Submission Inquiry into Prerequisites Nuclear Energy in Australia

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In the lead up of this parliamentary inquiry its chairman Ted O'Brien MP mentioned on ABC radio that the focus is on new nuclear technologies and that they would not look at legacy technology like in Chernobyl. Even though their focus is on new nuclear technologies, which are still some years away, it is important to review the performance of the nuclear industry so far.

In this submission the main two issues discussed are "*the suitability of the nuclear powerplants in the modern decentralised electricity grid*" and "*the economics of nuclear powerplants in general*".

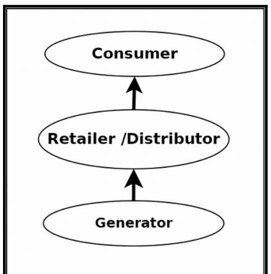
Nuclear powerplants and the electricity grid.

In the debate about energy supply a lot of jargon is used. It is not clear from listening to politicians, commentators and others if they really understand the jargon they are using. Here we try to explain two of the major terms and their relationship to electricity generation and demand. The explanation is given in two scenarios, namely how it worked in 20th Century and how it will work in 21st Century.

20th Century : Electricity Generation Utility Controlled

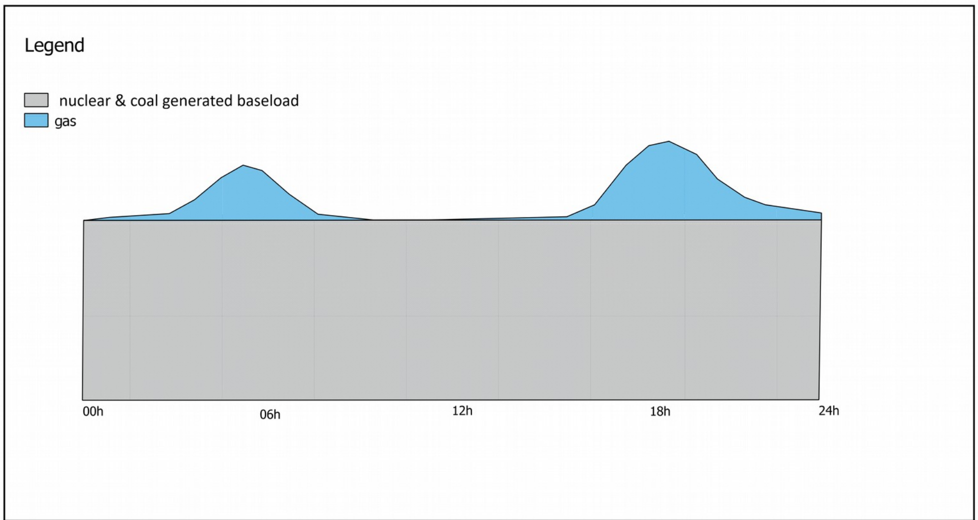
The standard setup for electricity supply in the 20th Century (20C) is to have baseload supplied by nuclear or coalfired powerplants and anything above it like peak demand, supplied by gas or diesel fired powerplants. The baseload demand used to be quite static therefore nuclear or coalfired powerplants were ideal to deliver electricity at a reasonable price. An additional reason for this simplicity was the centralised electricity generation.

During the 20C electricity demand was met by the despatchable electricity generated by a combination of baseload and peakload generation, as shown in figure 1. The term baseload was very relevant in 20C and even in the first few years of 21C.



The 20C flow of electricity

This diagram shows the Classic 20C flow of electricity from generator via retailer to customer.



The graph showing the grey block at the bottom representing the 'baseload' generated by coalfired & nuclear powerplants

The hatched 'gas' humps above it indicating the electricity generated by the gasfired powerplants, mainly at the two distinct periods in the morning and the other in the evening.

In this 20-Century scenario electricity generation equals that of demand. In other words all the despatchable electricity is used by demand.

Fig. 1. 20C electricity supply curves.

*21st Century : Customer Demand Controll*ed.

Now in the 21st century (21C) the scenario has changed and continues to change, it has lost its static simplicity of the 20C. In the current public energy debate the focus is often on baseload while it should be on the demand for electricity. The 20C way is basically telling the consumers that they should use electricity in a pattern that suits the generators. But it should be the other way around the generators should supply the electricity the consumers want and need. Consumer electricity demand from grid in the 21C has changed, because many have become *prosumers*. A prosumer is both a consumer and a producer, and in this case of electricity. The prosumer generates electricity with their solar-PV panels. This means that when they produce their own electricity they will not draw from the grid. All this generation is done "behind the meter" (BTM) out the reach of the public generator. Figure 2 shows the consumer demand curves for 2017, 2022 and 2027 [1]. The graph indicates that by 2022 the consumer demand for electricity in the middle of the day is significant less than what baseload powerplants produces, and by 2027 it is estimated that no baseload power is needed at all during about 1 hour around midday. The first suggestion could be, produce less baseload electricity. Well, that is a problem because nuclear and coalfired powerplants [2] can physically not slow down enough and later ramp up again for the amounts and in the time frames required. Logically the best way to deal with this problem is to close any nuclear or coalfired baseload producing powerplant. This is likely to cause some political problems for governments. Eloquently described on Sustainable Energy Now's website (SEN, 2019) "… *This scenario does not consider any commercial solar installations, which will accelerate the impact. Without government intervention, the situation will inevitably arise that coal-fired generation will only be needed during certain periods (therefore*

1 A full set of these curves is what is in jargon called the "**duckcurve**". Modelling has been done amongst others by Renew Economy (2019 a, b).

2 Ramping up and down is an inherent impossibility for brown-coal- , hyper critical (so called 'clean coal' plants) or other types of coalfired power plants. Starting or shutting down coalfired powerplants may take more than 12 hours. Nuclear powerplants have the same ramping problems and their startups and shutdowns take even longer.

raising consumer costs), or Government will need to legislate against consumer-generated solar electricity (causing political unrest). Governments will need to respond nimbly. …"

From the descriptions above it is clear that 'baseload' is now an outdated concept and this is recognised amongst others by the Australian Energy Market Operator (AEMO), AGL Energy, the Chinese government and many other governments. It is likely that the baseload problem will grow with the installation of BTM battery backup, when the time periods no baseload power is required widens.

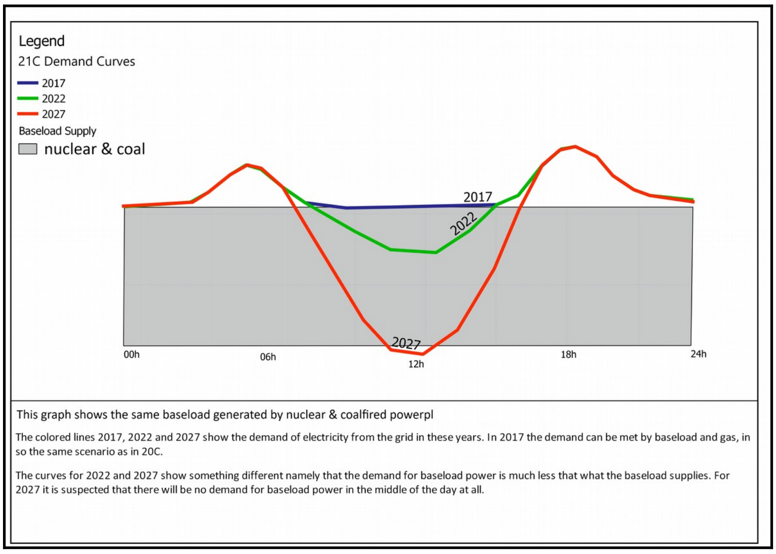
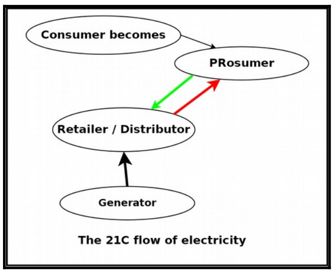


Fig 2. 21C Baseload supply and Duckcurves



Here the diagram that shows the electricity flow in the 21C.

On a separate note most nuclear powerplants need copious amounts of water to operate, as is shown in table 1. At a time when clean water is at a premium the use of large amounts of water unnecessarily is not socially permissible.

Economics of Nuclear Power Plants

Quoting from The Economist (2014) "... *China's rush to build nuclear power plants is dangerous. For most countries nuclear power is a poor option. Big reactors invariably cost more and take longer to build than predicted. As alternative sources of energy have proliferated , the economics of nuclear have worsened. The other worry is just safety. … Such worries increase the risk of politicians cancelling projects, which also raises the costs. ...China, however, faces none of these constraints. The government is willing to pay for countless loss-making infrastructure projects, ... The cost of renewable energy is dropping quickly and its efficiency rising sharply. Last year, over half of all new power-generation capacity installed* *in China was hydro, wind or solar. If China wants to accelerate its moves away from coal, ramping up those alternatives yet more would be a lot safer. ...*"

Energy production Type	Water requirement (liter/MW h)
Oil extraction	10 – 40
Oil refining	80 – 150
Coal integrated gasification combined cycle	950
Natural gas combined cycle power plant	200 – 3.000
Nuclear plant closed loop cooling	950
Geothermal power plant in close loop tower	1.900 – 4.200
Enhanced oil recovery (EOR)	7.600
Nuclear power plant open loop cooling	94.000 – 27.700

Table 1. Water usage by energy production; copied from Amaroux (2014).

This quote raises the question 'is nuclear power as cost effective as often portrayed'? When nuclear power is promoted are all real costs included? Three major issues about nuclear power plants are not always mentioned when they are proposed and promoted. Often costs are not transparently reported due to levels of obscurity (Gilbert, et al., 2016).

1. Insurance
2. Construction
3. Decommissioning

Point 1: Insurance. It is unlikely that a commercial insurer that will ever fully insure a nuclear power plant. As a result it is the government that is the insurer, so the taxpayer will foot the bill in case of a disaster. In the Fukushima case the cost is could be more than US$500 Billion dollars. What would the insurance premium be for this amount? This point is elaborated below.

In general for the electricity markets to function on a level playing field any subsidy, including insurance costs paid for by the taxpayer, should be reported transparently and accurately. It is clear from the case study about Fukushima-Daiichi (Laureto & Pearce, 2016) that the Japanese State had to take all the risks, including insurance risks, into account in any of their energy policies. The same research paper shows the importance of high-quality journalism, in this case reporting on energy policy, economic viability and the hazard to the public of nuclear power plants. It highlights the importance of transparent reporting of regulations for the energy sector. This type of journalism is important for a well-functioning democracy.

In any project liability and related insurance costs are essential components in the evaluation of its viability. This is no different for nuclear powerplant projects. There are in all jurisdictions caps in place for insurance cover to be provided by the operator, which basically covers only a fraction of the costs in case of a disaster. This "hidden subsidy" is a factor in the way figures are reported; according to Gilbert, et al. (2016) "*... despite major utilities admitting that full liability insurance would make nuclear power commercially unviable ...*".

Tables 2 and 7 are copied from the Laureto & Pearce (2016) research paper about the Fukushima-Daiichi nuclear plants in the wake of the disaster. The data show that the capacity factor (ratio of operating time for maximum output in a year, 8760 hours) ranges from 54% to 70% per year. When these reactors and that is true for any generator, are offline due to maintenance or breakdown, there need to be backup facilities. What is the cost of this compared to have a wind turbine turned off for maintenance? The same paper reports on insurance costs in US$/kWh sourced from different media outlets varying from US$0.22 to US$5.78 / kWh. Under Japanese law only US0.01 /kWh of insurance cover can be added to the cost of electricity by the operator to cover insurance, while the estimates from Forbes and The Economist produce insurance costs of more than US$5 /kWh.

lifetime electrical profile for Fukushima (Daiichi), as provided by the International Atomic Energy Agency (IAEA), is shown in Table 2.

Table 2. Lifetime and average yearly electrical output of Fukushima (Daiichi) reactors [6].

Name/Description	Lifetime Electrical Output (TWh)	Average Yearly Electrical Output ($\pm\sigma$) (GWh) [1]	Average Annual Time Online ($\pm\sigma$) (h) [1]
Fukushima Daiichi-1	82.35	1974.12 (1106.25)	4726.45 (2530.51)
Fukushima Daiichi-2	148.15	3857.78 (1585.06)	5402.95 (2132.41)
Fukushima Daiichi-3	155.94	4129.28 (1387.57)	5707.13 (1763.84)
Fukushima Daiichi-4	154.30	4528.18 (1490.63)	6154.74 (1943.56)
Fukushima Daiichi-5	156.43	4259.29 (1775.16)	5800.35 (2337.03)
Fukushima Daiichi-6	206.65	5899.66 (2392.47)	5658.03 (2253.11)

[1] Calculated from first grid connection to permanent shutdown date.

Table 7. Insurance cost per unit of energy USD.

News Agency	Insurance Cost $USD/kWh
Bloomberg	2.40
The Economist	5.08
Forbes	5.78
The Guardian	0.22
Reuters	2.38
The Wall Street Journal	1.43

4.3. Comparing Reported Nuclear Power USD/kWh to Researched True Nuclear Insurance Cost Subsidy USD/kWh

Point 2 : Construction Costs. History of the last 50 years shows that many plants cost 3 to 4 times more than the original cost estimate. That is not a good business model to start with.

Quoting from Portugal-Pereira et al. (2018) "… *Average overnight construction costs of newer reactors are considerably higher than the ones implemented in the earlier stages of the nuclear era. This finding suggests that the nuclear technology is significantly costly and takes too long to be implemented, which increases the project risks, given its high probability of cost overrun and construction delays. This threats the market and the financial sustainability of future and current nuclear energy projects. Therefore, nuclear technology is not at the forefront to cope with the need for climate change mitigation strategies to contribute to decarbonising of the power sector …*".

In the history of nuclear powerplants the reactors have become more complex and the safety standards have increased. This all leads to longer planning and constructing costs (Portugal-Pereira, et al., 2018). The overnight construction costs is a common measure, however all aspects of the construction costs are to be included, like the cost of capital and the time of construction. Nuclear reactors are large and mainly built onsite, with the construction phase taking up to more than a decade. In these circumstances the cost of capital becomes very important (Koomey, et al., 2017).

Figure 2 below copied from the research paper by Gilbert, et al. (2016) shows clearly the cost overruns by the nuclear industry compared with projects of energy and non-energy industries. The data was drawn from peer-reviewed papers. It is interesting to note the number of nuclear projects (180) is large, therefore there is no denying that cost overruns are a problem in the nuclear industry.

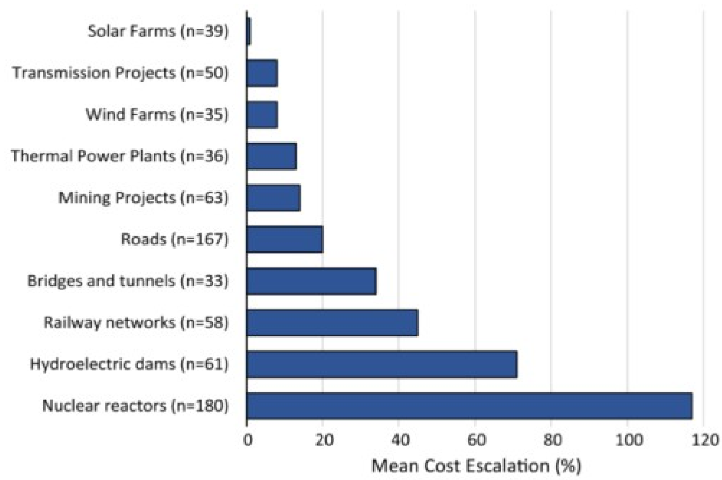


Fig. 2. Mean Cost Escalation for Various Infrastructure Projects.

As chairman O'Brien indicated the committee will look at small types of nuclear reactors. Proponents of these small modular reactors (SMRs) claim that they are safer and could even be located where currently coalfired powerplants are situated. However many of their designs are unproven (Lyman, 2013). Especially after the Fukushima disaster safety standards have been expanded, which also escalated the costs of construction and operation of SMRs and other types of nuclear reactors.

Construction costs of RE has been falling rapidly while cost for nuclear have been rising. Another point about construction of nuclear powerplants is that enormous amounts of concrete are used and for each ton of cement 1/2 ton of CO2 is generated. Another disadvantage of nuclear (and coalfired) powerplants is that they can only start generating electricity when the projects are totally completed. While RE projects could easily be designed that they start generating electricity incrementally, let say in six months' time slots.

Point 3 : Decommissioning. The cost of decommissioning is totally born by the taxpayer. None of the material from a decommissioned nuclear power plant can be recycled because it is deemed to be radioactively contaminated. In contrast a wind turbine can nearly be recycled totally.

In Germany they have estimated that a nuclear disaster like Fukushima would cost US$10trillion. Why is it that the real Fukushima disaster would cost much less (GlobalResearch, 2011)? Already by 2014, the in

2011 the Japanese predicted cost of the Fukushima disaster was doubled to US$105billion (Fukushima Update, 2014) and has upsurged even further over time.

Even though the clean-up costs of the Fukushima-Daiichi disaster cannot be equated to decommissioning costs, it nevertheless highlights the very high costs of a clean-up process. Unfortunately there is no comprehensive amount of academic research about decommissioning costs. It is possible that governments delay decommissioning so that problem has to be dealt with by future governments and therefore not having to face the costs now.

Conclusion

Instead of putting money into developing nuclear powerplants, the money should be used for energy efficiency implementation and RE projects and research in these topics. According to Madsen et al. (2009) directing U$300billion into energy efficiency would save US$600billion by 2030.

For all the above reasons nuclear power plants are not a good economic proposition, especially since the cost of renewable energy is getting lower all the time. This is in addition that they will not be suitable for a modern electricity grid due to their inflexibility. All the above concerns are likely to apply also for SMRs.

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