Cutting Australia's Carbon Abatement Costs with Nuclear Power

Martin Nicholson, October 2011

Abstract

The Australian Government Treasury modelling of a carbon price shows that Australia must purchase the benefits of overseas abatement efforts if it is to meet its emission reduction target by 2050. That is, foreign abatement will be required to supplement domestic abatement efforts. If more domestic abatement were available, fewer foreign credits would be needed. As an example, the analysis here shows that for the core Treasury policy scenario, Australia could save up to $185 billion net in abatement costs by 2050 if 25 gigawatts of nuclear generation capacity were built instead of building new fossil fuel generators.

Introduction

In July 2011, the Australian Government Treasury released its report titled *Strong Growth, Low Pollution - Modelling A Carbon Price* [1]. Treasury modelled a range of scenarios which explored different environmental targets and design features in a carbon pricing scheme.

To deliver Australia's electricity supply over the period to 2050, the Treasury modelling assumes a mix of renewable and fossil fuel technologies. To conform to current government policy, the Treasury modelling excludes any contribution from nuclear power in Australia. Here we model a technology scenario for Australia without that imposed constraint. The main finding is that including nuclear power in the abatement portfolio would make Australia much less dependent on overseas abatement credit purchases and would save the economy up to $185 billion.

For simplicity, we will consider the *core policy scenario* in the Treasury modelling where a carbon price is introduced in 2012, moving to a flexible price cap-and-trade scheme in 2015. The core policy assumes the world takes action to stabilise greenhouse gas concentration levels at around 550 ppm by around 2100. Although some will argue that this stabilised concentration level needs to be much lower, this core policy from Treasury provides a reasonably credible mid-range scenario, and provides for Australian emission reduction targets to be 5 per cent below 2000 levels by 2020 and 80 per cent below 2000 levels by 2050.

For Australia to achieve these reduction targets, the Treasury modelling shows that in addition to domestic emission reductions, Australia will need to purchase abatement permits from overseas. Our analysis of the Treasury modelling shows that it will be necessary to purchase a total of 9,100 Mt CO_2-e of overseas permits by 2050 at a cost of $716 billion.

The focus of this analysis is to consider whether some of this cost of purchasing overseas permits could be saved by investing some of that money in nuclear power to further reduce domestic emissions. Reducing domestic emissions negates the need for overseas permits, and is more easily verifiable as actual reductions.

In the Treasury core policy scenario modelling, the greatest reductions in domestic emissions occur in the electricity sector. Coal-fired generation is reduced, more renewable energy and gas are used to generate electricity, and carbon capture and storage reduces emissions from coal and gas (after 2035). Despite the decline in coal-fired generation, this scenario still has 45 per cent of electricity coming from coal in 2030 and 26 per cent by 2050.

In line with current government policy, nuclear power was specifically excluded from the Treasury modelling. This analysis aims to fill the resulting gap. Reference to "Charts" in this document refers to charts in the Treasury modelling report.

The Cost of Overseas Permits

Given the technology constraints, the Treasury modelling shows that domestic abatement alone cannot meet the emission reduction targets, making it necessary for Australian businesses to purchase permits from overseas to make up the shortfall (see Chart 5.2).

Based on Chart 5.2 in the Treasury report, the need for internationally sourced abatement rises progressively from 2012 to 2050 (see Fig. 1). Between 2012 and 2050, Australian businesses will need to purchase overseas permits for 9,100 Mt CO_2-e of emissions. At the same time the anticipated carbon price in the core policy shown in Chart 5.1 will also rise as shown in Fig. 1.

Calculating the total overseas abatement in each five year period and applying an average carbon price in each period yields a total cumulative permit cost of $716 billion by 2050 (see Fig. 7).

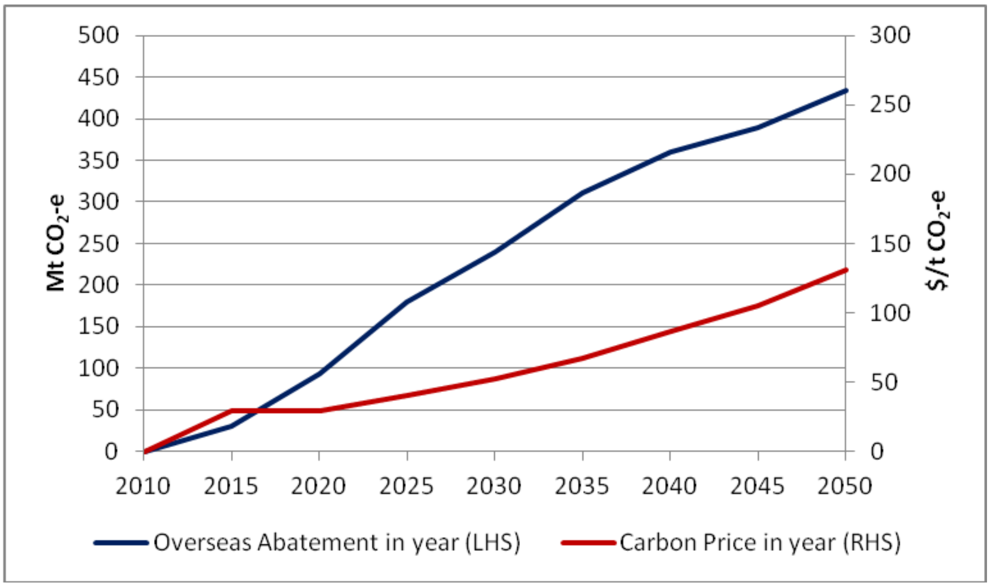

Fig. 1 Treasury overseas abatement and carbon pricing based on Chart 5.1 and 5.2

Replacing Fossil Fuels

Potentially, up to $716 billion (in terms of the cost of buying overseas permits) could therefore be saved by reducing domestic emissions further than proposed in the Treasury modelling. One source of reductions would be to replace all coal plants and some gas plants with nuclear plants. To assess the impact of this, it is necessary to estimate the installed capacity of coal and gas plants and the emissions from those plants in the Treasury core policy. This is not explicitly identified in their modelling.

By analysing Chart 4.11 and Chart 5.17 it is possible to assess the total electricity demand used in the Treasury modelling for the core policy scenario (see Fig. 2). Treasury believes that electricity demand will fall relatively because of more efficient consumption choices and production processes after a carbon price is introduced.

Chart 5.19 in the Treasury modelling shows the sources of electricity generation. For the purpose of this fossil fuel analysis, the core policy scenario prepared by consultants SKM MMA has been used. SKM MMA was chosen because it advocates a higher proportion of renewable energy than ROAM and therefore likely to deliver lower cost savings from replacing fossil fuels with nuclear power (in other words, the worse case of the two models).

Applying the percentage of generation for coal and gas it is possible to assess the probable installed capacity of coal and gas plants up to 2050 assuming the capacity factor of future plants remains unchanged (see Fig. 3).

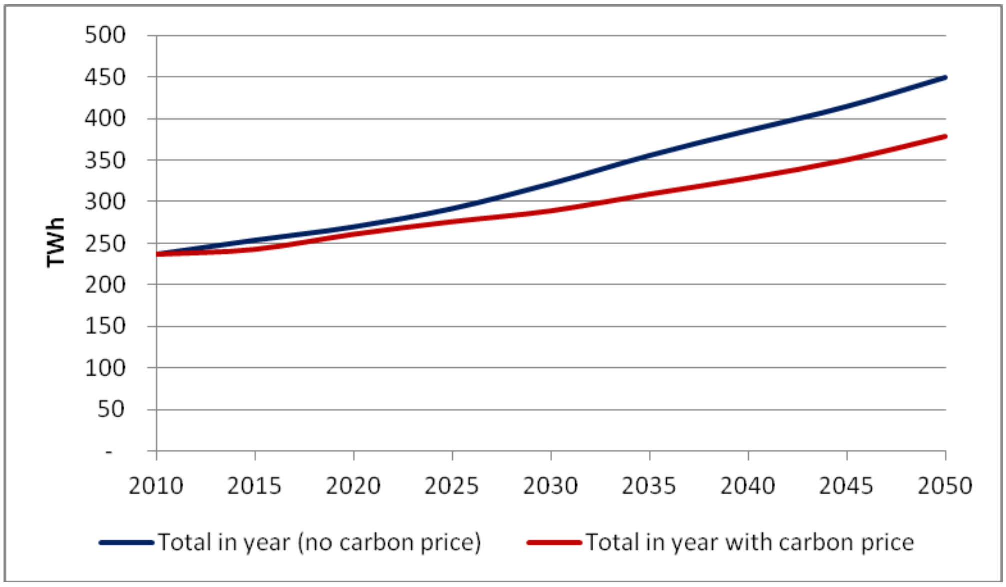

Fig. 2 Treasury projection of electricity generation with and without a carbon price

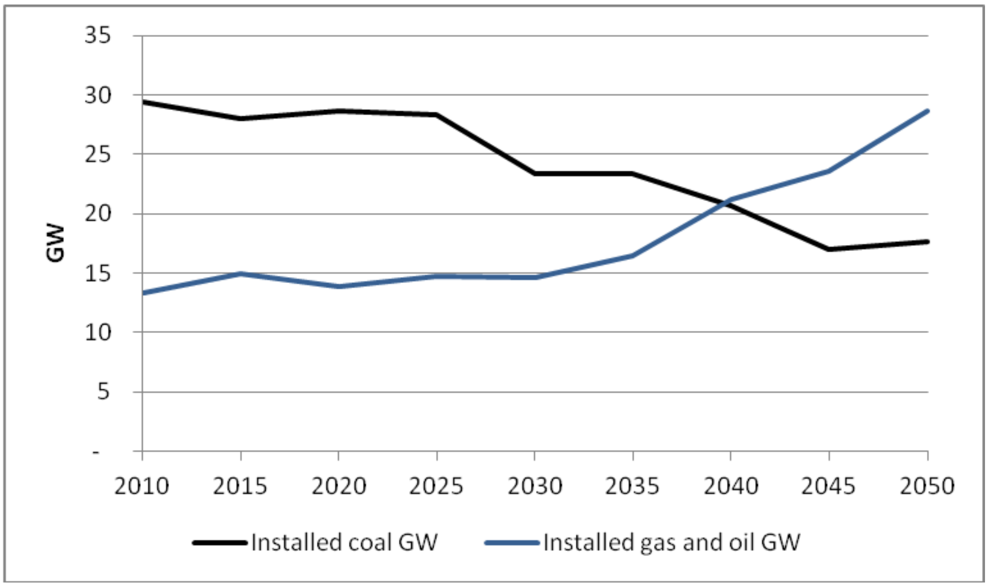

Fig. 3 Estimated operating fossil fuel plants to 2050 based on Treasury model

The current installed coal capacity is about 29 GW [2]. Our analysis shows that 23 GW of coal plants will still be operating in 2030 and 18 GW in 2050, at which point about 11 GW will be black coal with CCS and 7 GW will be black coal without CCS. All brown coal is phased out by 2040.

The current installed gas and oil capacity is about 13 GW. Our analysis shows that 29 GW of gas and oil plants will be operating in 2050. Of these, about 10 GW will be gas with CCS.

The average emissions intensity of the fossil fuel plants will progressively improve (see Fig. 4) as the brown coal plants are closed, some black coal plants are converted to CCS and more gas plants are built. This estimate of emissions based on the above analysis closely matches Chart 5.18 in the core policy Treasury modelling.

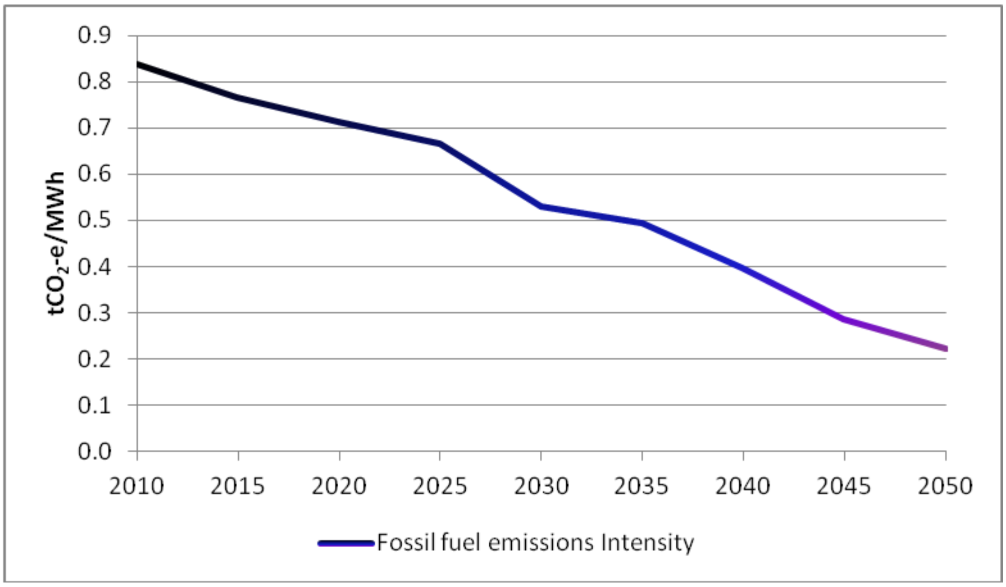

Fig. 4 Fossil fuel emission intensity based on estimate of installed plants

Applying the emission intensity in t CO_2-e/MWh to the fossil fuel generation in MWh up to 2050 gives the potential additional domestic abatement that might be possible from the electricity sector if all fossil fuel generation was eliminated. This additional domestic abatement comes to 5,700 Mt CO_2-e or nearly two thirds of the overseas permits proposed in the Treasury modelling.

Clearly it is not possible to replace all fossil fuels in the period as it would take time to build replacement generating plant. In the next section we consider replacing some of these fossil fuel plants with nuclear power by 2050.

Nuclear Build Program

In 2006, the Australian Government's Department of Prime Minister and Cabinet commissioned a report title *Uranium Mining, Processing and Nuclear Energy Review* or UMPNER for short [3]. Among other things, this report considered the possible contribution of nuclear energy in Australia in the longer term. An outcome of this consideration was as follows:

"Under a scenario in which the first reactor comes on line in 2020 and Australia has in place a fleet of 25 reactors by 2050, it is clear that nuclear power could enhance Australia's ability to meet its electricity needs from low-emission sources. By 2050 nuclear power could be delivering about one third of Australia's electricity needs."

It now seems timely to apply this suggested nuclear build to the Treasury core policy scenario. It so happens that 25 GW of nuclear plants (as proposed in UMPNER) will replace all the remaining coal plants in the core policy as well as some gas plants.

It will take several years to build 25 GW of nuclear plants. Fig. 5 charts one possible build program starting in 2015-2020 and completed by 2035.[a] Assuming the plants are commissioned progressively, Fig. 5 also shows the anticipated operating capacity in each period.

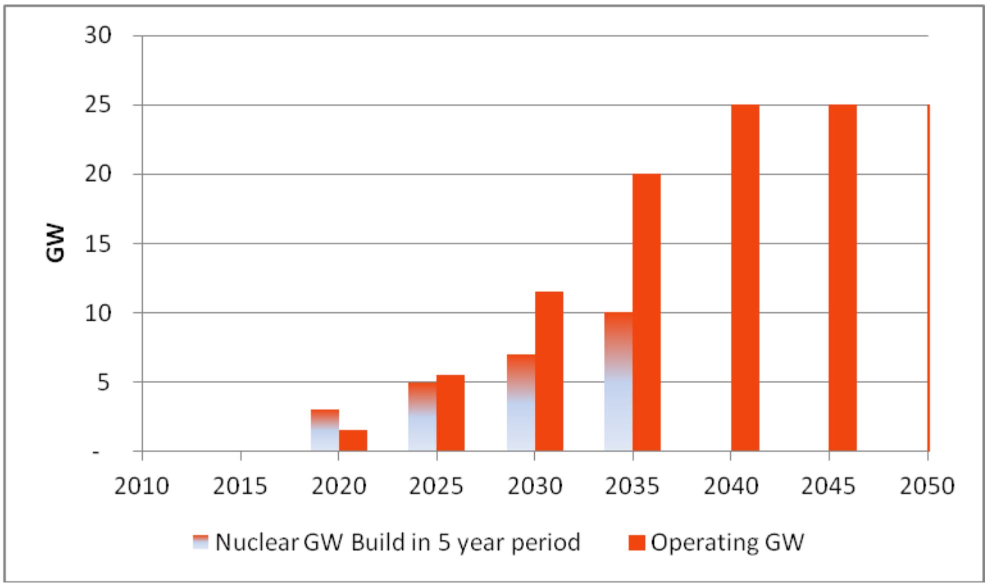

Fig. 5 Nuclear build program starting in 2015-2020

Fig. 6 takes the SKM MMA model in Chart 5.19 and adds the suggested nuclear build to the mix. In this analysis we have applied the nuclear plants to first replace brown coal plants, then black coal plants followed by coal with CCS and finally replacing some gas and oil plants. The amount of renewables has not been changed from the Treasury core policy.

As the Treasury core policy has the 2050 electricity demand at around 380 TWh (UMPNER assumed the demand in 2050 would be 554 TWh), these nuclear plants would supply 38 per cent of the electricity by 2050.

[a] The actual timetable and build size could (and almost certainly will) be varied. The issue here is to consider the concept not to set out a firm strategy.

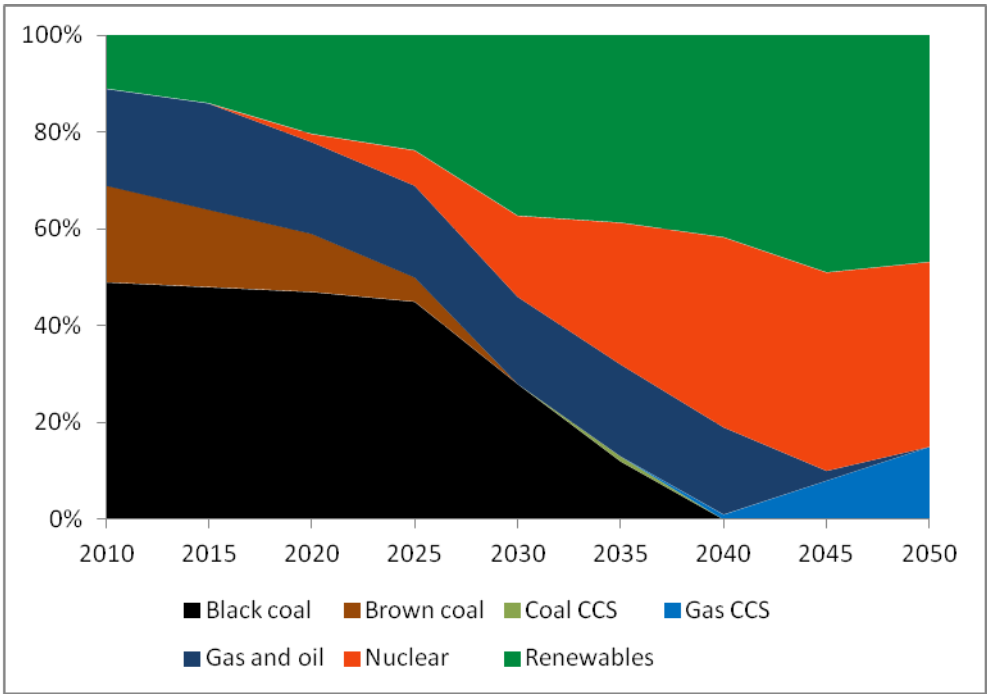

Fig. 6 Source of electricity generation including nuclear power

The net effect on emissions of using nuclear power is to reduce the need to purchase overseas permits by around 2,200 Mt at a cost of $185 billion, by 2050 (see Fig. 7). This reduction in domestic emissions also lowers the overall emission intensity of the national electricity sector to 26 kg/MWh by 2050 (see Fig. 8).

In absolute terms, emissions from electricity can be reduced by 95 per cent below 2000 level by 2050 using 25 GW of nuclear power in combination with the forecast growth of renewables already built into the core policy scenario.[b] The Treasury core policy scenario without nuclear only reduces electricity emissions by 53 per cent below 2000 level.

[b] Any change to the nuclear build timetable or capacity might change the renewable component depending on the cost competitiveness of each option.

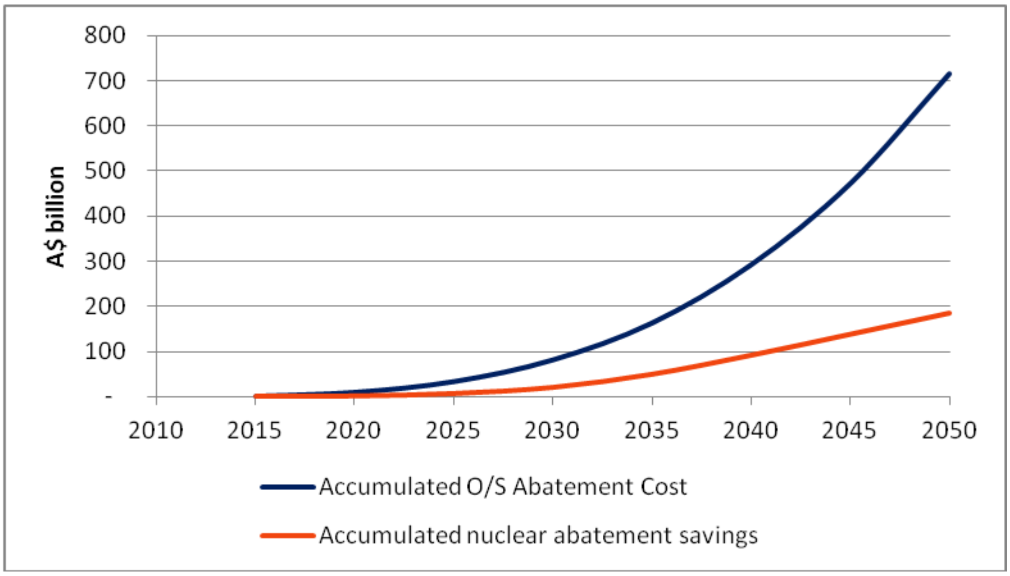

Fig. 7 Accumulated overseas abatement cost and nuclear abatement savings

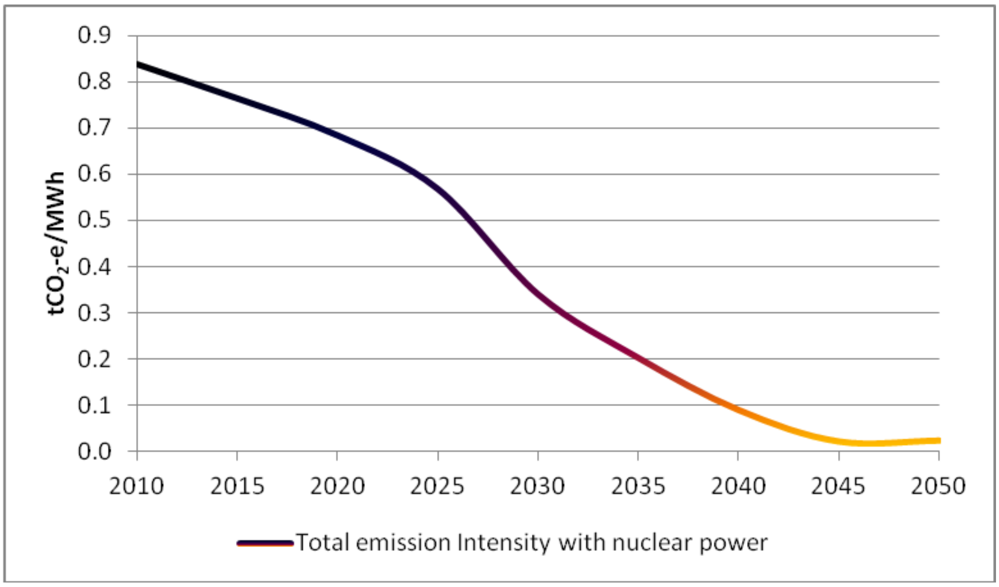

Fig. 8 Anticipated emission intensity of electricity generation with nuclear power

Nuclear Build Costs and Savings

To our knowledge, only two comprehensive studies have been made into the cost of building nuclear plants in Australia, both by EPRI[c]. The first, titled *Review and Comparison of Recent Studies for Australian Electricity Generation Planning* [4], was prepared in 2006 for the UMPNER report and compared and contrasted the results of contemporary studies examining the economic costs and other impacts of using nuclear, coal, natural gas and renewables for electricity generation. The second, titled *Australian Electricity Generation Technology Costs*

[c] Electric Power Research Institute

– *Reference Case 2010* [5] was prepared in 2010 for the Australian Government Department of Resources, Energy and Tourism.

Section 3.3 of the 2006 EPRI report looked at the overnight cost of building various fossil fuel and nuclear plants from five separate studies. The overnight cost (usually expressed in dollars per kW) is the present value cost that would have to be paid as a lump sum up front to completely pay for the construction of the plant.

Figure 3.3 in the 2006 EPRI report shows that nuclear overnight costs ranged from $1,750/kW to $3,000/kW. These costs were for countries that already used nuclear power and EPRI recommended in section 4.2.5.3 a scaling factor of 1.1 (10 per cent increase) for construction costs in Australia. This brings the range to $1,925/kW to $3,300/kW.

EPRI's 2010 report evaluated capital costs for Generation III reactors. Table 6-11in the EPRI 2010 report shows the 2015 overnight cost as $5,742/kW and 2030 overnight cost as $4,876/kW.

The IEA reported overnight costs for various projects in 13 OECD countries in its report *Projected Costs of Generating Electricity 2010 Edition* [6]. Table 5.1 in this IEA report shows nuclear overnight costs ranged from $1,556/kW to $5,863/kW, depending on the country, with a median overnight cost of $4,102/kW.

For another more recent comparison, South Korea is building a number of its third generation APR-1400 reactors. A recent report [7], has reported the overnight cost of APR-1400 at $2300/kW, compared with $2900/kW for EPR and $3580/kW for the GE Hitachi ABWR.

Based on the EPRI and IEA reports, the overnight cost in Australia to build 25 GW of nuclear plant would be between $39 billion and $147 billion. Based on the costs reported from South Korea, this could be a narrower band, between $58 billion to $90 billion. These ranges conservatively assume no further cost reductions beyond the cited 2015 baseline cost.

Building new nuclear plants will save the cost of building new coal CCS plants and reduce the cost of building some new gas plants between now and 2050. These are estimated in the Treasury report in section 5.4.3 (page 108) to cost $45-65 billion for the coal plants and $50-60 billion for the gas plants. Our modelling suggests that with a nuclear build, no new coal plants would be needed, saving $45-65 billion, and 45 per cent of the new gas plants would not be required, saving $20-29 billion. The potential total savings would be between $65 billion and $94 billion. In our modelled scenario, there will still be a $100 billion investment in renewables, with or without nuclear plants.

The additional cost to build the nuclear plants might be as low as zero if the South Korean APR-1400 reactors were built in Australia at the quoted price ($2300/kW). Based on the *highest* cost in the EPRI and IEA reports ($5,863/kW), the additional cost to build nuclear plants, rather than coal and gas, might range from $53 billion to $82 billion.

For a nuclear build cost between zero and $82 billion the country would save $185 billion in overseas abatement by 2050[d] and receive the ongoing benefit of an abatement cost saving of $10 billion a year beyond 2050. We discuss this in the next section.

[d] For clarification, this is a *net* saving between $103 billion and $185 billion.

Nuclear Operating Costs and Savings

Operating and maintenance costs (O&M) and fuel costs vary between coal, gas and nuclear plants. The O&M costs tend to be higher for nuclear than fossil fuel plants, whereas fuel costs tend to be lower for nuclear plants.

Based on Tables 10-4, 10-5 and 10-13 in the EPRI 2010 report, combining O&M and fuel, the total operating costs, excluding carbon cost, are $36/MWh for nuclear, $69/MWh for combined cycle gas, $23/MWh for black coal without CCS and $42/MWh for coal with CCS. This makes the total operating cost for nuclear less than gas and coal at any carbon price above $14/t CO_2-e.

The net effect on O&M and fuel costs of using nuclear power is a small increase over the period to 2050 of $7 billion. From 2050 on, there will be a net O&M and fuel cost saving from nuclear power of around $1 billion per year. This is because both CCS and gas (replaced by nuclear) have higher operating costs than nuclear.

Without nuclear power, the Treasury core policy will require fossil-fuel electricity plants to pay a total carbon cost of $335 billion between 2012 and 2050. With many of these plants replaced with nuclear power, the total carbon cost to 2050 could be reduced to $150 billion (see Fig. 9). Beyond 2050, the abatement saving from using 25 GW of nuclear power is estimated at around $10 billion each year.

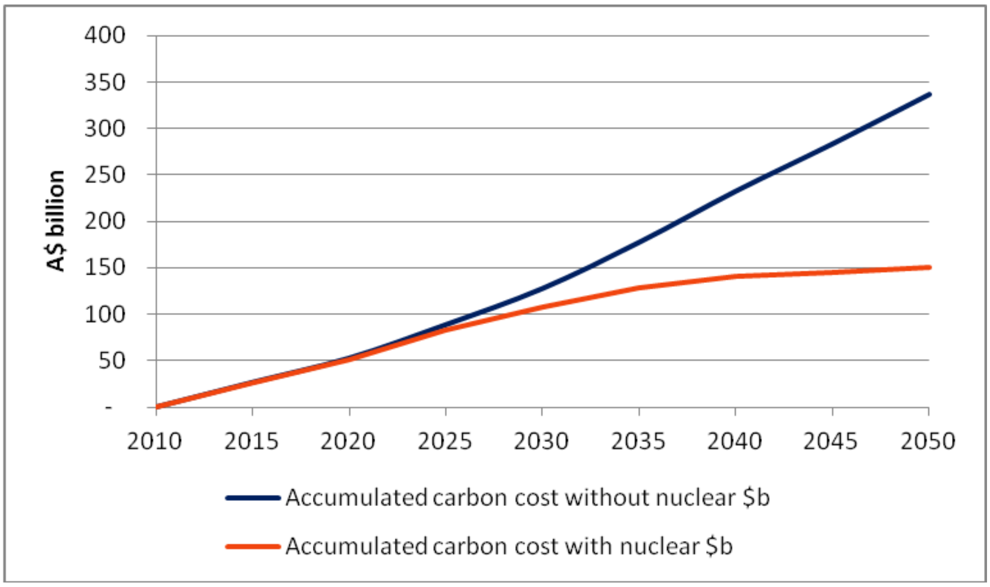

Fig. 9 Accumulated electricity generation carbon cost with and without nuclear

Why Not Renewables to Replace Fossil Fuels?

Chart 5.2 in the Treasury modelling shows the renewables share, by technology, of total generation. Again we have used the SKM MMA model as it proposes a higher rate of renewable energy in the mix (see Fig. 10).

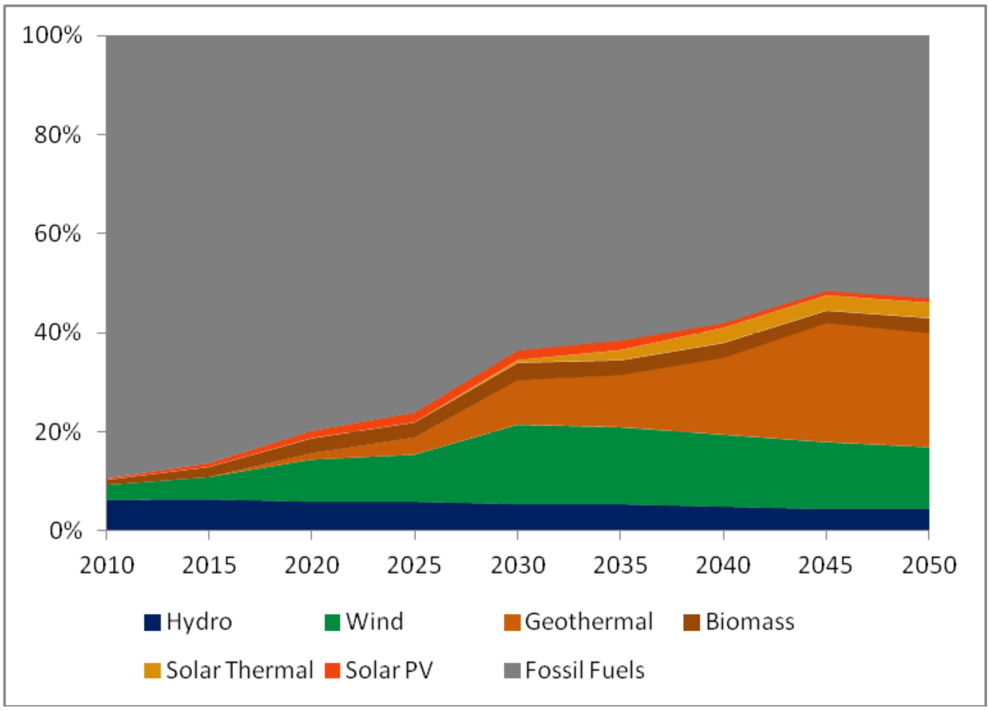

Fig. 10 Proposed renewable energy technologies in the Treasury model (SKM MMA)

SKM MMA anticipates that 47 per cent of electricity will come from renewables in 2050, up from 11 per cent in 2010. The greatest growth is in geothermal (presumably engineered/enhanced geothermal systems, EGS) which will provide 23 per cent of our electricity by 2050, provided the technology achieves commercial deployment within the next few decades.

To assess the ease with which the fossil fuels shown in Fig. 10 could be replaced with renewable energy we need to consider each technology separately.

In Australia, both hydro and biomass are restrained in growth by resource availability. The flat growth of both shown in Fig. 10 supports this view. So we can assume neither of these technologies will replace more fossil fuels than already proposed.

Because wind and solar are intermittent sources of energy they both either require energy storage or balancing generation from non-intermittent sources. That balancing is largely provided by fossil fuel plants (mainly gas) and some hydro today.

Large-scale energy storage is currently very expensive [8]. We may see technical breakthroughs over the next few decades that change this situation and might make wind and solar more competitive with less need for balancing generators, but this is far from certain.

This leaves the one potentially scalable and non-intermittent source which is geothermal. In Australia this largely means EGS using man-made deep hydrothermal reservoirs rather than conventional geothermal systems using naturally occurring hot reservoirs. Conventional geothermal systems tend to be limited to a few volcanic regions around the world, such as Iceland, California and New Zealand.

Australia has been developing EGS systems since the early 1980s with very limited success. Despite millions of dollars in investment, we are yet to see a functioning EGS electricity plant. SKM MMA is banking on this changing before 2020 with no certainty that it will ever be practical or cost effective.

Given the technical risks associated with both EGS and energy storage it seems that Treasury was prudent in not modelling an all-renewables strategy by 2050.

The nuclear solution for replacing fossil fuels does not involve the technical risks of EGS or large-scale energy storage. Producing electricity with nuclear power is proven technology widely used and accepted throughout the developed and developing world.

There are, however, some political and social issues in Australia that would need to be resolved before nuclear is legitimised here. We hope that a quantitative understanding of the economic consequences might speeds up a resolution to these political and social issues.

Conclusions

For an additional cost of between zero and $82 billion to add 25 GW of nuclear generators into the Treasury core policy, Australia could save up to $185 billion in overseas abatement cost by 2050 and reduce our emissions from electricity generation by 95 per cent below 2000 level by 2050.

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