CSIRO is losing its reputation over the stance they have taken on nuclear power. They are in an invidious position of having to accommodate the position Chris Bowen has on nuclear power, given his government is your pay master. You conceded in your 2021-22 report that SMRs could cost $7.9 million/MW by 2030 if demand took off but now you are saying they have no future because they will cost some $30 million/MW for a reactor that can't be purchased. To be consistent you should be opposed to pumped hydro given the Snowy 2.0 fiasco.

Pro nuclear France pays two thirds for its power compared to anti-nuclear Germany and the recent experience of the UAE show large scale nuclear reactors costing $A7.3 million/MW.

The following is my submission.

The 43% CO2 Reduction Target.

This article seeks to answer the following questions: -

1 If a 1000 MW coal fired power station is shut down, why does it need about 3000 MW of wind plus solar to replace it?

2 Having spent $X billion dollars on the above renewable farms, why does one then have to spend another $X billion on another energy system to overcome the inadequacy of the renewable system?

3 With governments around Australia talking up Australia's potential to become a world class green hydrogen energy hub, why does Elon Musk say of hydrogen "it is the most dumb thing I could possibly imagine for energy storage"?

4 1 Kg of coal burnt in a coal fired power station to raise steam will generate 2 KWh of power and 2 Kg of CO_2. 1 Kg of uranium 235 "burnt" in a nuclear power station to raise steam, will generate 8 million KWh of power and no CO_2. So, why shouldn't nuclear power be part of our energy mix?

5 Labour does not have good form in predicting the cost of things electric. Is Chris Bowen credible when he says the cost of going nuclear to replace 21.3 GW of coal fired power could be $387 billion?

1. BACKGROUND

Labour says it is going to reduce 2005 CO2 emissions of 560 million tonnes by 43% come 2030. That brings it down to 57% of 560 = 320 million tonnes as the 2030 target. Emissions for 2021were about 490 million tonnes so it will be reduced by 490 - 320 = 170 million tonnes, on the basis that the economy stays static. But the required reduction is going to be greater than 170 million tonnes because the economy will be growing.

Where does the 43 number come from? My guess is the person who selected it was a fan of the Hitchhiker's Guide to the Galaxy, and through a misremembered number thought the answer was 43.

The government has now set this target in legislation. Court challenges by emission reduction activists to coal or gas expansions, to name a couple, will now have in their armoury this legislation to support their case.

Curiously, the constitution gives the federal government no legislative power to dictate electrical power supply. It defaults to the states. The Snowy Mountain Scheme, back in 1960s and 1970s, was prosecuted by the Commonwealth Government asserting their power under the defence of the nation section of the constitution. The current government in WA, where I live, has no intention of aiming for 82% renewables come 2030. So, I ask myself, can the federal government dictate how electricity is to be generated? It has legislated the 43% reduction target, but can it enforce the 2030 CO_2 emission target via implementation of renewable energy?

Chris Bowen's has committed the federal government to finance 32 GW of renewables made up of 23 GW of wind and solar farms and 9 GW of storage. Based on a 50/50 split of the 23GW between wind and solar, this will cost $39 billion. One can't cost the storage cost without the GWh value. Does Bowen not know this? I have assumed 2 hours. Storage of 18 GWh will cost $12 billion. Basis of costings will be shown later in this article.

The biggest emitter of CO2 is power generation at 34% and that amounted to about 170 million tonnes in 2020. Where is Labour going to find its 170 million tonnes? I don't know, but if it gets 170 million tonnes of it from power generation, let's look at the consequences of going 100% renewable at some time in the near future.

Australia's contribution to global CO2 emissions is 1.3%, and of that 0.4% is from coal and gas electricity generation. So, because of the prevailing government position on the need to reduce these emissions with available technology ASAP, we will inflict the problems I cover in the rest of this article, costly unreliable power, for a reduction that will have no discernible impact on the average global temperature which is displayed by the IPCC as having no error bar associated with it.

If only 82% of the coal and gas generation was replaced and importantly, appropriately sized battery backup was built to support the removed generation, then the cost will be 82% of what I have calculated.

The reader will probably question some of my numbers and that is fine. I trust the methodology is sound and if the reader wants to use, for example, 30 GW as the quantity of coal and gas that needs replacing then follow my methodology and calculate the amount of wind and solar and back up.

2. DETERMINING THE SIZE OF REQUIRED RENEWABLE FARM.

If a PV solar farm of 1 megawatt (Power) nameplate capacity (MW- a million watts) is built, and it outputs a MW of power for each hour of the day for a year, it would generate 8760 MWh (Energy) of energy for the year. By monitoring the actual output over a year and adding up all the MWh, to take account of the 4 seasons, it is found for the typical farm that the yearly total is 1750 MWh. This is 20% or 0.2 times the 8760 MWh total. This 0.2 is called the capacity factor for the PV solar farms. For the average day, the 1 MW farm produces 1752/365=4.8 MWh. Expressed another way - for 24hours x .2 = 4.8 hours, it outputs 1 MW. In summer it will beat the average and in a wet winter it will be less than the average.

If the output of a 1 MW solar farm was plotted for the average day, with Y axis in MW and X-axis as a 24-hour clock, the graph would rise above zero at around 0830 hours, climb to a plateau of about 0.85 MW and descend back to zero at around 1730 hours. The area under the curve, in units of MWh, would be 4.8 MWh. I maintain my simplification of a rectangle of 1 MW in height and 4.8 hours wide, does not invalidate my calculation.

To calculate the size of the replacement renewable farm, one first must measure the typical energy output by the coal plant in 24 hours. Now let's look at the 2880 MW NSW Origin Energy Eraring coal fired power station that is marked for closure in about 3 years' time. If in a 24-hour day, it delivers power as following: -

2500MW for the periods 6am to 9am i.e. 3 hours for 7500 MWh
2700 MW for 5pm to 9 pm i.e. 4 hours for 10800 MWh.

2200MW from 9am to 5 pm i.e. 8 hours for 17600 MWh.

1700MW for 9pm to 6am i.e. 9 hours for 15300MWh.

This gives 51200 MWh for the 24-hour period. If this is to be replaced with a solar PV farm, how big does it have to be to produce this 51200MWh in 4.8 hours?

Farm output x 4.8 = 51800 MWh, so farm output = 10,700MW. This is 3.7 times bigger than the 2880 MW plant it is replacing. The 4.8 hours is for an average day. In summer more power will be made than required. In winter there will be brown outs.

In the 9am to 5 pm period the demand is 2200 MW so 4.8 x 2200 = 10560 MWh of generated power is consumed. The 51200 - 10560 = 40640 MWh has to be stored in batteries if CO_2 emissions from coal and gas turbines are not allowed.

The announcement on Eraring made in the press, said a 700 MW battery was planned as part of the shift to renewable energy. It did not state for how long this battery could output 700 MW and this is an annoying failure of reporters to not supply the MWh value for the battery. Typically, it could do so for 1.3 hours i.e. 910 MWh versus 40640 MWh required. This 700MW battery is only good for managing transient variations in supply. Where the 40640 MWh comes from was not identified.

Adam Bandt, Green's leader, clearly does not understand the difference between a firming battery and a transient response battery because he said, "when SA needed to firm it's supply, it built the world's biggest battery in under a month". This Tesla battery was 100MW/130MWh, cost $90 million, and if called upon to back up, that is firm, the loss of a 1300MW supply, it could do so for 6 minutes. (The owners of this battery are doing nicely from the fees charged to stabilise the grid from transient disturbances)

If a wind farm was used instead of a solar farm, the typical capacity factor is claimed to be 0.4 and the calculation becomes, wind farm output x 9.6 hour = 51200MWh. (24 x .4 = 9.6). So, the farm output = 5300MW, which is 1.8 times the 2880MW coal power station. (People who monitor wind farm outputs, reckon the average capacity factor is closer to 0.3. If my calculations are in error, I would rather understate the magnitude of the problem than the converse)

3. DETERMINING THE AMOUNT OF BACKUP AND THE COST.

To look at the costs involved, I will use a 50/50 mix of wind and solar farms. They are each going to provide 51200/2 = 25600MWh. So, the solar farm is 25600/4.8 = 5300MW and the wind farm is 25600/9.6 = 2650MW. A total of 7950 MW.

The current cost of the solar is $1.4 million/ MW and the land-based wind farm is $2 million/MW. So, cost equals $1.4 million x 5300 + $2 million x 2650 equals $12.7 billion.

Demand, driving large scale production, has seen the price drop, but soon the rush for every man and his dog to build a wind farm or solar farm will see demand drive the price up as is now being reported by European turbine manufactures. In the UK, the last auctions for offshore wind generation received no bids because the investors felt the strike rate was too low and the government has increased it by 66% to encourage bids.

The battery storage requirement is complicated because I don't know when the wind is blowing. So, I will **minimise** the storage requirement by saying no wind is blowing when the solar farm is operating. If it did, all the wind output would have to be stored because the solar farm by itself could supply the demand.

So, the solar farm outputs 4.8 x 5300 = 25500 MWh and as shown above,10560 MWh is consumed during this time leaving 14900 MWh to be stored. The wind farm outputs between 6am and 9am and between 6pm and 9pm, too good to be true, and 3.6 hours during the night. During those periods the demand is 3 x 2500 + 3 x 2700 + 3.6 x 1700 = 21700 MWh requiring 25500 - 21700 = 3800 MWh be stored. The total to be stored is 3800+14900 = 18700MWh or 18.7 GWh (G = billion). The battery efficiency is approximately 90%, so the batteries have to be rated at 18.7/.9 = 21 GWh. Battery storage costs $650 million per GWh installed, so cost of batteries is $13.7 billion. (For cost source see csiro aemo gen 2021 and tesla megapack site + Gensusplus KBESS2 Kwinana 250 MW/1000MWh battery) Note, my assumptions understate the storage requirement and do nothing about the need to have a prudent reserve of stored energy for more than one day to recover from a drop-out of expected wind and/or sun.

Managing the haphazard energy supply from renewables falls upon the power and process control engineers. For 21 GWh of storage they may install 4 assemblies each rated at 3GW/5GWh. When the renewables supply more than the demand, the excess is used to charge a not fully charged assembly and when the renewables are less than demand, an assembly supplies all the demand, and all the renewable energy is used for charging.

This brings the cost to $26.4 billion and the expense of the transmission lines to convey the electricity from the remote solar and wind locations to where it can be connected to a major transmission line, must be added onto this figure.

$26.4 billion/2880 MW = $9.2 million/MW replaced is a sobering number.

WA coal and gas generation is 1650 MW coal and 2550 MW of gas. These generators are connected to the states' distribution systems but exclude about 800 MW of gas generators because they are privately owned. To go 100% renewable would cost more than that required for Eraring. WA also has a Reserve Capacity Mechanism for the coal fired power stations, a 15% call on offshore gas production and a ban on the exporting of land-based gas production – except for a sweetheart deal McGowan did for the Waitsia Project. Note the absence of gas in the following statement, made for 2023/24 budget, and the small amount of money allocated.

The McGowan government is managing the orderly transition away from coal fired generation a state government spokesperson said recently. "As part of our plan we've allocated around $3.8 billion to invest in green energy infrastructure, including the development of 810 MW of wind generation and 1100 MW of energy storage over the next 7 years."

Alinta is to replace Loy Yang B 1000 MW coal station with an offshore wind farm and pumped hydro. Mr Dimery CEO of Alinta says "I paid $1 billion for Loy Yang, and I will pay $8 billion to replace it. So, let's talk about that and someone explain to me how energy prices still come down. I am missing something".

I don't have a price on a transmission line cost/km, but Labour's Chris Bowen said there was a need to rapidly spend $20 billion on major transmission lines on the National Energy Grid for the eastern states plus SA including $4 billion for Snowy 2, and that an extra 10,000 km of minor lines were required to replace coal and gas generation with renewables. $4 million/km is probably in the ballpark, and for 10,000 km that equates to $40 billion. In the TV clip where Bowen made this statement trying to convey the size of the transition, it included a piece from Danny Price of Frontier Economics saying, "if we shut down everything, we will have to replace it with three times as much".

The National Energy Grid has approximately 35000MW of coal plus gas generation capacity. (Statista May 2021). Since 2012, 7600 MW of coal generation has been shut down. WA, which is not part of the National Energy Grid, will increase this amount by about 4200 MW to 39200 MW of coal plus gas generation. So, for the whole country we are looking at 39200/2880 = 13.6 Erarings. And 13.6 x $26.4 billion = $359 billion plus the cost of transmission lines for 108 GW of wind and solar, 2.8 times the 39.2 GW and 285 GWh of batteries and pumped hydro.

So, $359 billion + Bowen's $20 billion + my guesstimate on extra transmission lines of $40 billion = $419 billion.

$419 billion/39200 MW = $10.7 million/MW replaced after including transmission costs and understating the battery backup requirement.

Bear this in mind when CSIRO and Bowen are telling you how cheap renewable electricity is, given the non-government suppliers, and often foreign, of the capital that will go into those solar/wind farms, transmission lines and storage will do nicely out of the return on their investments. I think the financiers hold off putting up the money until they are informed of the guaranteed rate of return, they will receive on their investment. So, Eraring replacement cost, including transmission, is 2880MW x $10.7 million/MW = $30.9 billion. For an 8% return on investment, it generates $2.465 billion per year. MWh generated in a year = 51600 MWh x 365 days/year = 18.834 million MWh. Cost per MWh = $2.465 billion/18.834 million = $130/MWh. Nationally, the cost of the electricity in your bill is about equal to the cost of transmission and distribution, so adding more transmission lines causes your electricity bill to rise.

Nov 24 – NSW has received bids at action for $35/MWh from proposed solar farms and $50/MWh from proposed wind farms. What the consumer will actually pay will be much higher than these numbers.

Tesla mega packs come with a 15-year standard warranty and the PV panels, in the absence of a hailstorm, and turbines are expected to last 25 years. This sets the time frame for additional expenditure to compensate for loss of efficiency on panels and batteries and don't overlook the expected large increase in electricity consumption.

While my calculation of required renewables aligns with Danny Price, my confidence is shaken by reading a Deloitte Access Economic report, commissioned by NAB, that says the infrastructure program will need to involve an estimated 10,000 km of news transmission, 44 GW of new renewables and 15 GW of firming capacity this decade according to industry experts.

The above calculation indicates 2.8 times more renewables MWs replacing the coal and gas MWs. To suggest, that when renewables are generating more than the grid demands, this is the time to divert that excess to making green hydrogen by electrolysis, doesn't hold water. If you want to make green hydrogen under my scenario, start adding more GWs to the 110 GW total. A 1 GW electrolyser will produce hydrogen at 20 tph.

The above logic should see the diminution of cheap excess renewables, that precipitated the shutdown of coal generators, from the grid; excess power, to be sold cheaply, appears after the batteries are fully charged and the pumped hydro water has been returned to the elevated dam. If Snowy 2.0 generates at 2.2 GW over 10 hours by the release of X cubic metres of water, that amounts to 22GWh. Wind and solar will then use close to 26 GWh of energy to pump that X cubic metres of water back up, through the tunnels, to the top dam. So, what goes around comes around.

I have couched my discussion in terms of cost. Bowen describes what must be done by 2030 for 82% in these terms: - "reducing emissions by 43% by 2030 will require the installation of 40, seven-megawatt wind turbines every month from now until 2030 and more than 22,000 500-watt solar panels be installed every day for the next eight years." Is this going to happen? I checked this with my calculations and agree with wind farm number for 82% renewables but reckon it should be 38000 panels. Nov 24 – Bowen has announced the tax payer will increase financing of batteries, wind and solar farms from 6GW to 32GW. Does he have constitutional authority to do this? How much this was going to cost was not stated, but it will be around $50 billion. He has done this because his 82% target by 2030 is "looking challenging" because private industry is not delivering. Why the federal government can overcome delays is not obvious and this taxpayer support makes private industry finance less attractive.

As the level of renewables climbs, I expect the unreliability of wind and solar will have become so obvious that the shutdown of gas fired generation will be suspended. Gas generates 400g of CO2/kWh versus 1000g of CO2/kWh from coal generated electricity.

In Australia the bulk of gas consumed is in other than power generation. Pushing renewables to replace gas generated electricity won't be much help to industry.

We currently have installed nameplate capacities of wind 9100 MW, solar farms 7000 MW and hydro 8500 MW, for a total of 24600MW. Roof top solar is not in solar farm number.

4. Why Forrest is Finding Green Hydrogen Such a Hard Sell.

Making and storing hydrogen as a way to support the intermittent energy from renewables is not an attractive solution. Elon Musk has said of hydrogen “it is the most dumb thing I could possibly imagine for energy storage”. Musk also makes dumb statements, but this is not one of them. If a GWh of renewable electricity was stored in a battery, it would release 0.9 GWh when called on.

If the GWh was used to make hydrogen by electrolysis it would, at 80% efficiency, make hydrogen with an energy content of 0.8 GWh and this has to be stored, which uses energy, somewhere until required. If this was used to drive an open circuit gas turbine with 44% conversion efficiency, the electricity generated would amount to 0.8 x 0.44 = 0.35 GWh versus 0.9 GWh from the battery.

The 44% energy conversion efficiency is for natural gas. I suspect H_2 will not achieve this efficiency – I got out of my depth trying to determine the answer. GE and Energy Australia are installing a turbine to run on natural gas and/or H_2 but they will not tell me what efficiency they will achieve at 100% H_2, assuming they know.

Making green ammonia as way to improve the economics of exporting hydrogen will involve consuming 66 kWh of energy to produce 1 kg of green hydrogen, with an energy content of 33.3 kWh, at point of usage after cracking the ammonia. Combust that hydrogen in an open circuit gas turbine generator with 44% conversion efficiency and one produces .44 x 33.3 = 14.7 kWh of electricity. Transportation energy not included.

Making green hydrogen to substitute for the 95 million tonnes/year now made using fossil fuels - e.g., for oil refining, ammonia production, industrial heating, hydrogen fuel cell usage, chemical feedstock and green steel are not to be put in the same basket as electricity production use. To produce 95 million tonnes per year of green hydrogen at 50kWh/kg will consume 4700 terawatt hours of green electricity.

5. Generating Power from Gas with Sequestration.

On the subject of CCUS - carbon capture, utilisation and storage, I see two obvious areas where it can be employed. In oil and gas, the valuable natural gas is contaminated with maybe 5 to 25% CO2 which must be separated out by an amine absorption and stripping circuit to produce a gas stream that should be 100% CO2 plus H2S – ideal for sequestration. Secondly, in power generation from coal or gas, where the exhaust is approximately 80% nitrogen, 15% CO2 and the balance oxygen.

Sequestration is charged by the tonnes of gas and to maximise storage in the reservoir, you don’t want gaseous nitrogen occupying 80% of the volume. So, CO2 has to be separated out and this is a big deal. For a smallish, 300 MW, coal fired power station in the US it is anticipated the carbon capture plant will cost $US600 million and it will consume energy.

An exciting development (2012 to present) is the Allam-Fetvedt Cycle for generating electricity via a gas turbine using CH4 and oxygen, not air, to heat a recirculating stream of CO2. Energy conversion efficiency is approximately 60% (almost twice that of conventional coal fired power station) and the off gas is around 95% plus CO_2, tailor made for sequestration.

One has to address the issue of where to site the power plant - is the CO_2 piped to where it will be sequestered, or are new transmission lines built from the remote power plant and where does the CH_4 come from? See the following link for details -

https://www.powermag.com/inside-net-power-gas-power-goes-supercritical/

6. Nuclear Power.

France emits very minor amounts of CO_2 when generating its electricity because its power source is 70% nuclear and 19% renewables. They reprocess their spent fuel to produce a mixed oxide fuel (plutonium and uranium) for sending back to the reactor and encapsulate the fission products in glassy material for long term disposal. This mitigates the issue of spent fuel disposal, but it will not satisfy those who are frightened of the nuclear power industry.

The French pay about 2/3 of what the pro green and anti-nuclear Germans pay per kWh despite Bowen saying nuclear power is too expensive. France has not had a 3 Mile Island, Chernobyl, or Fukushima. They are adding to their number of operating plants with a new, larger, more fuel-efficient design. This first model is proving an enormous headache with cost and time overruns. Critics of nuclear in Australia, like Chis Bowen, point to this problem the French are having as a reason not to entertain nuclear power as a solution.

Bowen's latest video (July 2023) detailing the problems with nuclear energy - cost, timing, location, lack of suitably skilled people and waste storage, look foolish given his government agrees with nuclear reactors sitting in Australian ports, is doing something about the lack of skilled people and has accepted Australia will store the nuclear waste from the subs. Seeing his comments endorsed by Turnbull reinforces my low opinion of Bowen's deceitful contribution. Cost issues are addressed by me in this article and on timing, yes they won't be ready until 2030 but we need to make nuclear power generation and fuel enrichment legal now so studying whether or not to use them can be progressed.(Lucas Height research reactor is legal because it does not generate power, just warm water and neutrons for making many nuclear medicines plus other products) Bowen could neutralise my low opinion of him if he said he opposes nuclear power because he if frightened by it and his technical incompetence would not be an issue.

If the French had Bowen's defeatist attitude, they would not have 56 operating reactors. To be consistent, Bowen should be anti-pumped hydro given the Snowy 2.0 financial fiasco he inherited. This was championed by Malcom Ego Turnbull as a $2 billion no brainer, now looks like costing $8 billion plus, as an afterthought, $4 billion for the transmission line, the Hume Link, to take the power from where it is generated to where it is used. Oct 2023 – opponents of the overhead 330 km power line are making the case for putting the line underground.

Bowen does not mention the UAE's entry into nuclear power. Starting in 2012, it commissioned 4 x 1400 MW Korean KEPCO pressurised water reactors. The first unit came online in 2021, the second in 2022, the third is near completion and fourth is 90% complete. And the cost comes out at $A7.3 million/MW ($US4.5 million/MW). I am uneasy about using this UAE data because I don't know if the UAE treats its workers like Qatar and the labour rate is unrealistically low.

In Australia it is probable a move in parliament to overturn our legislative ban on nuclear power and fuel enrichment, enacted in 1998 via an amendment to some legislation on the operation of ARPANSA moved by a Green WA senator, would succeed based on surveys of voter sentiment. Nuclear power in the US is a polarising issue as it is here. When I first visited the US in 1972 there was a pro nuclear demonstration going on in the LA airport terminal. Apparently, Senator Ted Kennedy and Jane Fonda didn't like nuclear power, for two of the signs carried by the demonstrators read - "more people are killed in the back seat of Ted Kennedy's car than in nuclear power station accidents" (alluding, in really bad taste, to his Chappaquiddick car accident) and "so what, Jane Fonda leaks everyday".

As someone who supports introducing nuclear power generation in Australia, I think we are fortunate in coming to it late. Look at Sellafield in the UK, owned by the Nuclear Decommissioning Authority - 2.5 square miles of headache where they will spend the next 100 years at a cost of £120 billion cleaning up the remains of Britain's early nuclear research industry - power and defence. Where they have 140 tonnes of plutonium contaminated waste to take care of and a machine gun armed security force to protect the site.

I however am not proposing we go for the big high pressure light water reactors (2200 psi) because they face so much regulatory impositions on the design and construction of the reactor vessel and containment vessel and take large amounts of time and money to get built. The reactor containment vessel, a steel shell under a concrete shell, must withstand being hit by a jet liner. It is so large because it must contain the reactor cooling water, when converted to steam at about 80 psi, as a result of reactor vessel rupture as would likely occur in core meltdown.

Modular high pressure light water reactors have been powering nuclear powered submarines for decades. The Virginia class submarine reactor is rated at 210 MW thermal. This class is one of the options under AUKUS. I am waiting for the development of hopefully successfully designed, tested, and competitively priced low pressure, like liquid sodium or molten salt cooled, small modular reactors (SMR) - notionally less than 300 MWe. Without light water for moderation, they require fuel enriched to between 5 to 20% U235 (HALEU- high assay low enriched uranium). Biden has allocated $700 million to kick start USA production of HALEU. Buying it from Russia was the plan before Feb/2022, and the loss of this source has caused Terra Power to announce a minimum 2-year delay in start-up date for their SMR. These SMRs may come onto the USA market by the end of this decade. It is proposed these SMRs be placed below ground level where a jet liner can't hit them, so the enormous 1-2-metre-thick containment vessel is not built."

Centrus Energy, Ohio, are to start production of HALEU, at 900kg/year scale, in Oct 2023 and will scale up as capital and demand arise. In addition grants are on offer for the enriched UF_6 to be converted to uranium oxide or uranium metal and consideration being given to legislation banning the import of HALEU from Russia. Maybe Terra Power will not be delayed as long as they predicted.

Lucas Height 20 MW thermal reactor uses fuel enriched to about 20% U235 because the quantity of fuel is so small. To sustain the chain reaction, they have to bump up the amount of fissile material.

Following commissioning of Terra Power’s first sodium cooled, fast neutron, SMR, subsequent units are projected to have an overnight construction cost of between $US 2.8 and 3 million/MW. Major backers of Terra Power are Bill Gates and Warren Buffet.

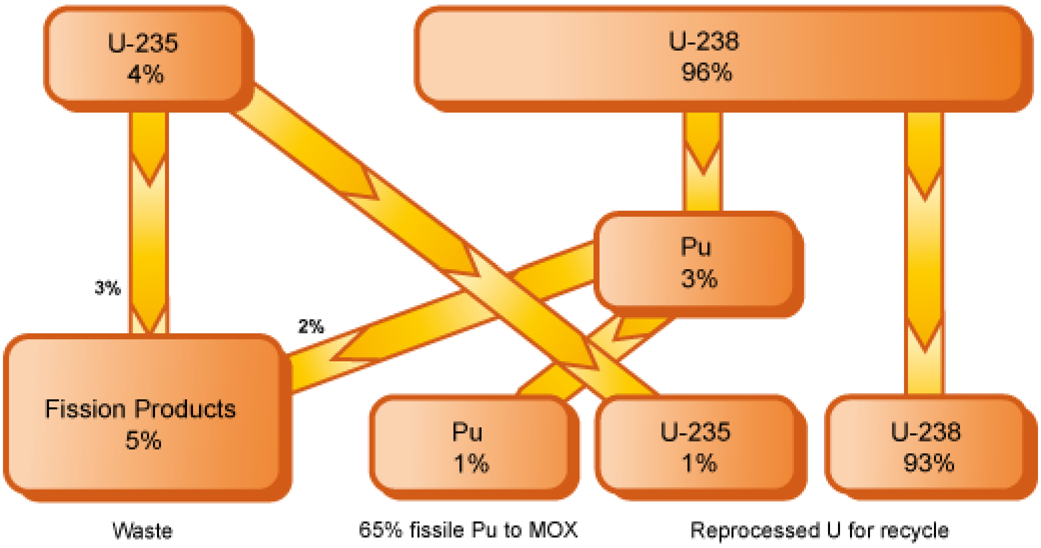
The US NuScale modular light water-cooled, high-pressure reactor, rated at 77 MWe, is further advanced than the above low-pressure reactors and maybe it will obtain a full Nuclear Regulatory Commission (NRC) license shortly. It is planned to come online in 2029, located at the Idaho National Laboratory. Using light water as a moderator, it is fuelled with 3 to 5% enriched U235. The US DOE has estimated this first plant cost will exceed $US6.8 million/MW. NuScale have estimated the electricity will cost $US89/MWh.

NuScale’s first commercial venture, 6 x 77MWe units, planned for a region in Utah, has been cancelled because insufficient customers would commit to taking the power. The estimated power price of $US 50/MWh was increased to $US89 in January this year. Nov 8 press release.

Some of the SMRs can be considered Generation 4 reactors especially the fast neutron reactors, given they have the aim of making them safer, improving the fuel utilisation and reducing the quantity and nature of the waste material. The US operated a liquid sodium cooled experimental breeder pilot scale reactor, 60 MWt, for 30 years, shutting it down in 1994. It produced more fissile fuel than it consumed, due to fuel reprocessing, and safely shut itself down when the safety systems were disabled.

The uranium in uranium ore deposits is 99.3% U238 and 0.7% U235. The vast majority of reactors run on fuel enriched to 3% to 5% U235 and the figure below uses 4% enrichment. These reactors slow down the neutrons or moderate them, so they are better captured by the uranium nucleus, but only the U235 will fission as a consequence. So, the bulk of the uranium has simply gone along for the ride when there is no fuel reprocessing. This represents an unacceptable waste of a resource and will see the depletion of the fuel resource accelerate as nuclear power use takes off around the world. The use of fast neutron reactors sees fission of some of the U238 and better fuel utilisation.

Reaction in Standard UO_2 Fuel



Basis: 45,000 MWd/t burn-up, ignores minor actinides

The Union of Concerned Scientist in the US feel strongly that the Gen 4 SMRs are not receiving enough critical push back from the NRC. So, watch this space.

The Terra Power and NuScale are 2 of the 3 SMRs being trialled under the Advanced Reactor Design Program in the USA supported by DOE grants. The third is the XE100 reactor, a high temperature gas cooled unit incorporating a new fuel design - Triso micro pellets of HALEU. At 80 MWe it is aiming for a 2027 startup date.

Canada's Ontario Power Generation plans to install a GE Hitachi BWRX-300 MW SMR (boiling water reactor at 1000psi) and bring it online in 2028. It is predicted to reduce capital cost by 60% per MW compared to big conventional nuclear plants.

Bowen was reported, Sept 18, on the possible cost of getting rid of 21.3 GW of coal generation via nuclear power as being $387 billion and suggested the taxpayer would have to pick up the tab. For a cost estimate of wind, solar and batteries you can plug in my calculated costs of $/MW to see what the renewable option will cost. Bowen does not say the taxpayer will have to pick up the tab for the renewable option.

SMR reactors were predicted to cost $16 million/MW to build as per csiro aemo gen 2020. This bizarre number is based on the premise that a smaller plant will cost more per MW assuming no innovation in the design. This is the number used by Bowen to obtain $387 billion. This cost has to be halved to be in the race. Detractors reckon this won't happen but some of these same detractors are confident the cost of green hydrogen will achieve the necessary 50% cut in production cost, with advances in efficiencies and design. CSIRO AEMO 2021-22 gen report concedes SMRs may cost $7.9 million/MW by 2030 if demand takes off but Bowen does not use this number and remember you can't buy an SMR at present.

If Generation 4 Small Modular Reactors were around now, we could begin to replace say 60% of the 39200 MW of coal and gas generation, 23500 MW, with 23500 MW of nuclear plants sitting beside those retired plants, using their cooling towers and transmission lines and retraining the work force to maintain high paying jobs and replace the remaining 16000MW with wind and solar and batteries.

Alan Finkel, ex chief scientist, flags the building of the transmission lines as the rate determining step in the roll out of renewables, yet he does not see a role for nuclear power.

Questioning the need to get rid of coal and gas is now cancelled. However, current modelling for The International Energy Agency predicts world fossil fuel usage will fall from about 80% now to around 60% by 2050.

If the cost of SMRs were reduced by 50% to $8 million/MW, the 39200 MW would cost $314 billion i.e. cheaper and much longer lasting than Labour's renewables $423 billion option. It is likely that by the time SMRs are ready for deployment in Australia their use will be satisfying the growth in electricity demand and in substituting them for retiring renewables and batteries.

The USA approach to reducing CO2 emissions from the power grid is to have a high penetration of renewables but they recognise that won't happen without the incredibly important critical role of base load power from nuclear power. They envision adding 200 GW of nuclear power to their grid over the coming decades.

Power generation in the US is 60% by fossil fuel, 20% nuclear and 20% renewables. In Australia it is coal 50%, gas 18%, oil 2% and renewables 30%. Don't confuse power generated with installed capacity as seen with 22460 MW of coal and 21500 MW of gas based including privately owned capacity.

6. Should Big Industrial Emitters be Promoting Nuclear Power?

Given the enormous pressure some large industrial CO2 emitters, >100,000 tpa of CO_2 excluding power generators, are going to come under from the government's Safeguard Mechanism - reducing the base line, is it attractive for those industries to put pressure back on the government to give them the option to consider installing modular reactors, by asking the government to introduce legislation to legalise nuclear power in Australia? They could gain emission credits by supplying green power to the grid and/or supplying their power demand, or depending on the reactor design, generating high grade industrial heat for their process.

I expect industries, forced to comply with the yearly 4.9% reductions in their baseline, every year until 2030, (30% over 7 years), will pass on the cost of their compliance to their customers if they can – like fired clay housing bricks, airline fares when the planes start using expensive sustainable aircraft fuel and aluminium to name a few. Industries can comply by reducing production, spending money on plant modifications to reduce CO_2 emissions and/or purchase and generate carbon offsets.

Since a renewable energy plant can generate carbon off sets, consider this suggestion and verify if it conforms to the regulations on carbon offsets. A coal fired power station makes 1 kg of CO2 per kWh generated. So, calculate the kWh generated when 5 million tonnes of CO2 are emitted. It is 5 billion kWh. If this is generated in a year, the power station is rated at 5 billion kWh/8760 x .95 hours of operation in a year, and this equals

600 MWh. (The regulators may insist the offset be based on the avoidance from a gas fired generator which emits only 400 g of CO_2 per kWh.)

If the big emitter builds a nuclear power station rated at 600 MWh, using the required number of SMRs, for $ 4.8 billion, based on $8 million/MW, then the big emitter sells the power to the market operator at 15 cents/kWh, earning $4.5 billion over 6 years, and claim 5 million tonnes of CO_2 offsets for each year of operation.

If the reader finds technical as opposed ideological errors, please bring them to my attention.

B A (Tim) O'Brien. MSc. Retired Extractive Metallurgist