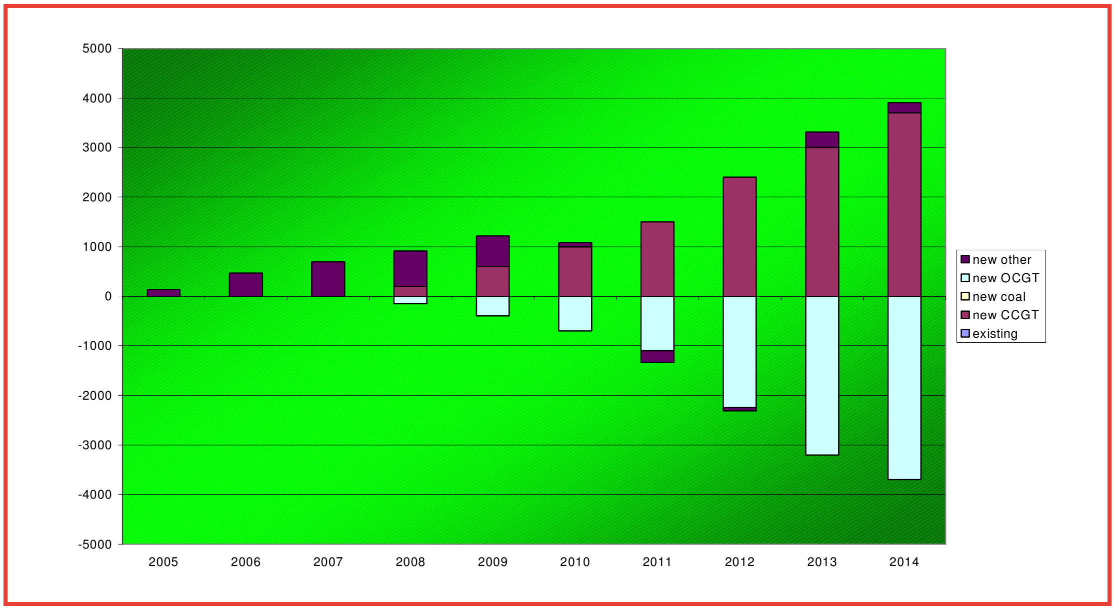

Figure 5: Differences in investment mix between BAU and cap and trade scenarios, 2005-2014 (MW)

The impact on the mix of output in the NEM is shown in Figure 6. This shows that the scheme is likely to encourage significantly more output from gas-fired plant – principally CCGT plant – at the expense of more emissions-intensive brown and black coal-fired plant.

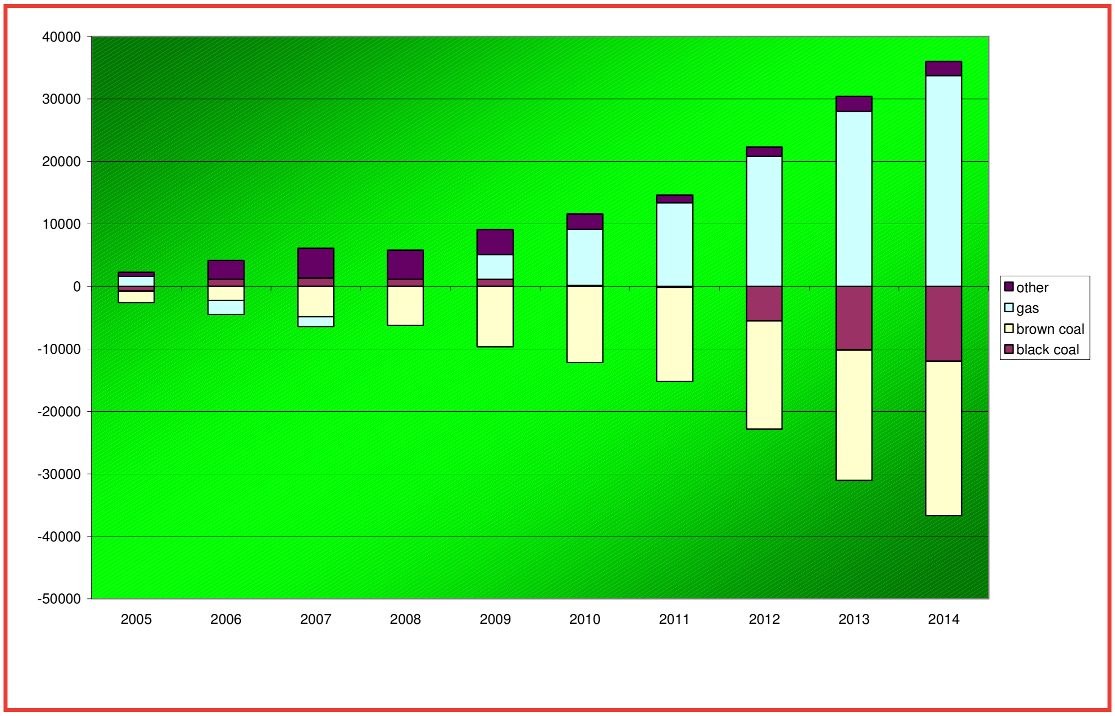

Figure 6: Differences in output mix, by fuel type, cap and trade compared with BAU, 2005-2016 (MWh)

The marginal cost of achieving such steep reductions in emissions is very high. The estimated price of an emission permit (representing the right to emit one tonne of carbon dioxide equivalent) is shown in Figure 7. This rises from around A$20 per tonne to around A$37 by the end of the period. We would expect that emission permits would trade at the marginal cost of abatement – that is, at these prices.

As for the impact on total costs, the marginal cost of abatement is a function of the stringency of the emissions cap and the cost and availability of different abatement options.

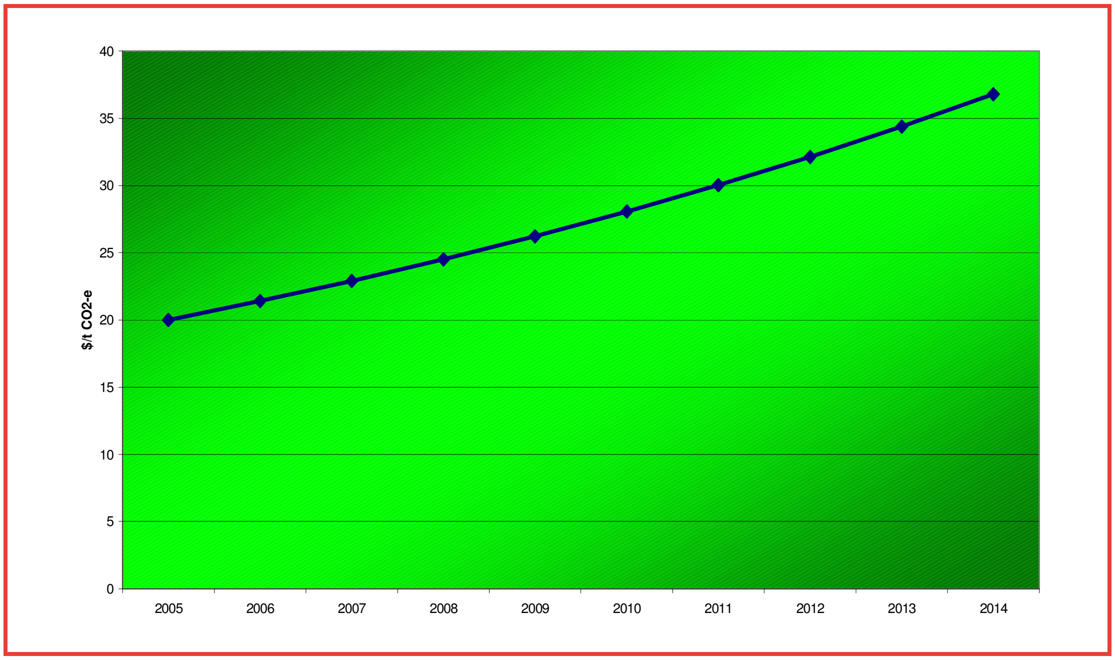

Figure 7: Estimated emission permit prices, 2005-2014 (A$/t$CO_2$-e)

NATGACs scenario

Meeting the emissions constraint under the NATGACs scenario is also expected to change the mix of capacity installed in the NEM over the next 10 years. This is shown in Figure 8. The effect on the investment mix is very similar to that under the cap and trade scenario: CCGT plant is constructed instead of CCGT plant. In this scenario, the ability to create and sell abatement certificates causes this change. Since CCGT plant are less emissions-intensive than OCGT plant, more certificates can be sold for a given level of output. This extra source of revenue means that it becomes economic to build a plant that is expected to run harder than a typical peaking OCGT plant.

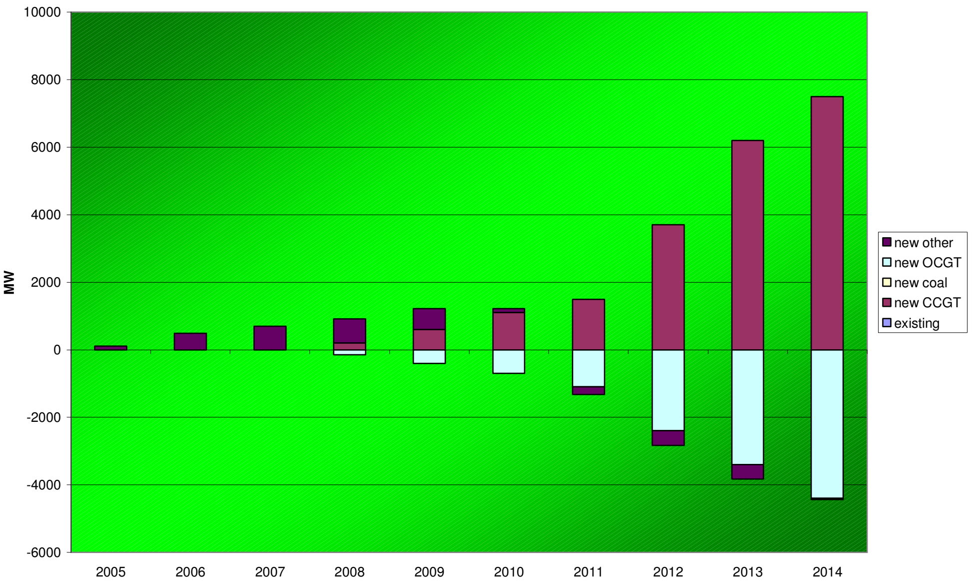

Figure 8: Change in capacity mix, by fuel type, BAU compared with NATGACs scenario, 2005-2014 (MW)

The change in output mix in the NATGACs scenario compared with the BAU is shown in Figure 9. This shows that the scheme is likely to encourage a reduction in coal-fired output, which is displaced by gas-fired output, principally from CCGT plant.

It is interesting to note that this scheme has tended to displace a greater proportion of black coal-fired output than brown coal-fired output, compared with the cap and trade scheme. We note that this result is sensitive to the target chosen, and the gas prices assumed. However, there is a general explanation why such a result might sometimes occur. In the NATGAC scheme, CCGT plant are rewarded with an additional stream of revenue through the sale of certificates. Their relatively emissions-intensive competitors experience no change to their costs. By comparison, a cap and trade emissions trading scheme alters the marginal costs of both a CCGT plant and the brown and black coal-fired plant. In this instance, the NATGAC scheme meant that CCGT plant became relatively more competitive with black coal fired plant than with brown coal-fired plant, and hence a larger proportion of the new CCGT plant was installed in a region dominated by black coal-fired plant, but with no brown coal fired plant (Queensland). In the cap and trade case, CCGT became more competitive with brown coal-fired plant, and so a greater proportion of this plant was located in regions dominated by brown coal-fired supply (Victoria and, to a lesser extent, South Australia).

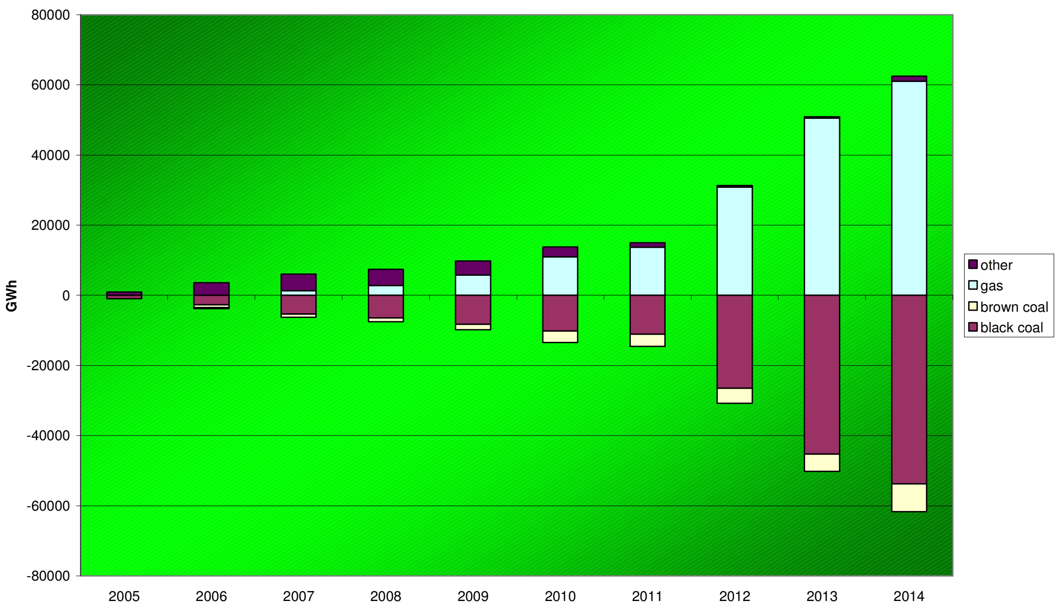

Figure 9: Change in output mix, by fuel type, BAU compared with NATGACs scenario, 2005-2014 (GWh)

The marginal cost of abatement under the NATGACs scheme will set the price of abatement certificates. The estimated price of certificates is shown in Figure 10. The cost of abatement certificates under the NATGACs scheme are somewhat higher than the cost of emission permits under the cap and trade emissions trading scheme. This reflects the fact that the NATGACs scheme relies on defined abatement activities, rather than allowing all subtle changes in output mix to contribute to the abatement task. This issue is discussed further below.

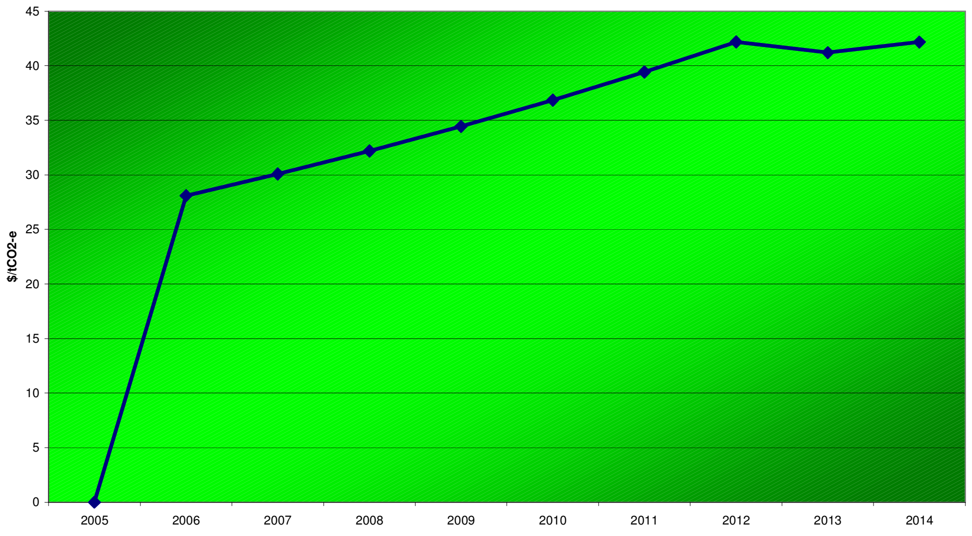

Figure 10: Estimated price of abatement certificates, NATGACs scenario, 2005-2014 ($/t/CO$_2$-e)

Total costs of meeting the targets

Meeting this relatively strict target in such a short space of time is expected to add to electricity costs.

The net present value of all costs incurred in meeting demand and complying with greenhouse constraints has been calculated for all three scenarios. The results are presented in Figure 11. This shows that both a cap and trade scheme and a NATGACs scheme would be expected to add significantly to total generation costs. The size of the increase depends on the stringency of the target, and the cost of abatement options.

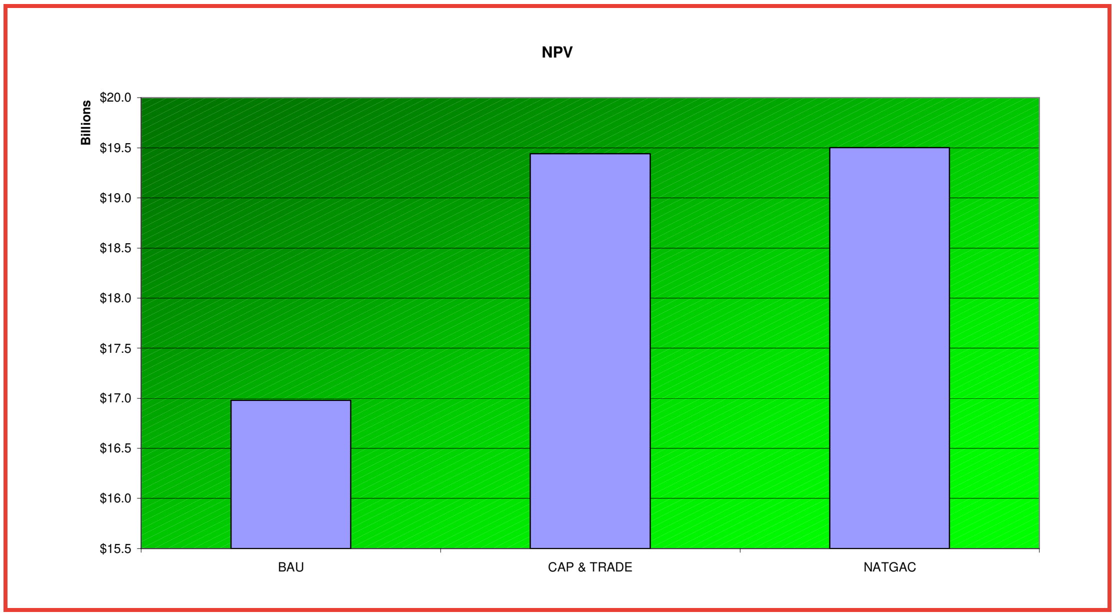

Figure 11: NPV costs of meeting demand under BAU, cap and trade and NATGACs scenarios, 2005-2014 (A$)

Interestingly, there is little difference between the estimated NPV costs of generation under the CAP & TRADE scenario and the NATGACs scenario. However, total generation costs are slightly higher under a NATGACs scheme than a cap and trade scheme. The main reason lies in the difference in the ways that the two schemes encourage abatement. The NATGAC scheme encourages abatement by rewarding a defined set of generators and other activities. It will not necessarily capture the fine adjustments in output mix that might be encouraged under a cap and trade scheme, for example, adjustments in the mix of output from existing emissions-intensive plant – some of which might be less emissions-intensive than others.

For the purposes of this exercise, we have not included a detailed list of potential energy efficiency measures that might be rewarded under a NATGACs scheme. It is possible (although not guaranteed) that a NATGACs type of scheme might be more successful in encouraging energy efficiency than a cap and trade scheme. A NATGACs scheme rewards energy efficiency measures directly – proponents are entitled to create abatement certificates, which can be sold to electricity retailers. A cap and trade emissions trading scheme rewards energy efficiency indirectly, by reducing proponents' electricity bills. To the extent that the NATGACs scheme is more successful in overcoming any 'psychological' barriers to implementing energy efficiency measures, it might encourage a more cost-effective response to the emissions cap.

SPARK results

The *SPARK* model generates the following results:

- equilibrium pool prices in each region;
- output, operating costs and operating profit for each generator;
- emissions for each generator;
- flows over each of the interconnects between each region.

For the purposes of this paper, we shall report on a subset of these results, to contrast the impact of the cap and trade scheme compared with the NATGAC scheme in a particular region.

Equilibrium results

SPARK produces multiple equilibria for each demand point and, mathematically at least, each equilibrium is just as likely to occur as any other. In some cases there can be hundreds of possible (equilibrium) bidding, and hence price, outcomes. Often widely different patterns of bidding can produce very similar pricing outcomes, while at other times there is a substantial range between the lowest and highest price outcomes for the same supply and demand conditions.

To provide a sense of this distribution of equilibrium prices a probability distribution curve can be formed of the equilibrium prices. Average equilibrium prices have been formulated from the range of equilibrium prices determined for each of the 10 demand points modelled. This has been achieved by taking a random draw of 8760 (i.e. number of hour hours in a year) equilibrium prices, based on the probability of each demand point occurring in each year and formulating a (time weighted) average price. This process of randomly drawing 8760 observed equilibrium prices was then repeated 100 times to provide the basis for developing a distribution of average (equilibrium) price outcomes.

An example of such a probability distribution curve is provided in Figure 12.

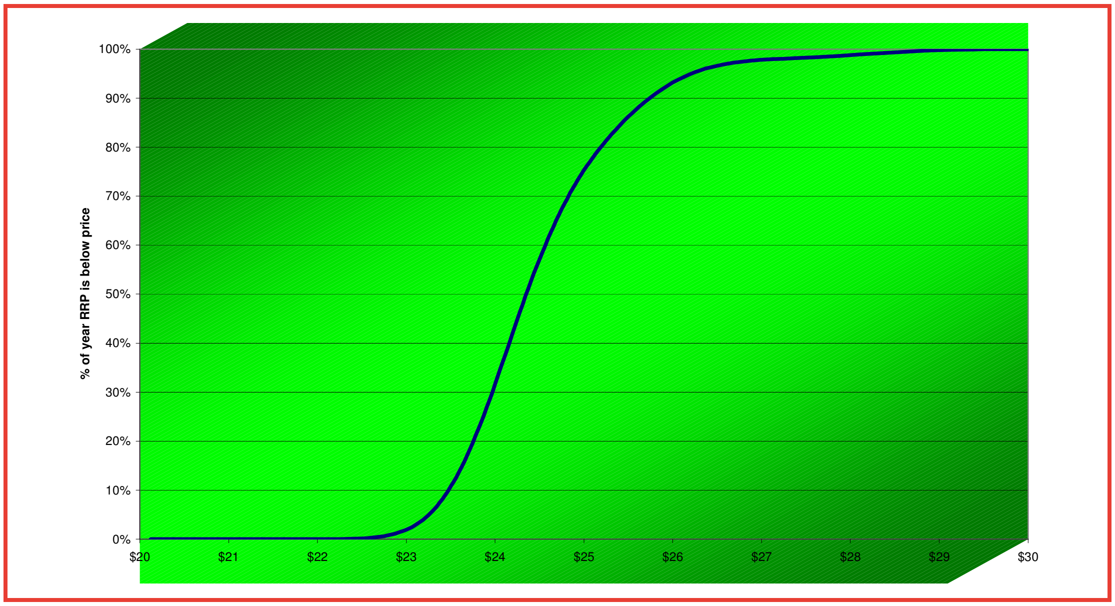

Figure 12: Average pool prices in Victoria, probability of exceedance (A$/MWh)

To illustrage the effects of the two different types of schemes on pool prices and the operating profits of different types of generators, we report a subset of results: pool prices in the Victorian region (which is dominated by brown-coal-fired plant) and the impact on two very different existing power stations, Loy Yang B (a brown coal-fired plant) and Bairnsdale, a relatively new OCGT plant.

Pool prices in the Victorian region

Estimated pool prices in Victoria under the three scenarios are shown in Figure 13. The columns represent point at which we estimate that there is a 50% chance that the pool price will be at least this high. Furher information about the distribution of equilibria is shown by lines above and below the bar height. The lower bar represents the price at which the probability of exceedance is 80%. The higher bar represents the point at which the probability of exceedane is 20%. The narrower this range, the more tightly arrayed were the equilibrium results. A wider band indicates that there is a greater variance in the equilibria results, and hence there is a greater degree of uncertainty over projected pool price outcomes.

The results show that a cap and trade scheme is likely to increase pool prices. This is because the need to purchase certificates increases the marginal cost of all fossil fuel-fired plant. The more emissions-intensive the plant, the greater the increase in marginal costs. The results for the NATGAC scheme are more ambiguous. In general and across all years, however, the NATGAC scenario tends to result in lower pool prices than the BAU, and substantially lower pool prices than under the cap and trade scenario. The logic behind this result is relatively straightforward. The NATGAC scheme provides certain generators (low-emissions generators, generally gas) with an additional source of revenue. This extra revenue stream means that they can afford to bid in lower prices into the pool and still be no worse off. Moreover, for existing generators that must generate beyond a baseline level before they are entitled to create certificates, there is an additional incentive to increase output compared with BAU. The only way that a gas-fired generator can increase its output is to bid below its rivals, which places further downward pressure on pool prices.

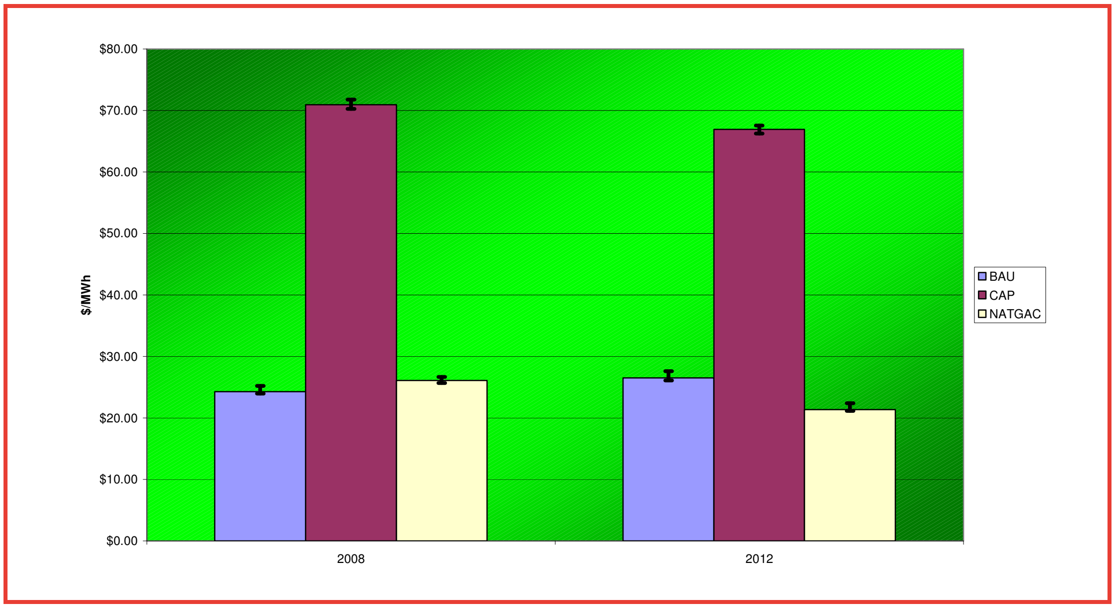

Figure 13: Estimated pool prices in BAU, cap and trade and NATGACs scenarios, 20%, 50% and 80% probability of exceedance

These price results can be contrasted with the information on the marginal costs of electricity generation obtained from *WHIRLYGIG*, as shown in Figure 14 below. If the NEM were perfectly competitive, pool prices would be expected to equal these results. The difference between the marginal costs estimated in *WHIRLYGIG* and the results found in *SPARK* can be attributed to the exercise of market power. Generators employ bidding strategies to increase pool prices to increase their levels of operating profit.

It should be noted that the reason why the marginal cost of electricity production estimated in *WHIRLYGIG* in the NATGAC scenario is less than the marginal cost of production in the BAU scenario is because it reflects the *incremental* cost of producing electricity, once the NATGAC target has been satisfied.

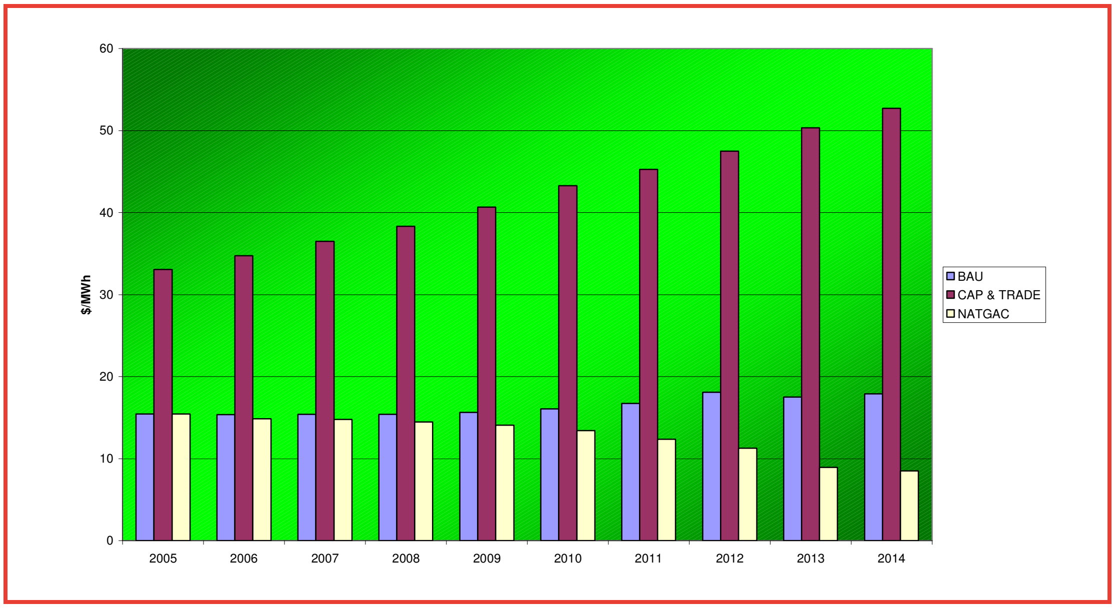

Figure 14: Marginal cost of electricity production, Victorian region, BAU, cap and trade and NATGACs scenarios, *WHIRLYGIG* results ($/MWh)

Impact on generators

The impact on different generators is likely to vary with the type of scheme implemented. This is illustrated by the results for the operating profits of one of Australia's more emissions-intensive plant, the brown coal-fired Loy Yang B.

The range of estimated operating profits in the years 2008 and 2012 is shown in Figure 15 below. In most years we find that Loy Yang B is worse off, because the benefit it receives from an increase in pool prices is outweighed by the increase in its costs. However, in some years, the increase in pool prices is so large that it outweighs this cost increase.

The estimated impact on the OCGT plant Bairnsdale, also located in Victoria, is shown in Figure 16. This shows that Bairnsdale is consistently better off under the cap and trade scheme than it is under the BAU scheme, because the increase in pool prices greatly exceeds the increase in its costs. Its fate under the NATGACs scheme is perhaps more surprising. Although it would be entitled to produce abatement certificates, its increase in revenue does not outweigh the reduction in pool prices that this scheme tends to create.

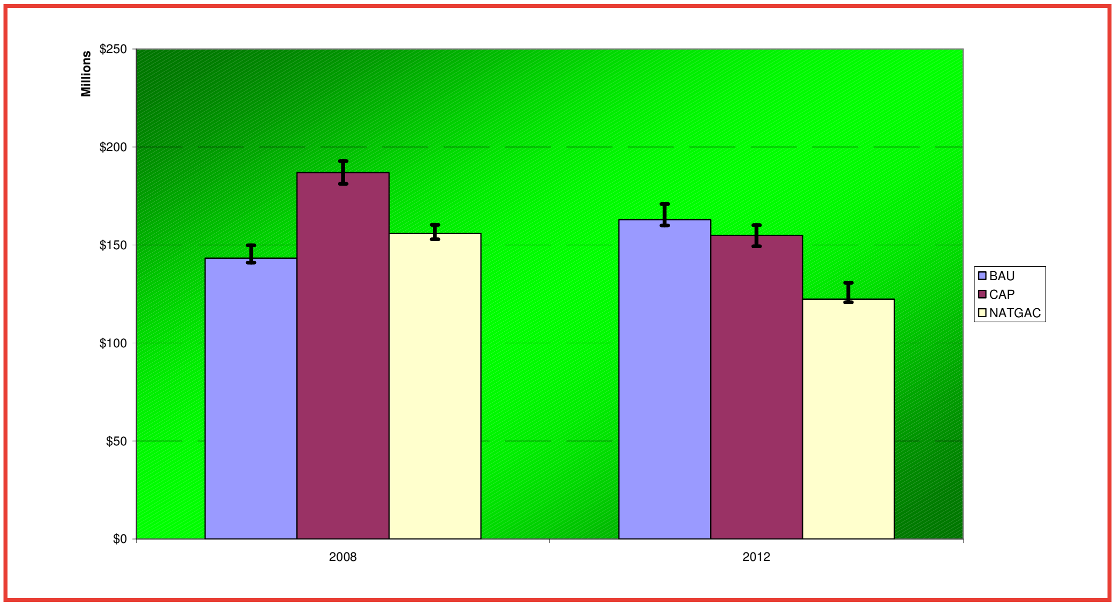

Figure 15: Loy Yang B operating profits, 20%, 50% an 80% probability of exceedance, 2008 and 2012

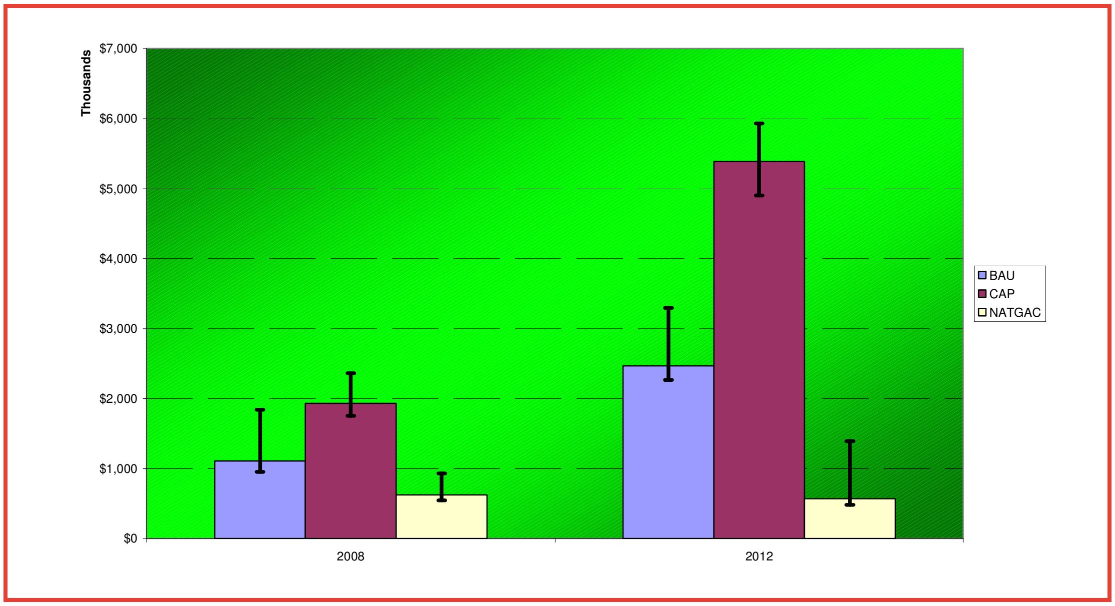

Figure 16: Bairnsdale operating profits, 20%, 50% an 80% probability of exceedance, 2008 and 2012

Caveats

As in all modelling exercises, the *SPARK* and *WHIRLYGIG* models are abstractions from reality, and are a product of their assumptions. In particular, it should be note that:

- the magnitude and in some cases even the direction of results are critically dependent on the emissions target chosen;
- different cost and availability assumptions for new plant options can lead to different results;
- we have assumed no changes in the capacity of interconnects between regions. New interconnects can significantly affect results;

- we have not undertaken a detailed review

More generally, the *WHIRLYGIG* modelling approach assumes that there is an omniscient central planner, who is able to optimise new plant installation, as well as the dispatch of all plant, to minimise overall costs. In practice, generation planning can never be perfect.

The *SPARK* model assumes that all generators act rationally, with the goal of maximising operating profits. In practice, we observe that, at times, generators either act irrationally, or are pursing goals other than profit maximisation.

Finally, we have assumed no hedging contracts in the *SPARK* modelling. We have adopted this approach to examine the underlying pool dynamics – which in turn would influence generators' and retailers' optimal contracting strategies. The existence of contracts

Conclusions

The *WHIRLYGIG* and *SPARK* models are capable of undertaking sophisticated analyses of greenhouse policy constraints in electricity markets. They may be adapted to any electricity market structure in the world, incorporating any number of nodes, demand points, generators, and regions.

For the purposes of this paper, stylised examples of an emissions trading scheme and a NATGACs scheme were modelled, to assess the impact of different types of greenhouse schemes on the electricity market.

The results show that a cap and trade scheme will tend to increase investment in new gas plant compared with coal, and will tend to encourage gas plant to run harder than they would in the BAU case. Wholesale pool prices would be expected to rise, as certificate prices add to generator costs. Not all generators will be harmed by such an event. Some low-emissions generators (gas, renewable) could potentially benefit significantly. This is because the rise in revenues resulting from increased pool prices and increased output would outweigh the increase in costs resulting from the need to purchase emission permits.

On the other hand, a NATGAC type of scheme would be expected to reduce wholesale prices compared with BAU. This is because those generators that are entitled to create abatement certificates would treat this source of revenue as a subsidy on their running costs. This allows them to bid into the market at a lower price than previously, dragging down average wholesale prices.

The impact on different types of generators under a NATGAC scheme depends on whether the generator is entitled to create certificates. Generators that are entitled ot create abatement certificates are lieklyt o be better off under such a scheme than under the BAU. This is because they are insulated from the effects of reducing wholesale prices by the extra source of revenue flowing from certificate sales. However, generators that are not entitled to create certificates (such as older coal-fired stations) are likely to be worse off under such as scheme than they would be under BAU.

For final consumers of electricity, the impact on retail prices is mixed. Under a cap and trade scheme, retail prices would certainly rise. Under a NATGACs-style scheme, final retail prices are a function of two factors:

- a reduction in wholesale prices compared with BAU; and
- a positive cost of certificates, which must be purchased by retailers.

It is impossible to say *a priori* which of these effects will dominate. It is likely that final retail prices will not rise as much under a NATGACs type of scheme compared with a cap and trade scheme.

The flexibility of the *WHIRLYGIG* and *SPARK* models in assessing the consequences of different emission mitigation schemes allows a systematic evaluation of the relative benefits and detriments of such schemes to be assessed. Given that, in the future, such schemes can only become more common and that their effects on market processes are significant, robust methods of analysing the impacts of emission mitigation schemes will become increasingly important.