AN OBJECT EXAMPLE OF THE INFEASIBILITY OF “RENEWABLE” ENERGY SOLVING THE ENERGY NEEDS OF NEW SOUTH WALES(NSW)

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Background

This paper does not seek to analyse NSW's present and future energy needs. I may investigate that later. Today, we were told that NSW intends to create a pumped hydro system that will generate 8 Gigawatts on a continuous basis. The inference to be drawn from this, as a consequence of the previous conversation, is that the majority of the power for this pumped hydro system will come from solar panels on the roofs of businesses and domestic dwellings. It may also come from wind farms and mass solar panel installations closely located to the pumped hydro-electric system.

Purpose

The purpose of this paper is to use this example as a means of highlighting the practicality and economy, or otherwise, of such a scheme, ie, a Pumped Hydro electricity system that is capable of delivering 8 Gigawatts on a continuous basis.

Some Basic Physics to Assist the Reader

A watt is a Joule of energy per second. A Joule of energy is expended with a force of 1 kg moves through a distance of 1 metre. When a kilogram mass of water (which is 1 litre) falls through a distance of 1 metre in one second, at 100% efficiency, it is capable of generating 9.80665 watts of power.

Scoping the System

So a system that is creating 8 Gigawatts of power requires that $8/9.80665\text{x}10^9$ litres of water flow every second = $0.8158\ \text{x}10^9$ litres of water per second through a distance of 1 metre. (Note: This assumes 100% efficiency in the process. I will deal with the matter of system efficiency later in this discussion.) If this system ran for 24 hours it will require $0.8158\ \text{x}10^9$ x 60x60x24 litres of water = $70{,}485.12\ \text{x}10^9$ litres = 70,485.12 Gigalitres/the elevation of the dam. The average height of the Great Dividing Range is around 600 metres so we will assume that all of the repositories in which the water is stored will be held at that elevation. The water would not run down to 0 metres so let’s assume for the sake of this calculation that an average drop of 400 metres would be possible. The number of Gigalitres that would be required to flow through the system to produce 8 Gigawatts for 24 hours is thus, 70,485.12 Gigalitres/400 =176.2128 Gigalitres (if the system was 100% efficient...which it would not be).

Pumped hydro works by pumping the water up to an elevation and then letting it run down hill though pipes (called penstocks) at the bottom of the drop of which are turbines, usually Francis Turbines, connected to electricity generators. The efficiency of a Francis turbine and generators is typically around 90%.

The pumps that move the water up to the elevation usually work at an efficiency around 80%. There is around a 10% loss through friction in the pipes and turbulence, so that overall efficiency of the system is 0.9x0.8x0.9 = 0.64, that is, for every watt of power input, you get 0.64 watts out in the form of electricity.

In addition to this there are losses in voltage transformation and through transmission of the electricity over power lines but these losses are similar to that which one would encounter with a conventional coal-fired base load facility and so, for the purposes of comparing the wind/solar/pumped hydro system with a coal fired generator, we can ignore calculating what these losses are.

This being the case, the amount of water now needed to provide 8 Gigawatts of power for 24 hours continuously is thus 176.2128 /0.64 = 275.3325 Gigalitres. In order to provide reliable power, to cover rainy periods (at the time of writing, in the Northern Rivers area, it has rained for 12 weeks continuously) and periods when the wind does not blow, it is estimated it would be necessary to hold at least 30 days supply of water. This increases the total size of the repositories to 8259.975 Gigalitres. *This is approximately 4.07 times the size of Warragamba Dam's total capacity*[1].

The Cost of Largescale Rooftop Solar

Let's now look at the cost of the roof-top solar systems that will provide the 8 Gigawatts of power on a continuous basis to the system.

For the purposes of this example, we shall assume that all systems are 5 kW capability and cost $8,000 to acquire and install.

These systems typically produce 15kWh per day of power during the winter and 30kWh per day of power during the summer.

Unfortunately, bright sunny days are not common except in the driest of areas where there are no houses and therefore no roof-top solar. To set up solar PV systems in the dry, sunlit areas of Australia then requires considerable investment in infrastructure in the form of ultra-high-voltage DC power lines with attendant transformation, inversion and transmission losses. So we will, for the purposes of this paper deal only with urban roof top solar systems. From https://www.currentresults.com/Weather/Australia/Cities/sunshine-annual-average.php we get the following table.

Average hours of bright sunshine a year

City	Day	Annual
Adelaide, South Australia	8	2774
Brisbane, Queensland	8	2884
Cairns, Queensland	8	2738
Canberra, Australian Capital Territory	8	2811
Darwin, Northern Territory	9	3103
Hobart, Tasmania	6	2263
Mackay, Queensland	8	2993
Perth, Western Australia	9	3212
Rockhampton, Queensland	7	2592
Sydney, New South Wales	7	2592
Townsville, Queensland	9	3139

There are approximately 8,766 hours in an average year of 365.25 days. Of this, 1/2 is nominally “daylight”, ie, 4,383 hours. It can be seen from the above table that, because of clouds, one could conservatively reduce the power being typically generated from roof top solar on a cloudless day by around 40%, ie, (15+30)/2*.6 kWh/day = 13.5kWh/day average production.
Given the 8Gigawatt /0.64(the efficiency)= 12.5 GW is needed 24 hours per day, all year round. To produce 24hr x 12.5 GW = 300GWh of power requires $300\text{x}10^9/13.5\text{x}10^3 = 22.22\text{x}10^6$ roof-top solar systems, ie, approx 22 million solar systems. These will cost a total of $\$8{,}000\text{x}22.22\text{x}10^6$ = **$177.760 billion**.[2]

For this investment, it would be possible to construct around 88 coal fired power stations, each with a capacity of between 1 & 2 Gigawatts or 44 Nuclear largescale power stations.

The Likely Cost of a kWhr Generated by this Means

1 2,027Gigalitre – See https://www.waternsw.com.au/supply/visit/warragamba-dam
2 This takes into account that, when the PV systems are operating, they must produce 8GW of power, plus they must provide the power to pump water up to reservoir so that, when the system are not producing power to the full extent or not at all, such as at night, power can still be provided to meet peak demand in the evening and the mornings.

These roof-top solar systems have an average life of 25 years. In 25 years, each system will generate 365.25 days in a year x 13.5kWh/day x 25 years = 123,271.875 kWh of electricity. (This does not take into account PV cell degradation which naturally occurs due to aging.) A system costs approximately 800,000 cents. This comes to 800,000cents / 123,271.875 kWh = approx 6.5 cents/kWh. This does not take into account the bank interest that is lost from this sunk investment.   The actual marginal cost is thus (@ 2% interest) in the order of $12,867.50 over a 25 year period which brings the cost of electricity generated by this means to **10.44 cents/kWh**.

This is only the cost per kWhr of electricity generated during the day by PV solar panels. When the sun does not shine and the wind does not blow (in the case of windmills), hydro is necessary and so the cost of a pumped hydro-elect system has to be added to this project.

The Likely Cost of the Pumped Hydro System

The cost of the pumping system, which includes the establishment of significant dams, the pipes, turbines, maintenance, etc is considerable. That cost can be assessed from the experience of the hydro-electricity schemes that do not use pumped hydro. To gain some understanding of this, see: https://www.irena.org/costs/Power-Generation-Costs/Hydropower

For large hydropower projects the weighted average Levellised Cost of Energy (LCOE) of new projects added over the past decade in China and Brazil was USD 0.040/kWh, around USD 0.084/kWh in North America and USD 0.120/kWh in Europe. For small hydropower projects (1-10 MW) the weighted average LCOE for new projects ranged between USD 0.040/kWh in China, 0.060/kWh in India and Brazil and USD 0.130/kWh in Europe.

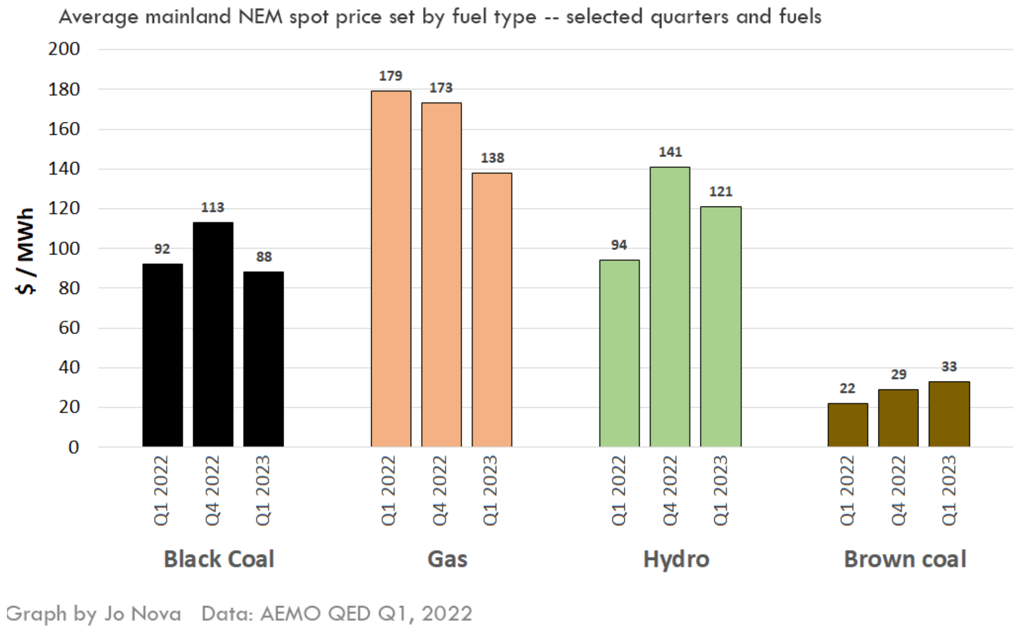
This figure is probably too optimistic in terms of its cost. The cost for the proposed New England project will require massive dams (as touched upon previously in this paper) at both top and bottom plus pumps as well as turbines at the bottom. It has been suggested that the intention is to have massive wind and solar farms fairly close by, thus reducing input transmission losses to the pumps (and the need for long periods of constant hydro), but Armadale is a long way from Sydney and transmission losses could exceed 20%. The total infrastructure and environmental costs would be without precedent in this country.

For this example, we will choose the modest figure of US0.084/kWh (taking the US example which would have similar labour costs.) This comes to 10.6 cents Australian per kWh at present exchange rates..

So the total cost of the proposed pumped hydro solar & wind system, if it is practical at all, is likely to be in excess of **21 cents/kWh**. Now we should compare this with the cost of power generation using nuclear, coal and gas-fired facilities.

Comparison with Nuclear, Coal and Gas Generation Systems

The following graph produced by Jo Nova uses actual data from the National Electricity Market (Australia) data



This graph shows that brown coal is by far the cheapest way to produce electrical power. It should be noted that these cost are based on systems that have been in operation for a long time and so their cost of acquisition has been well and truly amortised.

It is very difficult to obtain factual pricing for (new-build) nuclear, coal and gas however, the order of economy appears to be coal, nuclear and then gas. I have included costs determined by the US Department of Energy as at 2019.

U.S. average levelized costs (2012 $/MWh) for plants entering service in 2019

Plant type	Capacity factor (%)	Levelized capital cost	Fixed O&M	Variable O&M (including fuel)	Transmission investment	Total system LCOE	Subsidy1	Total LCOE including Subsidy
Dispatchable Technologies								
Conventional Coal	85	60	4.2	30.3	1.2	95.6		
Integrated Coal-Gasification Combined Cycle (IGCC)	85	76.1	6.9	31.7	1.2	115.9		
IGCC with CCS	85	97.8	9.8	38.6	1.2	147.4		
Conventional Combined Cycle	87	14.3	1.7	49.1	1.2	66.3		
Advanced Combined Cycle	87	15.7	2	45.5	1.2	64.4		
Advanced CC with CCS	87	30.3	4.2	55.6	1.2	91.3		
Conventional Combustion Turbine	30	40.2	2.8	82	3.4	128.4		

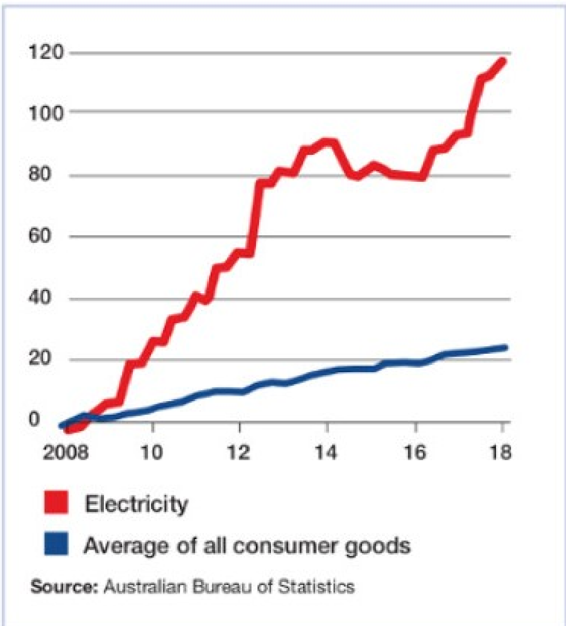
Advanced Combustion Turbine	30	27.3	2.7	70.3	3.4	103.8		
Advanced Nuclear	90	71.4	11.8	11.8	1.1	96.1	-10	86.1
Geothermal	92	34.2	12.2	0	1.4	47.9	-3.4	44.5
Biomass	83	47.4	14.5	39.5	1.2	102.6		
Non-Dispatchable Technologies								
Wind	35	64.1	13	0	3.2	80.3		
Wind-Offshore	37	175.4	22.8	0	5.8	204.1		
Solar PV[2]	25	114.5	11.4	0	4.1	130	-11.5	118.6
Solar Thermal	20	195	42.1	0	6	243.1	-19.5	223.6
Hydro[3]	53	72	4.1	6.4	2	84.5		

According to this, the cost of a kWh of power generated from a newly built coal fired power station is 9.5 US cents. Advanced nuclear is 9.6 US cents. These are for new installations. The US fossil fuel installations face special taxes because of their "carbon" pollution so, without these, the costs would be significantly less and closer to the graph shown above. China retails its electrical power for around US 5 cents/kWh. The costs attributed to nuclear are also controversial and likely to be inflated here.

The US figures therefore are likely to be on the high side compared to what would be experienced in Australia. We shall therefore estimate that **the present day cost of generating electricity using coal or nuclear is around AU 10 cents/kWh**.

It is noteworthy that Australian coal-fired power generation was, before the introduction of intermittent power sources into the network, amongst the cheapest in the world. Here is what has happened to the cost of electrical power after the Labor Government started its drive towards "renewables"

Cumulative percentage increase in nominal prices



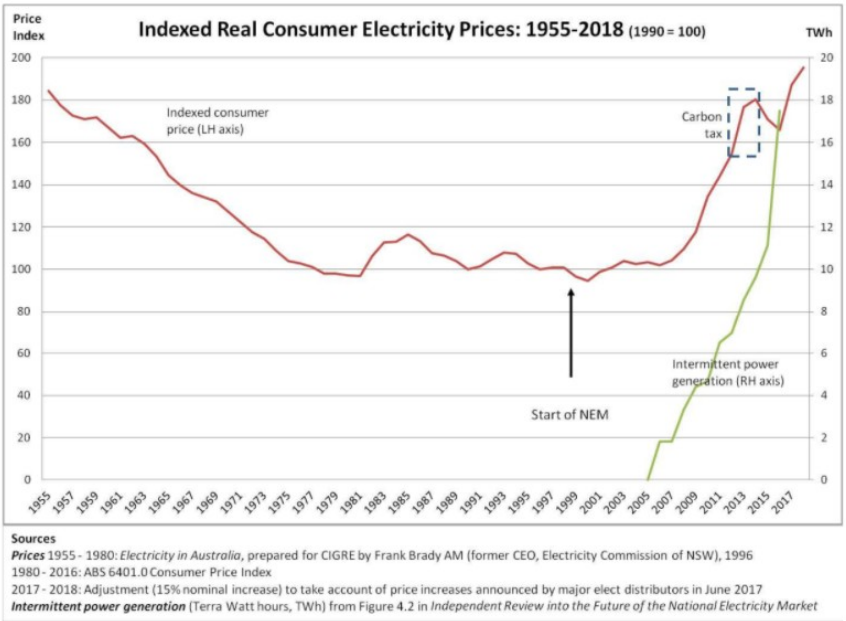
There is a cost of **$14 billion per year** incurred by consumers and taxpayers, or a total cost of **$140 billion over 10 years**.

Already 10 coal fired baseload power stations have closed in Australia.

With $140 billion, the Australian Taxpayer could have built **70 coal fired power stations!**

It can be seen that energy in Australia has risen by around 550% higher than the Consumer Price Index over the same period; starting in late 2007 through to 2018. The cost of electricity still rises on the same trajectory. Any suggestion, by advocates of this scheme, that they will achieve a 10% reduction in energy costs has to be viewed against this backdrop. There is a need to reduce energy costs by at least 550% to get back to the situation that existed in 2007-2008. Government could improve on that figure if it adopted coal and nuclear power generation and prevented the unreliable, intermittent inject of power from solar and wind into the network.

The following graph appears to show a correlation between the amount of power being injected intermittently into the grid and the resultant cost of electricity as a consequence.



If Australia is to have the cheapest and most reliable electricity possible, it is imperative that the injectiion of intermittent power into the grid be stopped. If unreliable solar and wind are to be used, they must be backed up by a storage system that ensure input will be reliable and variable according to demand.

Summation

The idea of having pumped hydro driven largely by roof-top solar systems that must be scrapped after 25 years, using components that are largely built in China, appears to carry a high level of risk and will not deliver the cheapest energy to Australian industry and society. This study suggests that:

1. The cost of electricity created by the proposed pumped-hydro, solar and wind scheme will be in the **order of at least AU 21 cents per kWh wholesale**.
2. The cost of producing electricity using coal or nuclear, without the disruption of intermittent injection of power by “renewables”, is likely to be significantly less than **AU 10 cents per kWh**.

Experience suggests it is likely that nuclear energy will be slightly cheaper than coal; especially if modular nuclear reactors are collocated at existing coal fired power generation facilities. Nuclear is also an interesting study because if Australia were to develop a nuclear processing and reprocessing industry, it has the potential to earn Australia many billions of dollars per year reprocessing the reactor rods of other countries. This would also aid in preventing nuclear weapons proliferation by tightly controlling the access to fissile material. Any country that did not return its rods for reprocessing would not receive any more enriched uranium.

Given the core justification for pursuing this method of power generation is to reduce emissions, the pumped-hydro project appears to be imprudent and a great waste of taxpayers' money.

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