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Submission to

House of Representatives Standing Committee on the Environment and Energy

Inquiry into Modernising Australia's Electricity Grid

24 April, 2017

INTRODUCTION

The Australian Nuclear Association is an independent incorporated scientific institution with members from the professions, business, government and universities with an interest in nuclear topics. Many of our members are professional scientists and engineers with considerable experience and expertise in nuclear topics.

The Australian Nuclear Association strongly supports the use of nuclear power in Australia as a low-carbon large-scale generator of electricity and as a low carbon emission source of heat for industry and industrial processes. Adding nuclear power to the Australian grid would be a major contribution to the desired transition to a low emissions economy.

The Australian Nuclear Association supports all viable actions to address anthropogenic global warming and recognises that the grid needs restructuring to incorporate technologies that limit carbon emissions.

Nuclear power provides the world with safe and affordable electrical power generation based on over 15,000 reactor years of operational experience since the first commercial power reactor in 1956. There are 447 nuclear power plants connected to the grid in 31 countries, with an addition 59 nuclear power reactors under construction and 164 nuclear power reactors on order or planned with approvals, funding or major commitment in place [World Nuclear Association, March 2017].

Around the world, nuclear power is a major generator of low carbon emission electricity. In the US alone, nuclear energy powers 20% of the country and accounts for 63% of all low emissions sources including hydro, wind and solar. In Europe, countries with nuclear power generate with extremely low carbon emissions. An example is France where its 75% nuclear electricity generation results in carbon intensities six times lower than its neighbour Germany. This fact holds despite Germany's multi-decade effort to transition to renewables and demonstrates the superiority of nuclear over renewables for making deep cuts to carbon

emissions. Nuclear power averages more than 90% in capacity factor, making it a most reliable and dispatchable form of electrical generation.

We agree with the statement in the Committee's *Discussion Paper* that Australia's electricity system is entering a significant period of transition driven by an increasing amount of non-synchronous variable energy generation such as wind and solar photovoltaic (Variable Renewable Energy or VRE) and the commitment to reduce carbon emissions.

The Australian Nuclear Association makes the following key observations:

1. Many studies estimating the costs of conventional and renewable technologies to address the reduction of carbon emissions fail to include the associated costs of modifying the transmission grid for the new technology. The grid is usually treated as an externally imposed constraint rather than using a whole of system approach. A high reliance on variable renewables requires the grid to be modified to an intermeshed network [Fursch et al 2013].
2. The architecture of the grid is a construct of the types of generators contained within the grid and the size and location of the loads. Where low carbon generators are included, their capacity factors and primary energy sources significantly influence the characteristics of the grid. A grid distributing primarily wind, concentrated solar power and solar PV generation will need to accommodate peak power levels that may be two or three times larger than the peak demand because extra electricity must be generated to cover times when there is low generation from the renewables. A grid depending primarily on wind and solar will be far larger and more environmentally intrusive than the current grid and will require substantial increased property easements.
3. Nuclear power plants are large-scale synchronous generators that could be sited near to load centres. Adding 1 GW nuclear plants to the Australian grid would only require upgrading of the main interconnectors. The installation of small modular reactors would require minimal increase in the current grid size.
4. No nation has reduced its greenhouse gas emissions using intermittent renewables at a rate that could achieve a 90% reduction of their electricity emissions by 2050 let alone meeting their current primary energy emissions. In contrast, nuclear energy has proven to be particularly successful in achieving deep emissions reductions in a short time frame.
5. Renewables should not be treated as a societal end in themselves. Instead renewables are options among a suite of technologies that could be used jointly to achieve the combined goals of environmental protection, cost-containment, and electric system reliability.

The following sections comment on specific questions in the Committee's *Discussion Paper*.

1. *The means by which a modern electricity transmission and distribution network can be expected to ensure a secure and sustainable supply of electricity at the lowest possible cost.*

Question 1.1: How are the objectives of security, reliability, sustainability, and affordability interrelated?

Real-world integration of climate change and electricity policy will be required for policy to succeed against the three fundamental objectives of reliability/security, affordability, and reduced greenhouse gas emissions –see Simshauser [2014] for a good description of this policy trilemma.

These three objectives may operate in opposition to each other.

Reliability and security may come at a cost which reduces affordability. The use of large amounts of variable renewables as a means of reducing carbon emission needs major backup or storage which adds to costs.

Sustainability includes designing the NEM to provide certainty for current and future electricity generators regardless of size. The current NEM has a very short-term focus and greatly limits the opportunity to provide reliability of supply and consider all options for future electricity generation.

The adoption of nuclear energy as an emissions reductions strategy would facilitate transition to a low-emissions economy and enhance the security and reliability of the grid. In Australia a grid distributing nuclear generated electricity from 1 GW plants would require upgrading of some main interconnectors though distribution from small modular reactors of 300 MW or less would require minimal increase in the current grid size. Such a grid could be largely confined to existing easements.

Question 1.2: What should be the highest priority objectives of a modern grid in Australia?

This issue is dealt with in detail in the response to Question 2.2 below.

In summary the grid is a construct of the types of generators contained within the grid and the size and location of the loads.

Australia's response to climate change will need to target the most effective and least costly method of achieving deep emissions reductions which conform, as a minimum to the 90% reductions pathway shown in Figure 1. This figure outlines the required greenhouse targets as recommended by the UNFCCC to 2050.

As stated elsewhere in this submission attempts to use variable renewables as the means to address deep emissions reductions will require a very large expansion of the grid and may well result in negligible benefits.

Therefore the highest priority objective of a modern grid in Australia should be resolved in the planning stage when its design is integrated with ideally a low carbon nuclear electricity generating system.

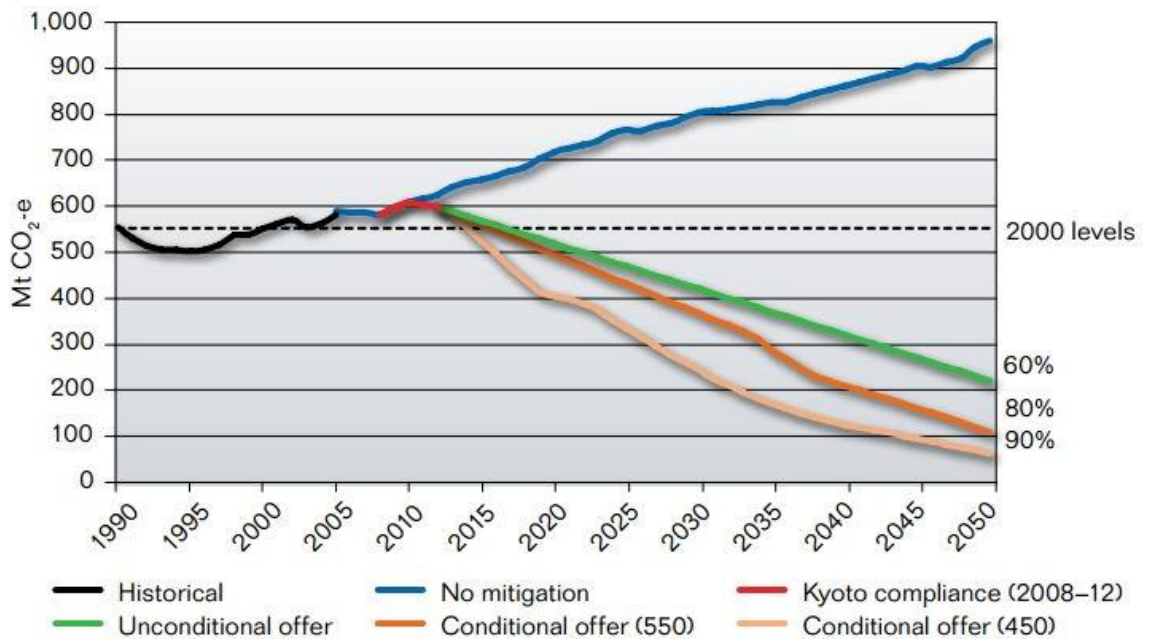


Figure 1. Australia's Emissions Trajectories to 2050
(reduction in total emissions) [Garnaut 2008]

2. The current technological, economic, community, and regulatory impediments and opportunities to achieving a modern electricity transmission and distribution network across all of Australia, and how these might be addressed and explored.

Question 2.2: What might be the role of new technologies in improving system security, reliability, sustainability, and affordability? What is the potential for new technologies to alter the inter-relationships between these objectives?

The architecture of the grid is a construct of the types of generators contained within the grid and the size and location of the loads. Where low carbon generators are included, their capacity factors and primary energy sources significantly influence the characteristics of the grid.

A grid distributing primarily wind, concentrated solar power and solar PV generation will need significant extension of the grid to accommodate peak power levels that may be two or three times larger than the peak demand in order to supply the storage required for reliability. It will be larger, more expensive and more environmentally intrusive than our existing grid and will require substantial increases in property easements. A German study from the Max Planck Institut found that large power surpluses begin to accrue when variable renewables exceed 26% of total demand because of the need to ensure reliability of supply [Wagner 2016]. In the case of Germany these surpluses exceed the electricity consumption of Poland or Sweden. They are produced by variable wind and solar generators whose capacity would need to be some four times the peak load.

In Australia a grid distributing nuclear generated electricity from 1 GW plants will require upgrading of the main interconnectors though distribution from small modular reactors (SMRs) of 300 MW or less may require minimal increase in the current grid size. Such a grid could be largely confined to existing easements.

The issues surrounding surpluses and the intermittency of variable renewable energy will be compounded by our small and isolated grid and our inability to shed the surplus into surrounding nations. Some of this surplus can be stored, but all storage increases the cost of electricity. Otherwise, generators will be switched off when surpluses occur. Attempts to store this surplus especially by chemical means such as hydrogen production will likely not be found to be economic due to significant conversion losses and intermittency [Wagner 2016].

Australia must have a fully detailed plan for our transition to a low carbon future which takes account of our largely islanded grid and lack of options for external backup. At present we are stumbling through the adoption of Renewable Energy Targets and Solar PV investment bonuses and feed in tariffs without an adequate plan for fitting these schemes into a properly designed generating and grid system.

Three possible pathways for a future low carbon electricity supply system are:

1. A transition to a 100% variable renewable energy (VRE) system will be characterised by a grid capable of harvesting generated energy from optimum sites often at large distances from load centres. This grid will be based on supply and must be capable of operating at high power levels of at least twice the peak demand [Wagner 2016]. It will have day storage used to move excess energy into periods of short term storage and will need to be sized to address the winter low PV intensity and high pressure atmospheric systems that result in low wind generation. Considerable uncertainty will exist regarding longer term storage in a grid that is operating at high power levels and surplus generation. The large installed production capacity, the high grid power level and the large amount of surplus electricity are major technical and economic obstacles.
2. A transition to an 85% nuclear electricity powered system will be characterized by a grid capable of meeting the actual demand. It will utilise Australia's exiting hydropower resources and some bio-energy for the remainder. Larger 1 GW nuclear reactors will be too large for Western Australia, South Australia, the Northern Territory and North Queensland and so either Small Modular Reactors (SMRs) will be used in these locations or significant grid interconnection will be required. Tasmania would remain with hydropower and the Bass Link. The ability of modern reactors to load follow negates the requirement for substantial day/night storage.
3. An amalgam of nuclear generated energy with VRE. In such a system, priority displacement of nuclear generators by VRE may not be economically acceptable. The high capital cost of nuclear generators and low fuel cost requires that they operate at the highest capacity factor achievable. Integration of solar PV is increased by orientating it to the west to increase its contribution to the late afternoon summer peak demand.

Clearly the greatest benefit of an inquiry into modernising the Australian grid would be achieved through it being an integral part of the planning of the nation's future low carbon energy supply system. This would include the generators, the grid and any storage options.

Question 2.3: How can the grid better accommodate the rapid pace of technological change, including an increasing level of variable electricity generation?

The grid is the delivery conduit for our power system and its cost needs to be an integral part of Australia's low carbon future. It may be that a grid whose ability to handle twice the peak demand load and connect to all VRE generators spread throughout Australia has a prohibitive cost when compared to alternatives.

At present there is a popular notion that variable electricity generation (VRE) will achieve emissions reductions of the level required to take account of fundamental environmental goals as highlighted in Figure 1.

The public has been conditioned to think that the challenge of climate change can be addressed by the "ice cream" solution of variable renewables for electricity generation. That if we just built more low intensity passive devices which address a minor portion of 12% of our emissions sources, namely residential electricity, then everything will be O.K. What is not addressed within the political or policy arena is the massive task ahead of meeting effective emissions goals whose sources are shown in Figure 2. In any study seeking to define a trajectory for Australia's future energy policy a core requirement will be a realistic assessment of the amount of clean energy required to address emissions goals.

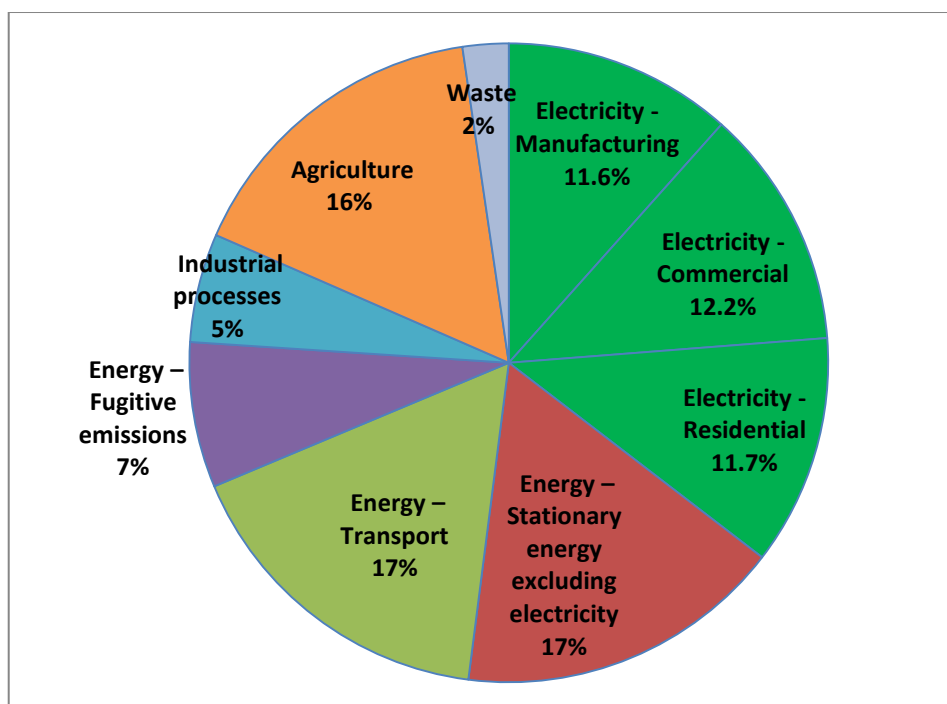
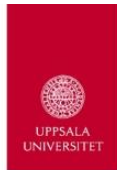


Figure 2 - Australia's CO2 emissions by sector 2011-12
[Data from Quarterly Update of Australian National Greenhouse Gas Inventory, June 2013]

No nation has reduced their greenhouse gas reductions using variable renewable energy to a rate that ensures a 90% reduction of their electricity emissions by 2050 let alone meeting their current primary energy emissions. Nations such as Germany have stalled on emissions reductions and are now embracing lignite coal plants while their electrical greenhouse intensity remains around 430 g. CO₂/kWh.

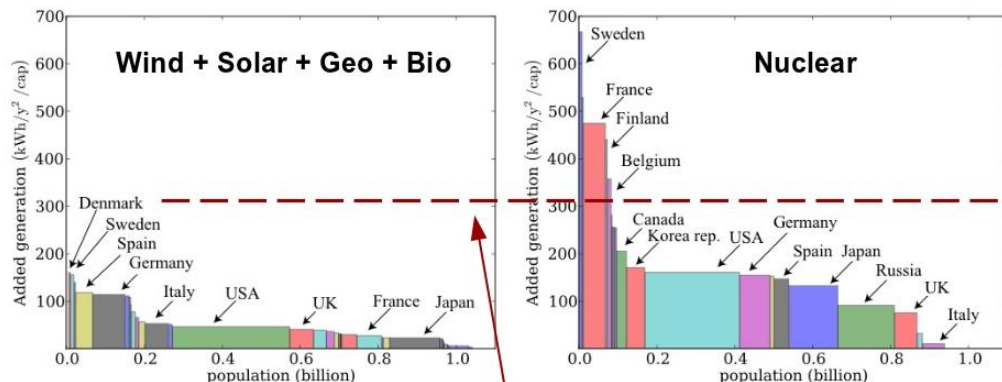
An effective plan for Australia's decarbonisation of its energy system which includes the costs of the grid as well as storage and generators has yet to be devised. It may well be that an enhanced grid to enable VRE has costs that overwhelm the generating system and will take decades to implement.

What is certain however is that technical change can occur rapidly and for speed of implementation, nuclear energy has been very successful as shown in Figure 3. France built a nuclear generating system of 63 GW, containing 58 reactors over a twenty two year period and there's entirely no reason why Australia could not repeat that performance.



How fast is fast enough?

Fastest added generation of electricity per person and year



analys.se

Required rate for 2 degree target

Source: World Bank & BP Statistical Review, picture by Carl Hellesten

Figure 3- Fastest added generation of electricity per person per year
[Mattias Lantz 2017]

Question 2.6: What opportunities are there for consumers to benefit from the modernisation of the grid? How can we ensure that these benefits are able to be shared equitably by all consumers?

The grid provides a public benefit to all consumers. With the increase in domestic PV generation it will be necessary to recover grid costs through a grid availability charge and reduce the variable price component paid for power used. In this way the grid cost recovery becomes more equitable.

Question 2.7 What sort of community attitudes or concerns will need to be addressed in order to successfully modernise the electricity grid?

Consumers have been conditioned by a narrative surrounding "gold plating" of the grid that they are being exploited. Figure 4 shows the comparatively high impact that network costs are having on residential electricity tariffs. Was Australia playing "catch-up" and coming off a very low base? Economists who choose to quote Australia's diminishing capital productivity in our electricity networks likewise may not be acknowledging that at times our nation's infrastructure has been allowed to become less reliable and was in need of a timely overhaul.

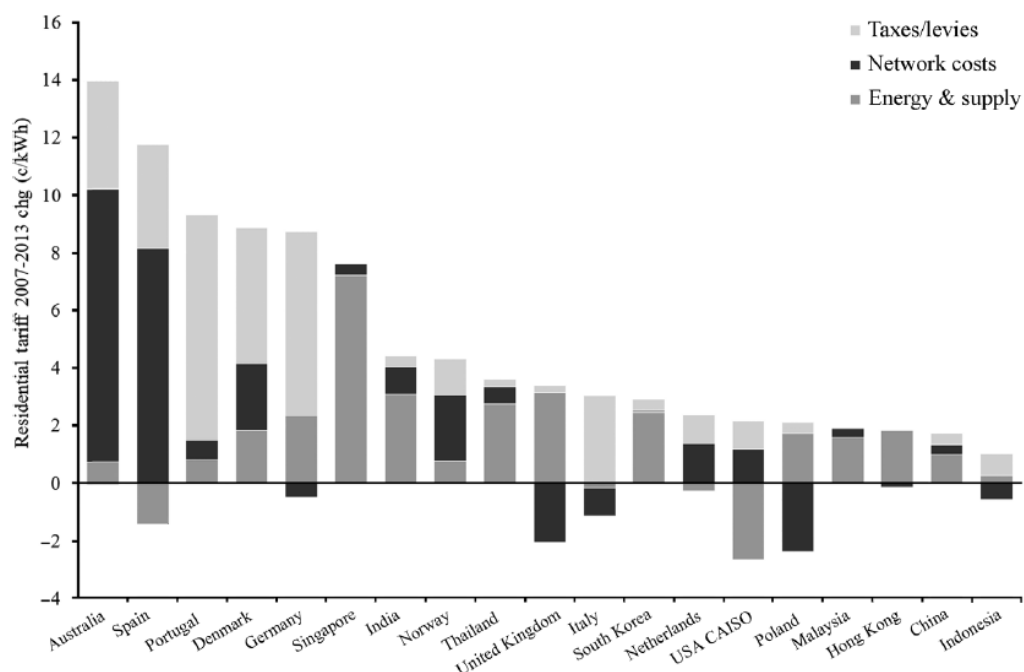


Figure 4 - Change in Electricity Tariffs (US\$) 2007 – 2013 [Simhauser 2014]

Further modernisation of the grid to address a program of variable renewables will incur opposition due to its cost and environmental impact. In Germany, grid extensions to enable wind generated power from the north to flow to southern Germany are encountering significant opposition to the extent that large interconnectors are being buried underground. The scope of large high voltage transmission upgrades in Europe through to 2050 is very significant with 280,000 kilometres or a 76% increase on the existing being undertaken [Fursch 2013].

3. International Experiences and Examples of Electricity Grid Modernisation in Comparable Jurisdictions.

Question 3.1 What are the key similarities and differences between the electricity system in Australia and those of other countries?

Australia has a very low population density, high individual electricity use and an islanded grid. These are significant reasons why our per capita grid costs would be higher than most other nations. The lack of linkages to grids in neighbouring countries prevents us from distributing large temporal surpluses created by variable renewables. Nor can we draw on external resources in times of deficit.

Question 3.2 How does Australia compare with other countries in the rate of adoption of variable electricity generation and other new technologies?

The integration of low carbon emitting generation into the NEM currently consists of variable renewable energy made reliable by support from gas powered generation, low spooling coal power and a very reliable but limited hydro power resource. Our energy market is beset by high price volatility caused by the combined impacts of intermittency and the Renewable Energy Target.

It's wise to reflect upon the scale and challenge involved in decarbonising our primary energy systems of which actual electricity generation accounts for only about a third of our emissions, Figure 2 **Error! Reference source not found.** In dealing with our overall emissions, electricity generation is probably the easiest nut to crack. The much harder parts of our economy to decarbonise are those of agriculture, transport and industrial processes. Because electricity is easier and the solutions are ready for deployment, second best medium level reductions are not good enough in this sector.

In the laboratory of real life, France, Sweden and Switzerland have all pointed the way installing large amounts of nuclear energy in a short time as shown in Figure 3. France built a nuclear generating system of 63 GW, containing 58 reactors over a twenty two year period and there's entirely no reason why Australia could not repeat that performance. Instead Australia has become enmeshed in a complex scheme of trying to blend intermittent wind and solar with fast response gas generation all underpinned by coal powered generators.

This is all very similar to the compromised path down which Germany has travelled at huge expense and with little reduction of emissions as shown in Figure 5. The emissions intensity of the electricity produced is shown with Germany at 424.9 gr. CO₂/kWh being over 12 times higher than those of France at 34.8 gr. CO₂/kWh and over 40 times that of Sweden at 10.5 gr. CO₂/kWh all in 2014.

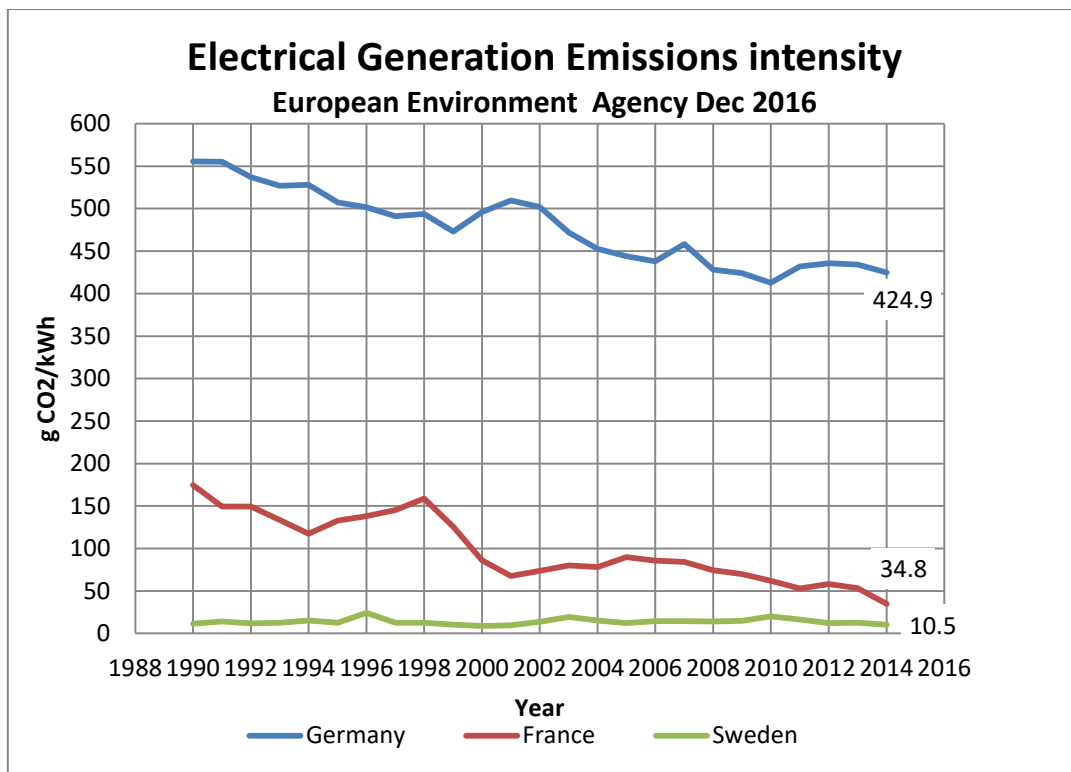


Figure 5 - Electrical Generation Emissions Intensity

Evidence for nuclear energy's comparative advantage in reducing emissions can be seen by comparing the generating capacity and electricity production proportions in 2013 for Germany as shown in Figure with that of France shown in Figure .

Both Germany and France have generating capacities of a similar order of magnitude however the results of the German example are a clear warning to Australia of the difficulty of reducing emissions by just installing more renewables.

In Germany where wind, solar and biomass are steadily expanding and rely upon gas, inadequate hydro and coal for grid stabilisation, the outcome is poor. Germany's renewable generating capacity amounts to 48% of its total generating capacity but produces only 26% of its total output. It's 7% of nuclear capacity however generates 15% of the total output.

France on the other hand has 49% of its generating capacity as nuclear energy. This generates 78% of its total electricity while its 11% of wind and solar contribute only 4% to the total.

If Australia follows Germany's example of steadily increasing the intermittent renewable capacity we can expect to see:

- Electricity production of intermittent renewables being about a third of installed capacity and
- Only modest reductions in carbon emissions and certainly not at the sub 70 g CO₂/kWh levels or lower evident in Sweden, Switzerland or France.

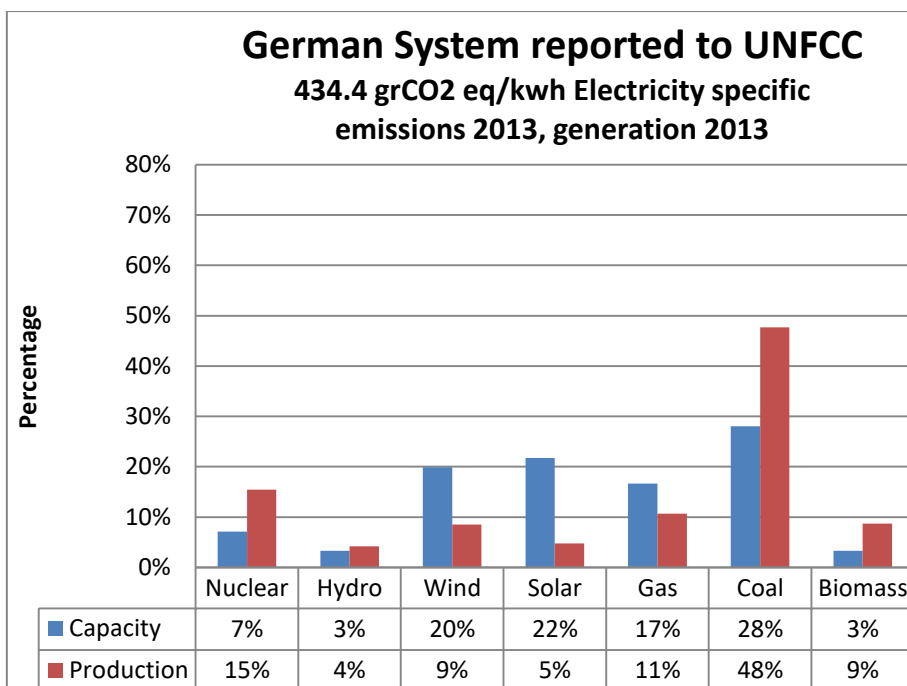


Figure 6. German Generating Capacity and Production in 2013

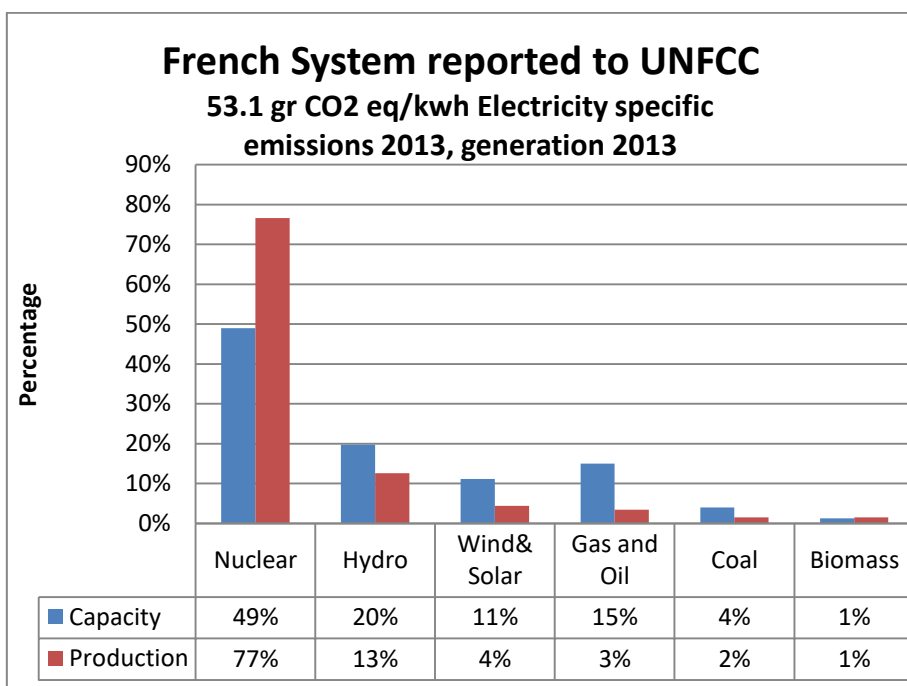


Figure 7. French Generating Capacity and Production 2013

RECOMMENDATIONS

The Australian Nuclear Association recommends that:

1. nuclear energy be included as an essential part of a low carbon generating system and that all impediments to its use be removed. Without nuclear energy Australia cannot meet the low emissions path ways to either 450 ppm limit for a 2 degree temperature increase let alone a 350 ppm for a 1.5 degree increment.
2. legislation preventing the construction of nuclear power plants and other parts of the nuclear fuel cycle in Australia be repealed. At present the nuclear regulator, ARPANSA, is prohibited under the ARPANS Act (1998) from issuing a licence for a nuclear power plant and the Minister is prohibited under the EPBC Act (1999) from making a declaration or approving an action relating to a nuclear power plant.
3. emissions pathways for at least a 90% reduction in emissions for electricity generation by 2050 shown in Figure 1 form the basis of future policy and design of the electricity market. This could be achieved reliably using nuclear power but not from intermittent renewable sources alone.

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