DO WE NEED BASE-LOAD POWER STATIONS?

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Date: December 2015

EnergyScience Coalition

Briefing Paper No. 16 (revised)

The EnergyScience Coalition is an independent non-governmental organisation established as a collaboration of concerned scientists, engineers and policy experts. www.energyscience.org.au

One of the principal claims used to justify a substantial role for nuclear energy in combatting global climate change is that renewable energy cannot supply *base-load* electric power. Underlying this claim is the assumption that the only way of supplying base-load electricity demand is by means of base-load power stations, such as nuclear and coal, that operate at full power 24/7. This notion is being widely promulgated in both Australia and the UK.

For example, former Australian Industry Minister Ian Macfarlane claimed at a uranium industry conference that "Base load, zero emission, the only way it can be produced is by hydro and nuclear".[1] UK Energy and Climate Secretary, Amber Rudd, attempted to justify the decision to build the proposed Hinkley Point C nuclear power station on the grounds that "We have to secure baseload electricity".[2]

The concept of base-load demand is illustrated in Figure 1, which shows the daily variation of electricity demand in summer in a conventional large-scale electricity grid without much solar energy. Base-load demand is the pale blue region across the bottom of the graph. Traditionally base-load demand has been supplied by so-called base-load power stations. Because they are inflexible in operation, in the sense that they are unsuitable for following the variations in demand and supply on timescales of minutes and hours, they are supplemented with flexible peak-load and slightly flexible intermediate-load power stations. Peak-load power stations are hydro-electric systems with dams and open-cycle gas turbines (GTs), essentially jet engines. They can respond to variations in demand and supply on timescales of minutes.

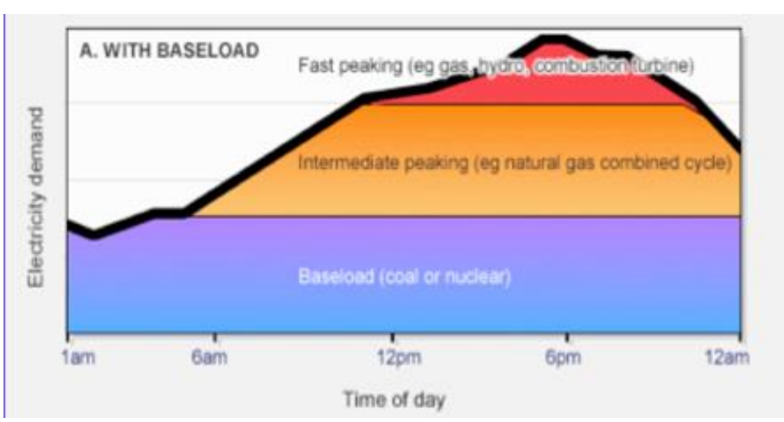

Figure 1: Daily electricity demand and supply in a conventional large-scale system with little renewable energy.

The assumptions that base-load power stations are necessary to supply base-load demand and to provide a reliable supply of grid electricity have been disproven by both practical experience in electricity grids with high contributions from renewable energy and by hourly computer simulations.

As an example of practical experience, in 2014 the state of South Australia had 39% of annual electricity consumption from renewable energy (33% wind plus 6% solar) and, as a result, the state's base-load coal-fired power stations are being shut down as redundant.[3] For several periods[4] the whole state system has operated reliably on a combination of renewables and gas with only small imports from the neighbouring state of Victoria.

The north German states of Mecklenburg-Vorpommern[5] and Schleswig-Holstein[6] are already operating on 100% net renewable energy, mostly wind. The 'net' indicates trading with each other and their neighbours. They do not rely on base-load power stations.

"That's cheating", nuclear proponents may reply, "they are relying on power imported by transmission lines from base-load power stations elsewhere." Well, actually the imports from base-load power stations are small. For countries that are completely isolated (e.g. Australia) or almost isolated (e.g. the USA) from their neighbours, hourly computer simulations of the operation of the electricity supply-demand system, based on commercially available renewable energy sources scaled up to 80-100% annual contributions, confirm the practical experience.

In the USA a major computer simulation by a large team of scientists and engineers found that 80-90% renewable energy is technically feasible and reliable. (They didn't examine 100% renewable electricity.) The 2012 report, *Renewable Electricity Futures Study*. *Vol.1. Technical report TP-6A20-A52409-1* was published by the US National Renewable Energy Laboratory (NREL) and can be downloaded.[7] The simulation balances supply and demand each hour. The report finds that (p.iii): *"renewable electricity generation from technologies that are commercially available today, in combination with a more flexible electric system, is more than adequate to supply 80% of total U.S. electricity generation in 2050 while meeting electricity demand on an hourly basis in every region of the United States."*

Similar results have been obtained from hourly simulation modeling of the Australian National Electricity Market with 100% renewable energy, published by Ben Elliston, Iain MacGill and me in 2013 and 2014, based on commercially available technologies and real data on electricity demand, wind and solar energy. (Peer-reviewed publications listed here.[8]) There are no base-load power stations in the Australian model and only a relatively small amount of storage. Recent simulations (to be published) span 8 years of hourly data.

These, together with studies from Europe, find that base-load power stations are unnecessary to meet standard reliability criteria for the whole supply-demand system, such as loss-of-load probability or annual energy shortfall. Furthermore, they find that reliability can be maintained even when variable renewable energy sources, wind and solar PV, provide major contributions to annual electricity generation, up to 70% in Australia. How is this possible?

Firstly, the fluctuations in variable wind and solar PV are balanced by flexible renewable energy sources that are dispatchable, i.e. can supply power on demand. These are hydro with dams, biofueled open-cycle gas turbines and concentrated solar thermal power (CST) with thermal storage, as illustrated in Figure 2. It is not essential for every power station in the system to be dispatchable. Being able to draw upon a diversity of renewable energy sources, with different statistical properties, provides reliability.

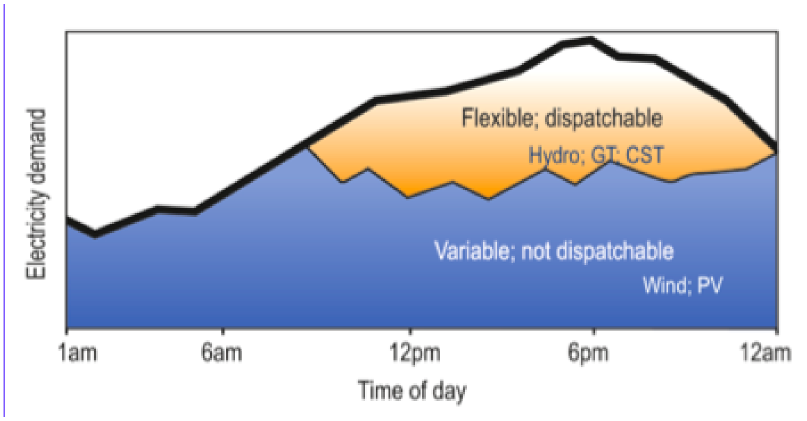

Figure 2: Electricity demand and supply in a large-scale system with a large contribution of variable renewable energy

Secondly, spreading out wind and solar PV farms geographically reduces the fluctuations in their total output and so reduces the already small contribution from biofuelled gas turbines.

Thirdly, new transmission lines may be needed to assist achieving wide geographic distribution of renewable energy sources and to multiply the diversity of types of renewable energy source feeding into the grid. For example, an important proposed link is between the high wind regions in north Germany and the low wind, limited solar regions in south Germany. Texas, with its huge wind resource, needs greater connectivity with its neighbouring US states.

Fourthly, introducing smart demand management, to shave the peaks in electricity demand and to manage periods of low electricity supply, can further increase reliability. This can be assisted with smart meters and switches controlled by both electricity suppliers and consumers, and programmed by consumers to switch off certain circuits (e.g. air conditioning, water heating, aluminium smelting) for short periods when demand on the grid is high and/or supply is low.

As summarized by the NREL study (p.iii): "RE (Renewable Energy) Futures finds that increased electricity system flexibility, needed to enable electricity supply-demand balance with high levels of renewable generation, can come from a portfolio of supply- and demand-side options, including flexible conventional generation, grid storage, new transmission, more responsive loads, and changes in power system operations."

A recent study by Mark Jacobson and colleagues went well beyond above studies. It showed that *all* energy use in the USA, including transport and heat, could be supplied by renewable *electricity*. The computer simulation used synthetic data on electricity demand, wind and sunshine taken every 30 seconds over a period of 6 years.

In the words of former Australian Greens' Senator Christine Milne: "We are now in the midst of a fight between the past and the future". The dissemination of the base-load myth and other myths denigrating renewable energy falsely[9], and the refutation of these myths, are part of that struggle.

Further reading

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