For the Sake of a Credible Climate Change Policy in Australia – Revisiting the Nuclear Energy Option

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Abstract: This article models the impact on the costs of introducing nuclear power into Australia's energy mix. Energy from nuclear plants progressively replaces that from coal and a proportion of energy from gas by 2050. Cost savings are found to be substantial by reducing the need to purchase overseas abatement and by reducing carbon taxes. The analysis is presented in the belief that sound policy-making requires that all energy options should be on the table, notwithstanding the fact that there are many other considerations, apart from cost, in the adoption of nuclear energy in Australia.

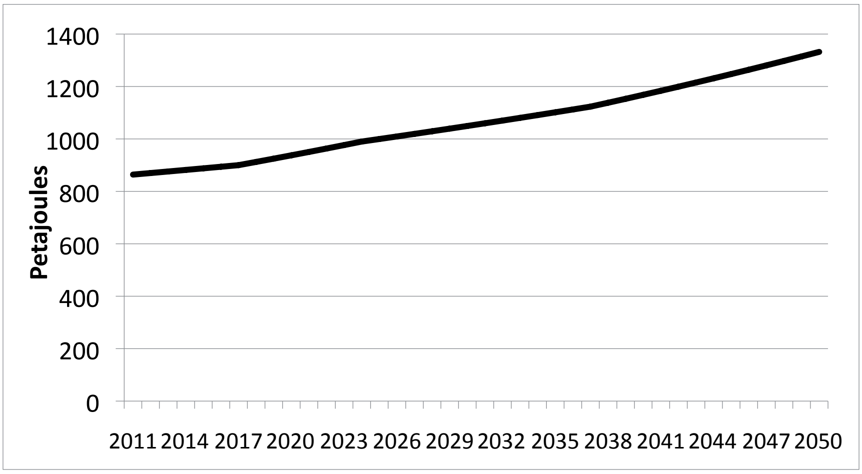
I. INTRODUCTION

The Government's Clean Energy Legislation came into force after passing the Senate on November 8 2011. The legislation embodies a fixed but rising price on carbon emissions for two years from 1 July 2012, to be replaced by a cap and trade scheme. A price on carbon dioxide equivalent (CO_2e) emissions will increase the cost of the carbon intensive coal relative to gas, and the cost of fossil fuels relative to renewable sources of energy. However, Treasury modelling (Commonwealth of Australia 2011a 2011b) of the fuel mix, that meets Australia's energy requirements and its greenhouse gas targets with the introduction of a carbon price, is exclusive of the nuclear option.

This article presents an analysis of a scenario where twenty nuclear power plants are commissioned in Australia between 2021 and 2035. In this model, the electricity the nuclear plants generate substitutes for an equal amount of the electricity generated by carbon-intensive fuels in Treasury modelling (Commonwealth of Australia 2011a 2011b), to 2050. First, the electricity from brown coal is substituted, then that from black coal followed by that from brown coal carbon capture and storage and black coals CCS, and then that of gas. The growth and composition of renewable sources of electricity is unchanged from that in Treasury modelling.

While Treasury modelling is not explicit with respect to electricity generation year by year, fitting data to the curve in *Table 2*, in Treasury (2011), enables annual energy generation modelled under a carbon price to be estimated. This is shown in *Figure 1*.

Figure 1: Electricity Generation under Carbon Pricing

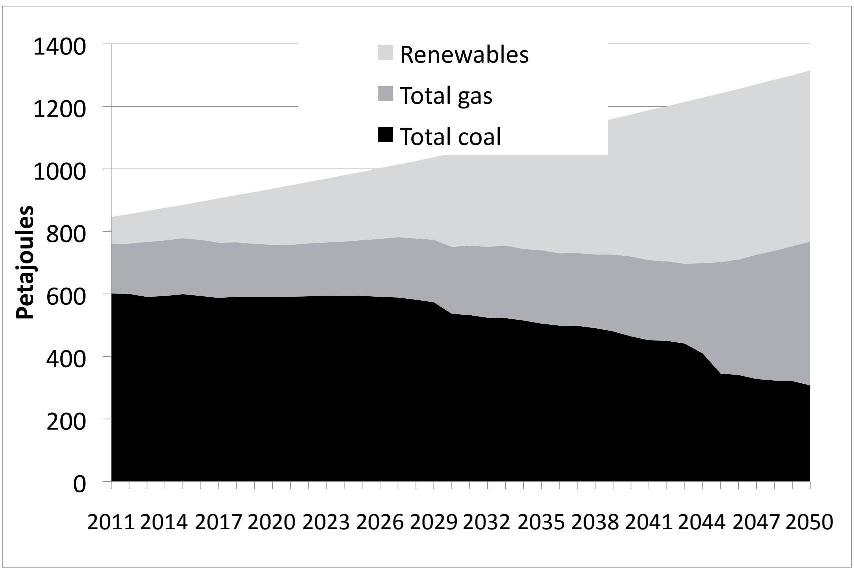


Source: Treasury (2011: Table 2).

II. TREASURY'S ENERGY MIX

Treasury modelling (Commonwealth of Australia 2011b: Chart 5.20) suggests that by year 2050 renewable energy with comprise 41% electricity production. Nevertheless, gas (36%) and coal (23%) are still important in the energy mix (see *Figure 2*).

Figure 2: Sources of Electricity Generation, without Nuclear Power

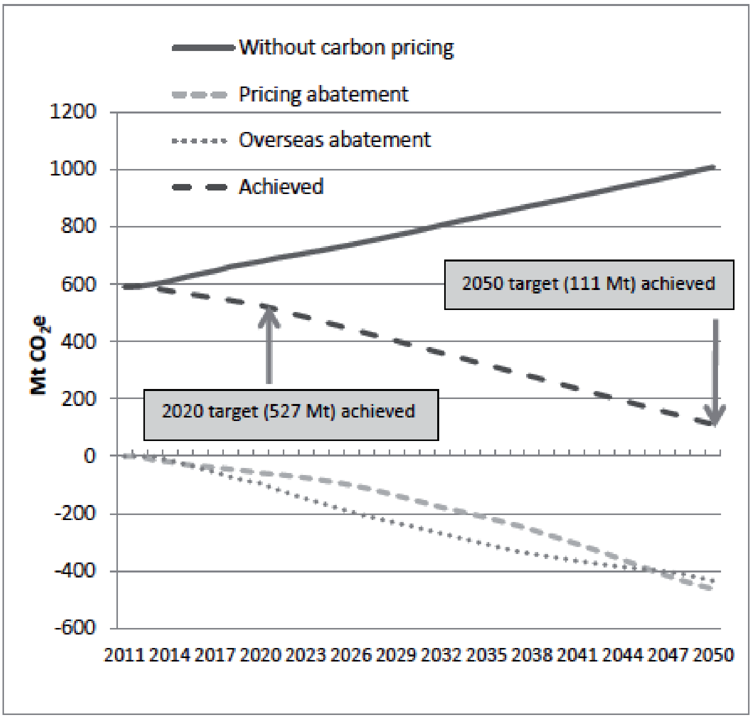


Source: *Figure 1*; Commonwealth of Australia (2011: Chart 5.19).[1]

[1] The average of the two forecasts of energy sources in Chart 5.19, by SKM MMA and ROAM, is adopted for *Figure 2*.

Central to the objective of the Australian government's energy policy is meeting its commitments to reduce greenhouse gas emissions. The targets are a 5% reduction on the level of CO_2e emissions by year 2020 and an 80% reduction by year 2050, both compared with year 2000 levels. *Figure 3* shows Treasury forecasts of emissions without carbon pricing, the sources of abatement, emissions with carbon pricing and the targets achieved in 2020 and 2050.

Figure 3: Emission Abatement and Targets, without Nuclear Power



Source: Commonwealth of Australia (2011b: Chart 5.2).

On these pages in 2011, I suggested that Australia will have difficulty in meeting its energy requirements in year 2020 while at the same time achieving the emissions target of 5% below 2020 level emissions; no less than 30% of energy requirements would need to be from sources of zero emissions, i.e. from renewables, or a combination of renewables and the purchase of overseas abatement (Hunt 2011: Table 3). Treasury modelling comes to a similar conclusion, requiring in year 2020 a combination of 10% reduction in energy consumption by carbon pricing — mainly through a switch to renewables — together with an offset of 17% of energy consumption by overseas abatement[2], to enable the 2020 target of 527 Mt of CO_2e emissions to be met, as in *Figure 3*.

[2] Energy intensity data, emissions abated (Commonwealth of Australia 2011b: Chart 5.2, 5.18) and an energy consumption forecast (ABARES 2011: Table 9) provide the basis for the calculation of the energy equivalent of carbon price abatement and overseas abatement.

As well as an increase in electricity generation from renewables to 41%, Australia's 2050 emissions target is achieved by a switch to less carbon-intensive gas from coal, together with the adoption of carbon capture and storage (CCS) for the remaining coal-fired generation and a large proportion of gas-fired generation, making a total of 30% of electricity generation under CCS (Commonwealth of Australia 2011b: Chart 5.19).[3]

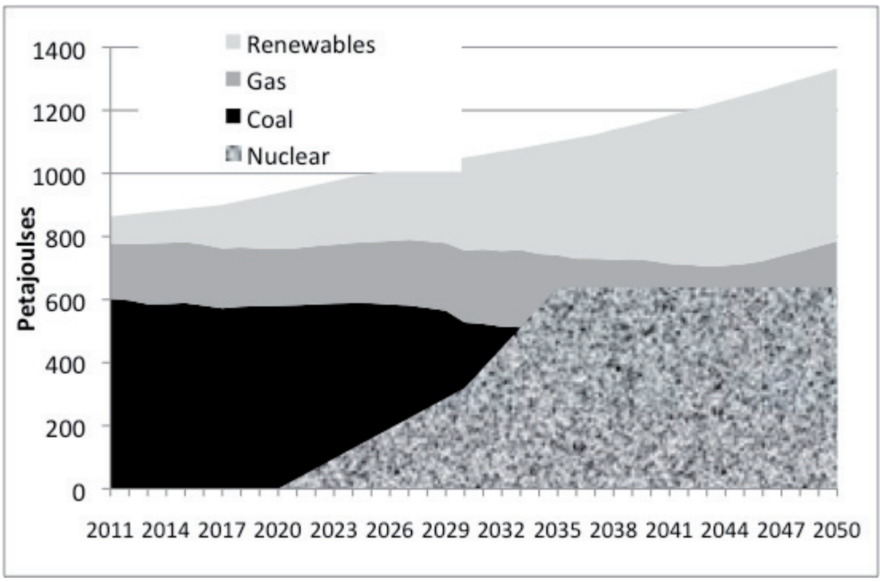
Meeting the year 2050 target will involve large capital investment in new energy generation and CCS. Cumulative cost forecasts for 2050 average around $A100 billion for the switch to gas and CCS, plus $A100b for renewable energy (Commonwealth of Australia 2011a: Table 5.13). These costs are compared below with the costs of nuclear power.

III. THE INTRODUCTION OF NUCLEAR POWER

The scenario of the introduction of nuclear power is for 20 plants, each of 1,112,000 Kw capacity[4], becoming operational by 2035, making a total capacity of 22 Gw. The first plant is commissioned in 2021, one a plant being completed every year to 2030, and the two plants every year to 2035.

The sources of electricity with nuclear energy are shown in *Figure 4*. All of coal-generated electricity is replaced and most gas-generated electricity, some gas with CCS remaining, while energy sourced from renewables is unchanged from Treasury modelling. The effect of this substitution is to further lower emissions from total energy generation to 46 Mt CO_2e in year 2050 from 111Mt.

Figure 4: Sources of Electricity with Nuclear Power



Sources: Commonwealth of Australia (2011b: Chart 5.19); author's calculations.

[3] The average of the two forecasts of energy sources in Chart 5.19, by SKM MMA and ROAM, is adopted here.

[4] The capacity factor adopted, i.e. the ratio of energy output against plant capacity is 91.2% (Nuclear Energy Institute Resources and Stats).

The final generating mixes by percentage are in *Table 1*.

Table 1: Sources of Electricity Generation in Year 2050, without and with Nuclear Power

Source of electricity	Without nuclear Power		With nuclear power	
	PJs[a]	%	PJs	%
Nuclear	0	0	638	48
Coal	308	23	0	0
Gas and oil	478	36	147	11
Renewables	548	41	548	41
Totals	1333	100	1333	100

[a] PJ = petajoule

Sources: Commonwealth of Australia (2011b: Chart 5.19); author's calculations

IV. COMPARATIVE COSTS OF ELECTRICITY GENERATION WITHOUT AND WITH NUCLEAR POWER

4. 1 Costs without Nuclear Power

The methodology adopted is to compare capital and operating and maintenance costs without nuclear power, in the Treasury model, against costs associated with the introduction of nuclear power.

The average costs of new electricity generation estimated by Treasury consultants (Commonwealth of Australia, 2011a: Table 5.13) is $A209 billion by 2050. Most of the investment takes place after 2020, with the cost divided equally between renewable energy installation and CCS.

In Treasury modelling, the quantity of overseas abatement that needs to be purchased to achieve emission targets rises steadily from year 2013 (see *Figure 2*), and so does the real price of this abatement per tonne of CO_2e — from $A21 in year 2013 to $A131 in year 2050 (Commonwealth of Australia: Charts 5.1, 5.2). The cumulative cost of overseas abatement thus reaches $A757 billion by year 2050. The same price structure applies to emissions from fossil fuels under a carbon tax scheme and the subsequent cap and trade scheme. While emissions from the electricity sector fall over time (see *Figure 2*), the cost nevertheless rises with the tax rate, accumulating to $A339 billion by 2050.

4.2 Costs with Nuclear Power

The source of the cost of nuclear plants at $A5,742/Kw is EPRI (2010: Table 9-2), the cost of 20 plants totalling 22.24 Gw is thus $A128 billion.[5] No new investment in coal-fired electricity is required, energy from this source being completely replaced by nuclear power. An

[5] This is close to a recent US estimate of $US5,000/Kw (Connecticut Academy of Science and Engineering, 2011:xx).

investment of $A23 billion in gas generation is still required until nuclear generation begins to replace gas in 2034.

The cumulative costs of purchasing overseas abatement and the carbon tax are the largest overall costs for electricity generation, both without and with nuclear energy. Fuel cost for fossil fuel plants are greater than fuel costs for nuclear energy production but the latter tend to have higher operating costs; over a 50-year period their comparative O&M costs are not dissimilar.

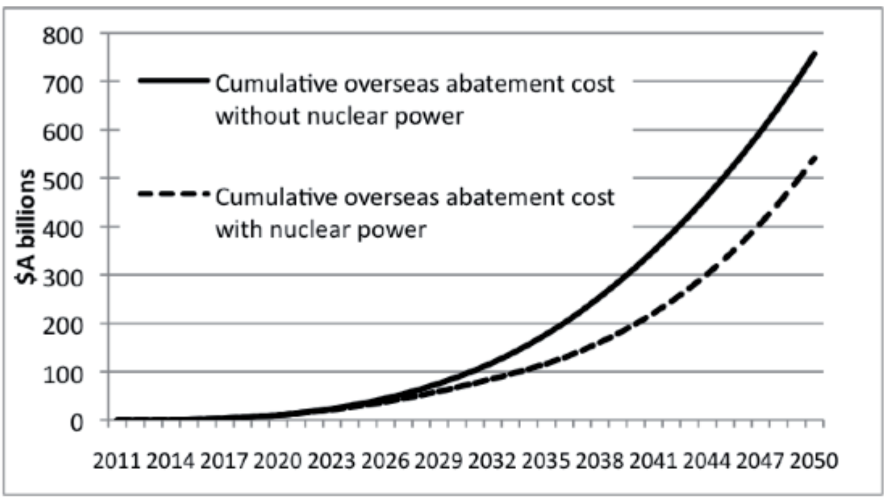
Table 2 summarises capital costs, the costs of overseas abatement and the carbon tax, without and with nuclear power.[6] The largest costs savings are in overseas abatement and carbon tax; savings over time are illustrated in *Figures 5* and *6*.

Table 2: Capital, Overseas Abatement and Carbon Tax Costs of Electricity Generation without and with Nuclear Power

Cumulative costs to 2050	Without nuclear $A billion	With nuclear $A billion
Building nuclear plants[a]	0	128
Building coal and gas plants[b]	209	23
Overseas abatement[c]	757	541
Carbon tax[d]	339	123
O&M[e]	329	326

[a]2009 $A; [b]2010 $A; [c,d]2010 $A; [e]2009 $A
Note: Costs of decommissioning are included in nuclear plant capital costs.
Sources: Commonwealth of Australia (2011a: Table 5.13; 2011b: Charts 5.1, 5.2); EPRI (2010: Tables 10-4, 10-5, 10-13); author's calculations.

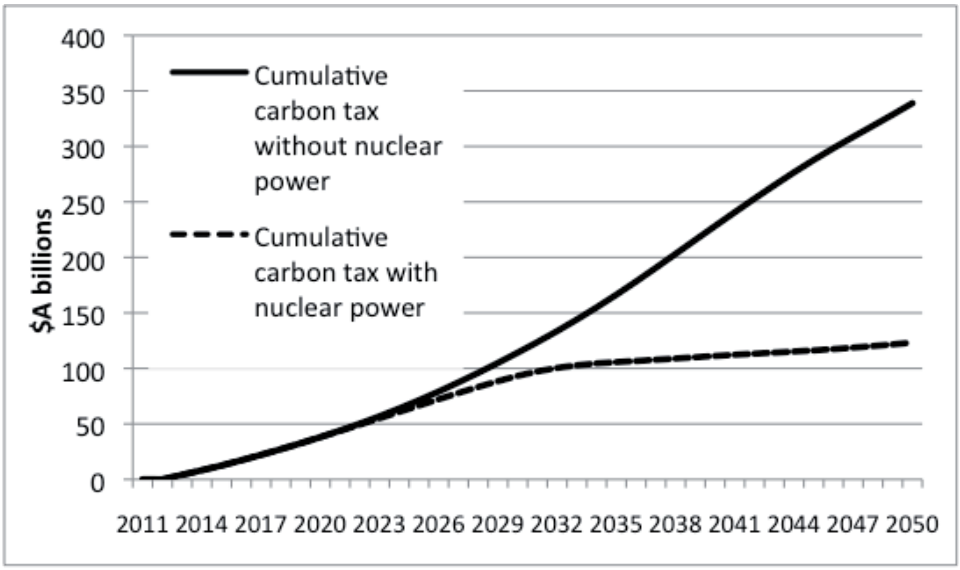
Figure 5: Costs of Overseas Abatement without and with Nuclear Power



Sources: Commonwealth of Australia (2011b: Charts 5.1, 5.2); author's calculations.

6 Costs are in current dollars. That is, future costs are not discounted to give present values. Given that current dollars vary from 2009 to 2010, depending on the source, the costs for each category in *Table 2* are not added.

Figure 6: Cost of Carbon Tax without and with Nuclear Power



Sources: Commonwealth of Australia (2011b: Charts 5.1, 5.2); author's calculations.

V. DISCUSSION

Treasury modelled the physical and financial implications of Australia's policy of pricing carbon, which will lead to the substitution of clean sources of energy for fossil fuels and the adoption of CCS for fossil fuels. Overseas abatement is purchased to augment the introduction of renewables, enabling the attainment of year 2050 emission targets (Commonwealth of Australia 2011a 2011b).

Neither the advanced renewable energy sources that are modelled by Treasury nor CCS are proven technically, let alone commercially (EPRI 2010). A major question-mark hangs over Treasury's heavy reliance (30%) of electricity being derived from fossil fuel sources subject to CCS in 2050 (Commonwealth of Australia 2011b: Chart 5.19). In contrast, nuclear technology is proven.

An uncertainty, additional to that around the commercial viability of new energy sources or CCS, that could put Australia's greenhouse policy at risk, concerns fugitive emissions in the use of natural gas. There is potential for the upward revision of the quantities of fugitive methane associated with the mining, transport and processing of natural gas, as well as an upward revision of methane's global warming potential (Shindell 2009, Howarth 2011, Hunt 2011b, Wigley 2011).

This article suggests that the introduction of nuclear power in Australia could provide certainty in terms of electricity supply and greenhouse gas reductions while at the same time making large cost savings in the electricity generating sector by reducing overseas abatement costs and domestic carbon taxes. Nicholson (2011) finds similar cost savings by the substitution of nuclear power for fossil fuels.

New nuclear plants are being built and planned elsewhere — there are five plants under construction in the US and 10 planned for Britain in the next decade, not to mention the many plants planned in Asia and Russia (Connecticut Academy of Science and Engineering 2011, *The Telegraph* 2011a, *The Telegraph* 2011b). The Generation III+ and particularly Generation IV plants are much safer than the Japanese plants (US Department of Energy 2009) and sites could no doubt be found in Australia with low geological and climate risks. However, the safety issue will turn on the availability of siting a repository for radioactive spent fuel, rather than on the safety of the plants themselves.

In the US, the 100 operating nuclear plants are forced to store their highly radioactive waste on site, and there is a potential for the release of material from the stores as a result of accident or terrorist activity. Large sums of money have been spent on developing a national repository for nuclear waste, which was approved by Congress. But the Obama administration has withdrawn its support for the site, resulting in 66 utilities successfully suing the administration for breach of contract in not accepting spent fuel, at potential cost of $US11 billion (Connecticut Academy of Science and Engineering 2011: 86).

A national repository for nuclear waste would undoubtedly be a prior requirement for the introduction of nuclear energy in Australia. Given the US experience this could be a lengthy and highly politicised process. The cost of a repository would need to be added to the costs of nuclear energy, and the time taken to site and develop a repository added to the lead time for building plants. The long lead time necessary is highlighted by the British experience where planning is advanced but the first plant is still not expected until 2019.

The Australian Government's *Draft Energy White Paper*, while reiterating the Government's opposition to the use of nuclear power in Australia, nevertheless leaves the door open:

> The best case supporting future consideration of nuclear power would be the failure to commercialise new low-emissions baseload energy or energy storage technologies within the timeframe that economic analysis suggests is necessary to meet long-term global and national emissions reduction objectives (from 2025 onwards)…Estimates of future costs for representative electricity generation technologies suggest that nuclear might then represent an economically competitive backstop baseload energy option (Commonwealth of Australia 2011c: 224).

Given the long lead time, a decision would need to be made in the near future if nuclear power is to be available in 2025.

VI. CONCLUSIONS

There will be technological advances in renewable energy and in CCS over the next few years, which will determine the final energy mix by 2050. Meanwhile, nuclear energy is already a very cost-competitive and reliable source of energy and improvements will undoubtedly be forthcoming, making it even more efficient and safe.

Having said that, the reality is that there is fierce opposition in Australia among NGOs and the Australian Greens against the nuclear option; and at the same time there is undoubtedly a good deal of circumspection among the public, continually reinforced by these vocal opponents and by the publicity surrounding the recent Fukushima disaster. A change in circumstances —

such as heavy cost pressures of renewables and CCS or their failure to deliver, combined with rising temperatures — will be needed to force a reappraisal of the nuclear option.

Notwithstanding the political realities it is argued that no energy options should be omitted from consideration on the grounds of political incorrectness, given the uncertainty surrounding whether the constrained technical solutions proposed can meet future climate change imperatives while maintaining economic growth.

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