Providing a reliable and continuous supply with wind and solar power is very expensive

We are often told that renewable energy is cheaper than any other form of power generation and, by implication, it can provide a reliable and economical supply. Not so. The storage that is needed to give a reliable supply is enormously expensive.

Any large-scale adoption of wind or solar power must take into account the cost of storage to meet the energy demand when the sun is not shining or the wind is not blowing and also provide system inertia to stabilise the frequency, short-circuit current to maintain voltage during faults and reactive power to stabilise the voltage (system support).

I analysed the cost of adding 4000 MW of wind and solar power generation to a system where the 4000 MW increment needs to include storage and system support to ensure a reliable supply.

This is the situation that New Zealand would be in if the government instituted a policy that would shut down geothermal, gas and coal generation because they emit carbon dioxide, added 1000 MW of load from electric transport and replace it with wind and solar power. Wind and solar power have capacity factors in the region of 35% and 15% respectively so it would take at least 14,000 MW of wind and solar to provide the energy needed by a system with a load factor in the region of 55% (~20,000 GWh pa for 4000 MW) and also provide for the 25% of losses attributed to the energy storage system.

As the peak demand that needs to be met is 4000 MW, the surplus solar power will need to be fed into a storage system – pumped hydro or batteries – when solar output is over 4000 MW. This will involve losses of 25% so the solar generating capacity needs to be increased by a further 2750 MW to cover these losses. Solar and wind farms seldom produce more than 80% of rated output so we need to install 17,750 MW of solar power and 8,800 MW of storage capacity. The end result is that 26,550 MW is needed to reliably supply 4000 MW of load!

The storage capacity has to be able to provide the 264 GWh needed in winter time when there is likely to be five days of cloudy weather and the solar output is negligible. At the current $US200/kWh this amounts to $NZ81 billion. 17,750 MW of solar power at the current $US1200/kW will cost another $NZ33 billion to give a total cost in the region of $NZ114 billion. The lifetime of batteries and solar cells will not exceed 20 years so the annual cost to recover capital and provide for operation and maintenance will be about $NZ12 billion.

By way of comparison, the largest battery in the world at Hornsdale in Australia can store 130 MWh. 2000 of them would be needed to store the 264,000 MWh needed for a reliable supply to the 4000 MW load. This battery capacity is equivalent to all the batteries in all the electric cars in the world. Each car battery requires about 25 kg of cobalt and there is simply not enough cobalt in the world to provide the battery storage that would be needed for a worldwide switch to solar power. A revolutionary new technology is needed and that is at least 10 - 20 years away.

$NZ12 billion for 20,00 GWh equals 61 NZ¢/kWh: at least 10 times the cost claimed by proponents of solar power and four times the current wholesale cost of electricity. Domestic electricity prices are likely to increase from the present $0.30 to about $0.90.

Further calculations showed that a wind power installation with a capacity factor of 35% and the possibility of five days without wind costs 53 NZ¢/kWh.

If solar storage is provided by hydro pumped storage instead of batteries, the cost drops to about 37 cents/kWh. It is difficult to find suitable sites for 8800 MW of pumped storage (the Onslow pumped storage scheme is 1200 MW) and it will be even more difficult and time-consuming to get them through the Resource Management Act. Total construction time could exceed 30 years.

Further calculations show that solar and wind power cost 15 and 9¢/kWh respectively if storage and system support are ignored. Claims that it is much lower than this must be regarded with suspicion. It is possible that the figures come from overseas where it is heavily subsidised.

The need for 26,000 MW of solar power plus storage capacity to supply a 4000 MW load means that there is little chance that large-scale renewable energy can provide an economical and reliable supply for the foreseeable future.

The 17,750 MW of solar power that would be needed to replace 4000 MW of CO2 emitting generation would occupy about 30,000 hectares – six times the urbanised area of Auckland city.

The environmental effects of shading 30,000 ha from the sun would need to be considered carefully. Keeping it free of invasive species and predators could be quite difficult.

These calculations do not include the cost of extra equipment to provide the needed system stability, voltage support and short-circuit current or the 15 - 220 kV transmission lines that would be needed to transmit the 12,000 MW. This could add 2-4 cents/kWh.

The conclusions are:

A) large-scale wind and solar generation is impossibly expensive because of the high cost of storage;
B) there is not enough cobalt in the world to support a fraction of the batteries needed for a worldwide switch to large-scale wind and solar power.

The corollary is that if there really is a need to reduce man-made emissions of CO2 from power generation hydropower and nuclear power are the only credible options.

Note: the study does not consider the need for energy reserves to keep the lights on in a dry year. That is another very difficult problem. According to the Interim Committee on Climate Change the only satisfactory solution at an acceptable cost is holding gas or coal in storage for dry years. The government chose to ignore this report and banned further gas exploration which means that we will need to burn more coal in dry years.

Bryan Leyland MSc, DistFEngNZ, FIMechE, FIEE(rtd), MRSNZ. 8/11/20