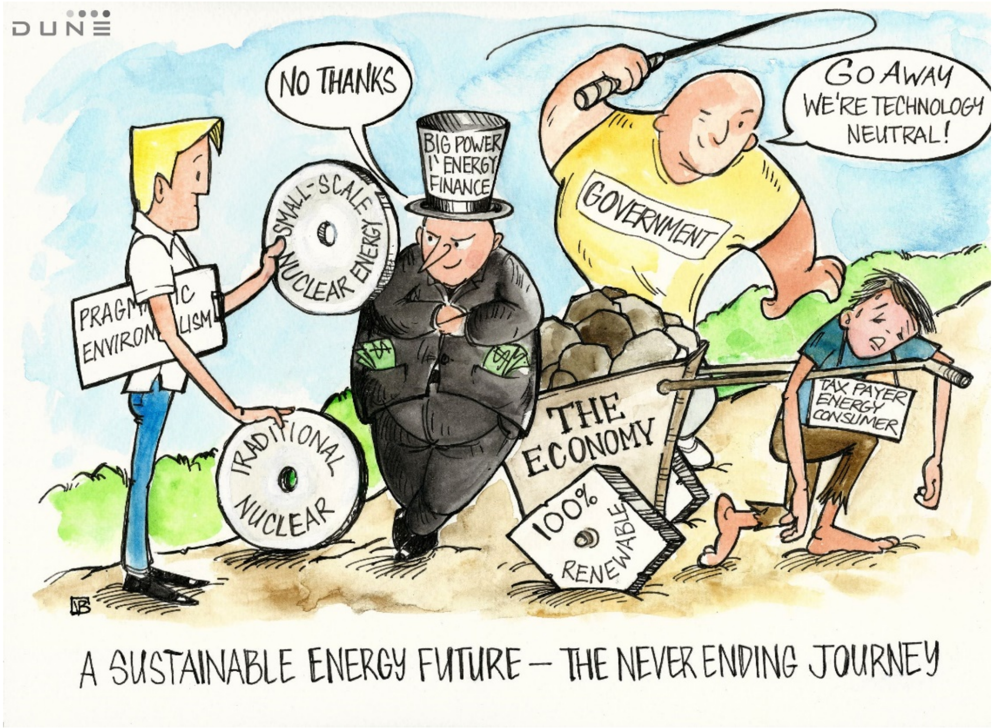
Nuclear for CLIMATE AUSTRALIA

NUCLEAR ENERGY - AUSTRALIA’S LEAST COST LOW CARBON ENERGY SOLUTION

AMMENDED 20-7-2021



Introduction

Angus Taylor has an inquiry going into dispatchable energy and storage options for electricity production. The terms of reference suggest the need to enable Variable Renewable Energy Sources (VRE) such as wind and solar to be integrated into the National Electricity Market (NEM) in a dispatchable or usable form.

Our analysis of AEMO’s Integrated System Plan (ISP) out to 2042 and ultimately to a decarbonised electricity sector demonstrates that a system based on nuclear energy will have much lower costs and achieve carbon reductions more quickly. It will achieve these cost benefits in part by eliminating the need for large amounts of energy storage and the expansion of the existing transmission and distribution system.

Our submission to the inquiry directly compares the costs and emissions profiles of such an integration with those of a nuclear energy based system. The headings in this article address some of the key terms of reference.

Current and Future Needs

The current and future needs are taken to be the current and future annual energy demand on the NEM as outlined in AEMO’s National Electricity Forecasting at http://forecasting.aemo.com.au/Electricity/AnnualConsumption/Operational.

There are a great many scenarios that make up AEMO's Integrated System Plan 2020. For brevity we quote the current and future electricity demands in 2042 as follows:

Scenario	Year	Operational Sent out energy (GWh/yr)	Small Non-Scheduled Generators and Roof top PV (GWh/yr)	Total Demand (GWh/yr)
Central DP1	2021	175,717	20,910	196,627
	2042	193,655	48,382	242,036
Step Change DP1	2021			182,177
	2042			224,887

The total demand in 2042 will form the basis of comparison of VRE and Nuclear energy-based systems. Many of the remaining AEMO ISP scenarios could be compared however the relative benefits of nuclear energy will remain.

Existing, new and emerging technologies

The small nuclear power plant used in this comparison is the General Electric BWRX boiling water nuclear power plant from General Electric Hitachi.

From GE's promotional material this plant's benefits are:

- Cost competitive: projected to have significantly less capital cost per MW when compared with a typical water-cooled Small Modular Reactors (SMR)
- World class safety: designed to mitigate loss-of-coolant accidents (LOCA) enabling simpler passive safety – Emergency Planning Zone EPZ limited to site boundary
- Innovative cost-competitive design: designed to allow the Nth-of-a-kind (NOAK) BWRX-300 to be competitive with the levelized cost of electricity of natural gas and renewables
- Passive cooling: designed to allow steam condensation and gravity to cool the reactor for a minimum of seven days without power or operator action
- Quick Deployment: Deployable as early as 2027, thanks to proven know-how, supply chain, components, certified fuel and simpler construction techniques

Figure 1 Anticipated view of BWRX 300

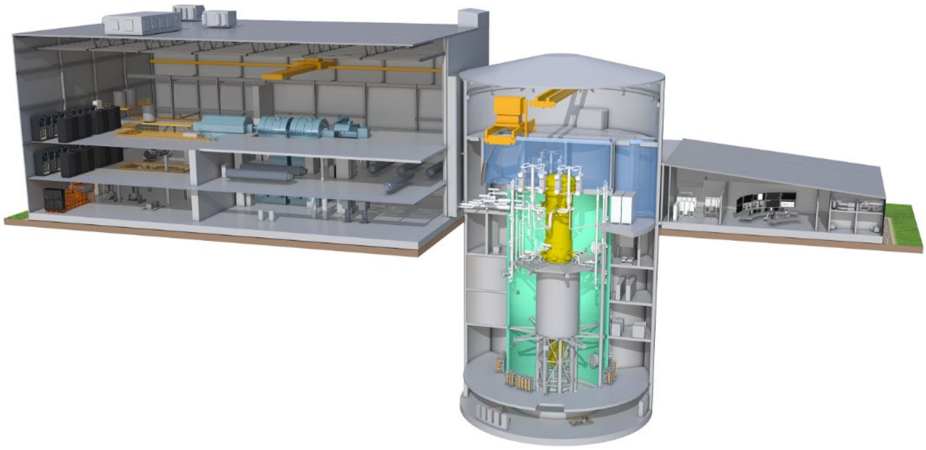


Figure 2 - Section through BWRX 300

BWRX 300

300MWe boiling water nuclear power plant from GE-Hitachi US$2,500/kW, Allow A$4,580/Kw

A$1.374 Billion per unit

General Electric are focused on ensuring the BWRX 300 is cost competitive in the very tight North American market where shale gas prices are making other generators uncompetitive. The cost sensitivity is shown in Figure 3 where the BWRX 300 has a significantly lower levelised cost of generation than other nuclear power plants and is on a par with shale gas generation and renewables.

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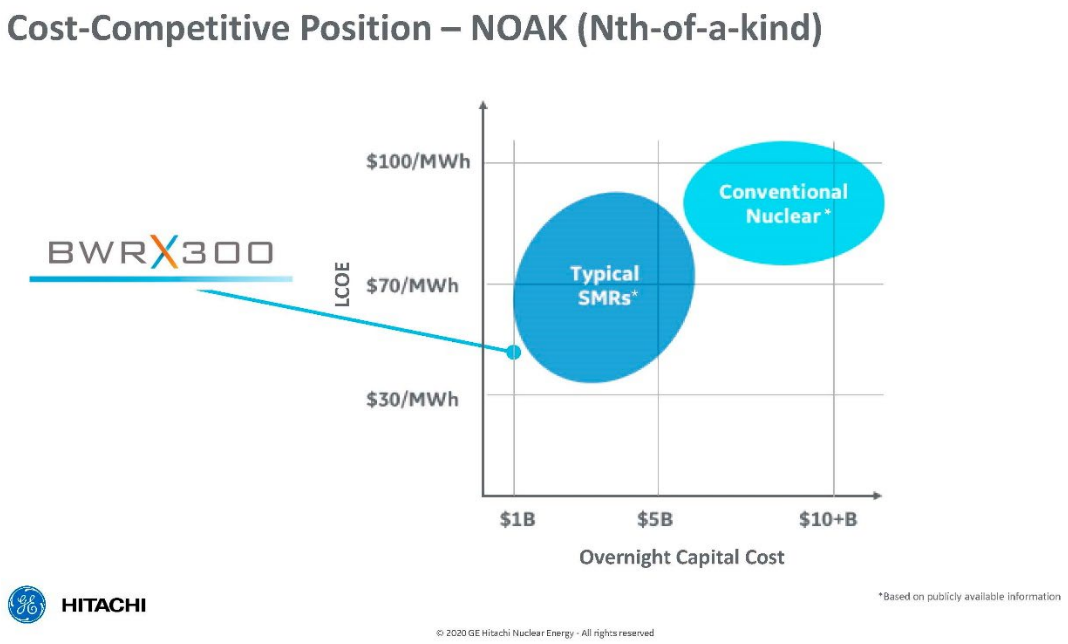

Figure 3 Cost competitive position for the BWRX 300 "Nth of a kind" in US$/MWh on a cost per plant basis

Comparative efficiency, cost, timeliness of development and delivery, and other features of various technologies

The comparative analysis of renewable and nuclear based systems is shown in the charts in Figure 4 and Figure 5. Both comparisons shown are based on the costs for wind, solar, batteries, pumped storage and fossil fuel generators derived from CSIRO Gen Cost 2020-21. The cost for nuclear energy is based upon the publicly available General Electric (GE) anticipated cost adjusted for deployment in Australia.

https://nuclear.gepower.com/build-a-plant/products/nuclear-power-plants-overview/bwrx-300

For the purposes of this comparison we have used a capital cost of A$4,580/kW for the GE BWRX 300 small nuclear power plant. Further significant gains are also made in the staffing levels and so the operational values used are A$8.47/MWh for fuel and A$16.72/MWh for operations.

Figure 4 utilises CSIRO costs in 2021 for each technology. Much is made of the future anticipated cost reductions for batteries, solar and wind technologies. These reduced values are reflected in Figure 5. While the costs of a fleet of small nuclear power plants would also decline with time, this has not been assumed in our comparisons.

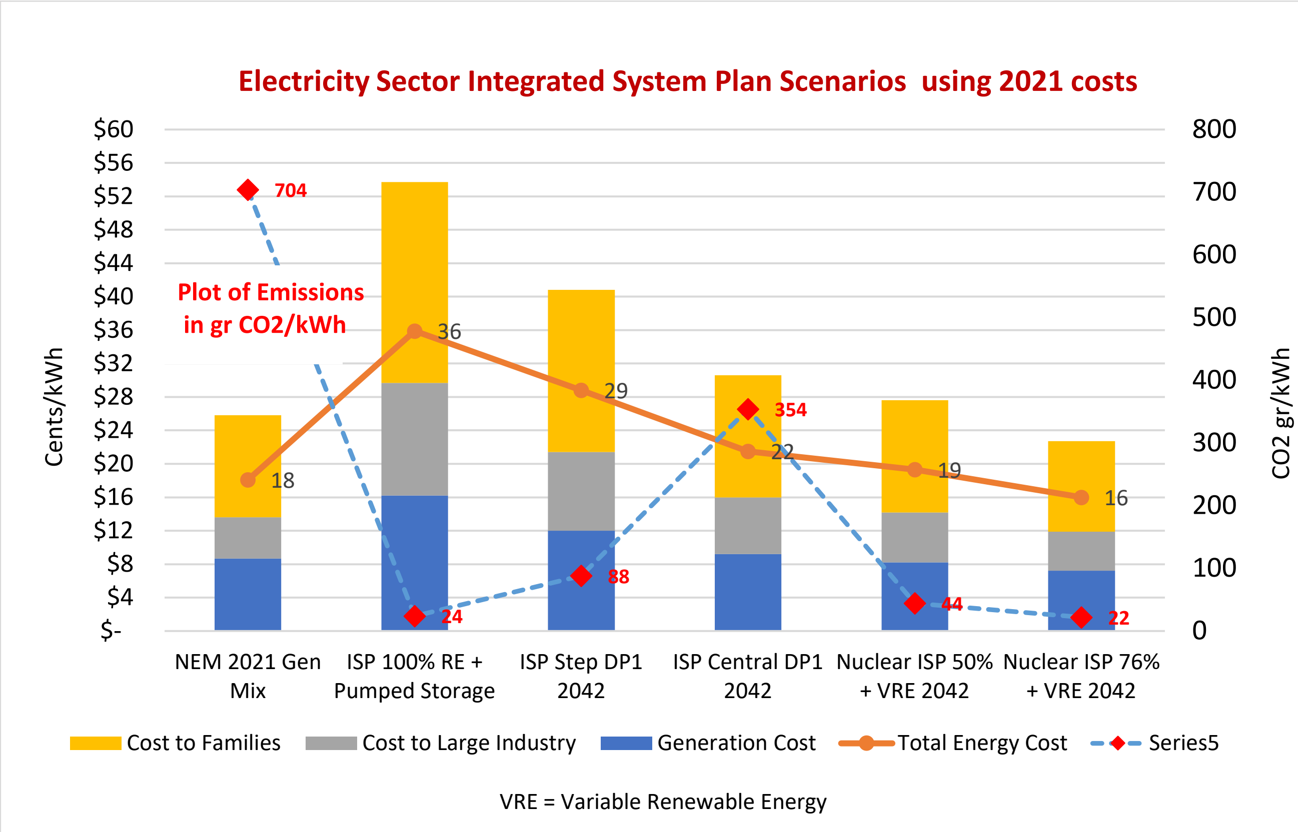

Figure 4

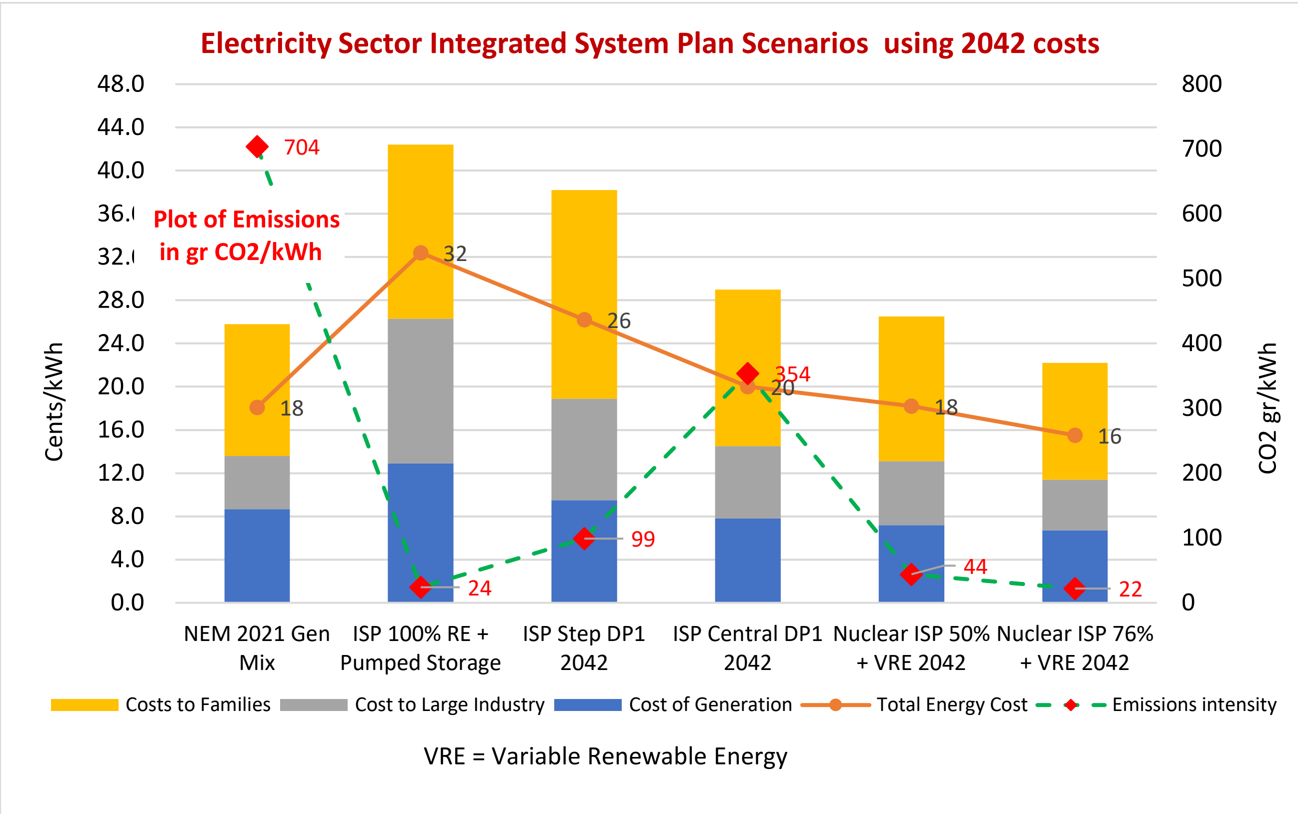

Figure 5

Comparison assumptions and outcomes

Six energy plans are shown in the charts. Each energy plan has been run through the Electric Power Consulting's Energy Model. The model matches a mix of energy generators and storage devices to meet the demand on the National Electricity Market (NEM) which uses about 199TWh/year.

It contains demand data for three consecutive years from 2017. The demand is measured at half hour intervals.

Inputs into the model include:

- Capital costs
- Fixed and variable operational costs
- Discount rates,
- Min and max generation limits for each generator
- Ramp rates
- Carbon emissions both from combustion and embedded.
- Arbitrage options
- Transmission, Distribution, loss factors and retail margins

Using these inputs the model derives the System Levelised Costs of Energy (SLCOE) and energy prices to wholesale and low voltage retail customers.

The model also calculates the actual shares of energy for each generator, capacity factors and costs of carbon abatement.

Description of the six energy plans:

1. NEM 2021 Gen Mix – this uses the existing NEM based mix of coal, gas, wind, solar and hydro with the existing transmission, distribution and ancillary services costs. It is intended to act as a "control" for subsequent plans and demonstrate the correct order of costs and emissions.
2. ISP 100% RE + Pumped Storage – This plan uses wind, roof top and utility level solar and existing hydro as the generators. Storage is provided by 5.1GW of batteries and 21GW of pumped hydro.
3. ISP Step DP1 – This plan was determined by AEMO and uses the residue of coal plants, existing hydro, combined and open cycle plants, plus wind and roof top and utility grade solar. Storage is provided by 12.8GW of batteries and 9.7 GW od pumped hydro.
4. ISP Central DP1 – This plan determined by AEMO is a less aggressive option than the Step Change and uses more coal and gas. Storage is provided by 6.6GW of batteries and 7.7GW of pumped storage
5. Nuclear ISP 50% + VRE 2042. This plan eliminates coal use and allows for the use of 15.25GW of small nuclear power plants which would amount to 54 generating units on the NEM grouped in large plants in the same manner as our existing coal plants have multiples of coal generators. They would be located primarily at the sites of existing coal and gas

generators or close by the grid at coastal locations. Additional generation is provided by 7.1GW of existing hydro, 2.5GW of open cycle gas, 11 GW of wind and 41 GW of roof top and utility solar. Storage is provided by 6.5 GW of Pumped Hydro and 7GW of batteries.

6. Nuclear ISP 76% + VRE 2042. This plan eliminates all coal and gas. It also eliminates the use of wind energy due to its high reliance on gas energy as a backup resource. It utilises 23GW of small nuclear power plants amounting to 82 generating units on the NEM grouped in large plants. They would be located primarily at the sites of existing coal and gas generators or close by the grid at coastal locations. Additional generation is provided by 7.1GW of existing hydro and 22.5 GW of roof top and utility solar. Storage is provided by 4 GW of pumped hydro and 4.5GW of batteries.

Results of Comparison

Both the 2021 and 2042 CSIRO cost base scenarios, plus our assessment of the GE plant, show significant cost benefits when nuclear energy is included in the mix compared to systems based on exclusively on variable renewables. These results are consistent with a recent OECD[i] study of the Texas ERCOT (Electricity Reliability Council of Texas) system. This highlighted the impact that variable wind and solar have on electricity system costs and the cost of the extra backup generators, costly transmission lines and excess capacity required.

Table 1 - Costs based upon 2021 CSIRO Cost base plus Independent assessment of BWRX 300 costs

Plan	Costs of Generation	Costs to Large Industry	Cost to Families and Low Voltage consumers	Cost compared to NEM 2021 Gen Mix	Emissions intensity gr CO2/kWh
NEM 2021 Gen Mix	$87	$136	$258	1.00	704
ISP 100% RE + Pumped Storage	$162	$297	$459	1.78	24
ISP Step DP1 2042	$120	$214	$408	1.58	88
ISP Central DP1 2042	$92	$160	$306	1.19	354
Nuclear ISP 50% + VRE 2042	$82	$142	$276	1.07	44
Nuclear ISP 76% + VRE 2042	$72	$119	$227	0.88	22

In particular, the plan which deploys 76% of nuclear energy is the least cost and eliminates all fossil fuel combustion. Its minor emissions of 22 gr CO2/kWh are derived from embodied carbon in the construction of all the generators.

System Management – a grounding in reality

The use of nuclear energy on the NEM would provide a system free from the consequences and complexity of juggling a variable renewable system with all attendant storage and ancillary services costs.

Figure 6 shows the interaction of the generators and storage required to meet the load. The nuclear power plants are running at high and economic capacity factors of 84% and are meeting the base load power demand. During the daily cyclic demand, a combination of the existing hydro plus solar and storage are meeting the load. The option exists to substitute open cycle gas plants for some of the storage at a modest overall emissions intensity of an additional 10 - 20 gr CO2/kWh.

Reference to international examples.

This system has precedent – it's very similar to that deployed in France for the past 30 years and has created amongst the lowest cost energy systems in the EU. France built 63 GW of nuclear energy over a 22 year period. Their Generation II plants had a materials intensity at least double that of the modern BWRX 300 plants. In effect Australia, with only 23 GW of installation, would be set with a construction project consuming about 20% of the effort made by France in the 1970's to 1990's.

Only a massive loss of confidence would prevent Australia from doing the job in one or two decades.

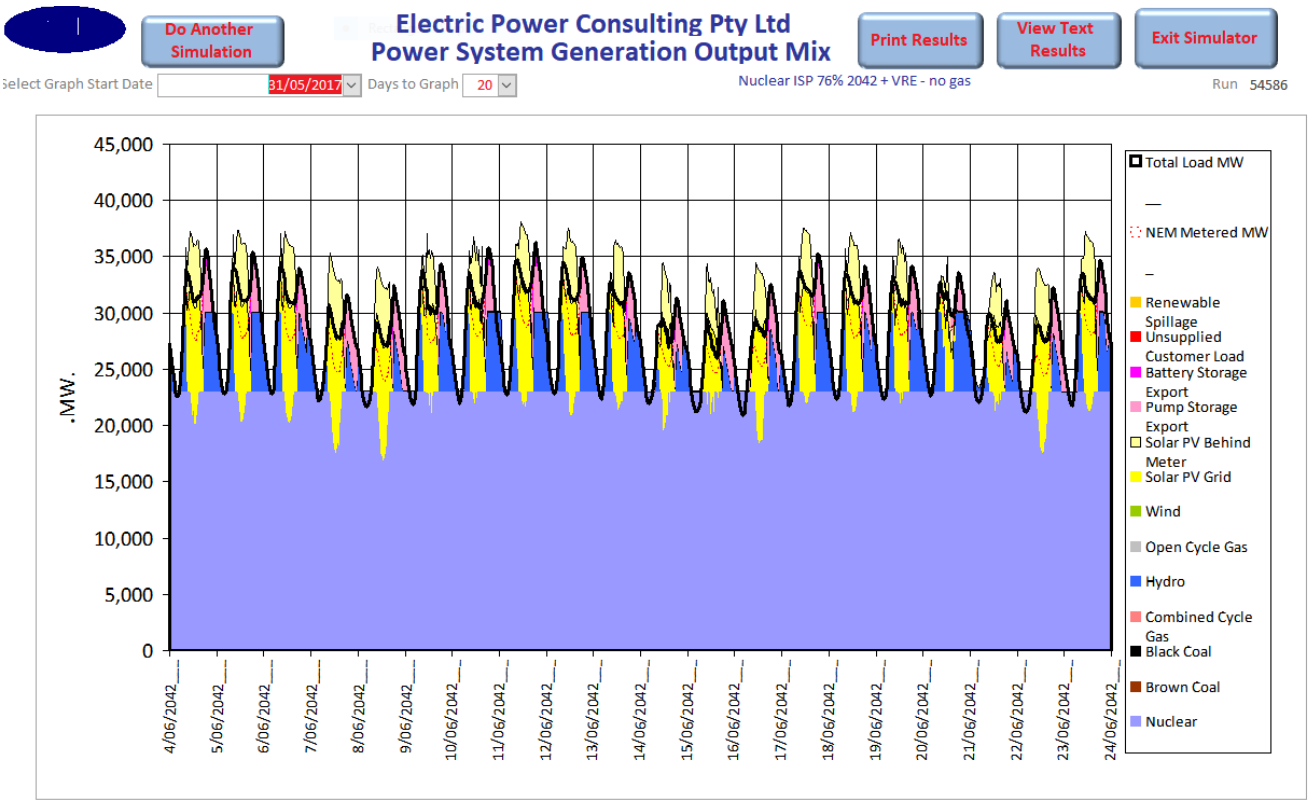

Figure 6 - Nuclear ISP 76% + VRE

In Figure 7 and Figure 9 we see examples of the complex juggling act required to manage systems dependent on variable renewable energy with storage. In figure 8 we see the large amount of surplus solar that is “spilled” under VRE systems. It’s highly variable occurrence on a daily basis means its use in hydrogen manufacture is problematic. In figure 9 we also see the problem of managing coal plants with high levels of solar. These will have vacated the market long before this type of operation is attempted.

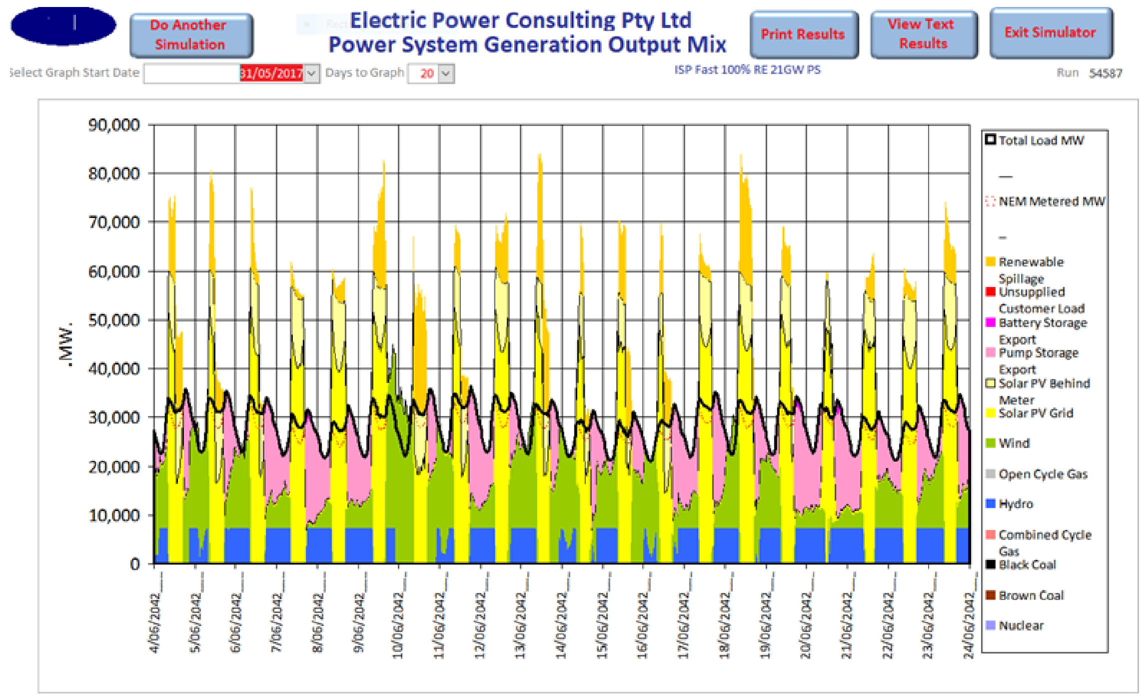

Figure 7 - ISP 100% RE + Pumped Storage

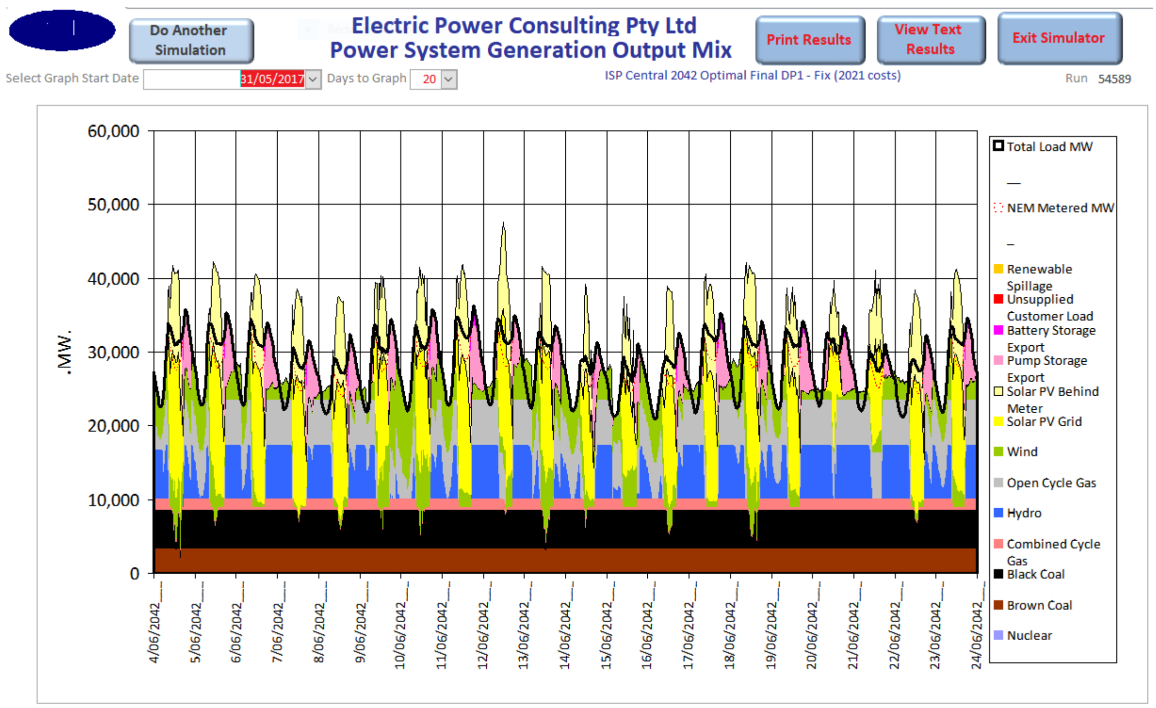

Figure 8 – ISP Central DP1

Concluding Remarks

Under the current NEM market structure no investment in base load generation or even large scale pumped hydro storage will take place without Government intervention. Therefore to enable Australia to have a low cost, low carbon electricity system will require mechanisms to be put into place that guarantee a return on investment and ensure consumers are insulated from excessive financing costs.

As can be seen from Figure 4 and Figure 5 the costs of energy generation is a minor portion of the total cost of electricity yet the type of generator determines the scale of transmission required. We must focus on keeping the costs of transmission and distribution to a minimum if we are to have competitive electricity prices.

A system using high levels of nuclear energy:

- Maximises the benefits of the existing transmission and distribution system and existing transport and cooling resources
- Eliminates the need for large amounts of storage and grid expansion
- Minimises the impact of weather induced risks.
- Will operate reliably and economically for at least 80 years and save on the vast costs of periodic replacements required by wind, solar and batteries.

Such a system will provide a large number of very highly skilled jobs and stabilise local communities. It will provide a massive lift in the levels of education and security to regional Australia and along the way it eliminates carbon emissions to the electricity sector.

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[i] THE COSTS OF DECARBONISATION: SYSTEM COSTS WITH HIGH SHARES OF NUCLEAR AND RENEWABLES, NEA No. 7299, © OECD 2019