Is the energy system really ready for sustainable energy?

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New research into sustainable energy systems focuses on integrating renewable and nuclear power plants into the electrical grid – a topic high on the agenda for scholars, industry and policy makers.

Dr Giorgio Locatelli, from the School of Engineering at the University of Lincoln, UK, has published a series of research papers on key aspects of sustainable energy systems in the leading academic journal 'Energy'. The main findings of which are outlined in the following report.

A supply and demand problem

"'Electrical grids can work if, and only if, the amount of electricity inserted into the grid from power plants is matched, second by second, to the amount of electricity extracted from the grid by consumers'. If this doesn't happen there are black-outs.

In order to maintain this equilibrium we must focus on two things: demand and supply of electricity into the grid. Firstly, we must predict the consumption of electricity (as has always been the case) and secondly, we must have the capability to 'tune' power plants to produce the exact amount of energy required. This second task is getting more difficult, especially with intermittent renewable sources such as wind and solar. Supply here is of course determined by that most notoriously unpredictable of variables: the weather.

There are two options to balance supply with demand. We can store electricity when it is produced but not needed so it can be inserted back into the grid when required, or use the electricity for other 'off-grid applications' (for example, desalinating salt water to produce fresh water) in periods of low demand, such as during the night or at weekends.

Over the last decade electricity production from renewable sources has increased across the world. In Europe, where the further development of large hydroelectric plants is now limited by the shortage of new locations, solar, biomass and particularly wind farms will become more prominent in the renewable energy mix over the coming years.

The increasing penetration of variable renewable energy technologies in power provision is already raising difficult questions for the overall efficient management of electrical grids. Many of these technologies require flexible power systems that can react quickly to variability in supply and demand.

Alongside academic colleagues, I have been working to develop a new methodology to assess the economics of energy storage plants. We believe our findings have three key implications for how the energy industry adapts to this challenge.

Firstly our research suggests the possibility of establishing an 'optimum size capacity' for storage plants. Secondly, without subsidies, none of the existing energy storage technologies are economically sustainable. Thirdly, the possibility of operating energy storage plants for multiple purposes was identified as a mean of decreasing subsidies for the energy storage technologies.

The nuclear option

Other than renewables, the only other technology currently available to produce electricity with a negligible amount of carbon dioxide emissions is nuclear power. Small Modular Reactors (SMRs) are part of a new generation of nuclear power plant designs receiving increasing attention from industry and government.

Modern SMRs are a relatively 'new product' in the nuclear industry, but there is a growing interest in the technology, both in the UK and overseas. The attractiveness of SMRs, as an investment, is mostly based on the principle of modular deployment. Their small size makes them a good option for locations that cannot accommodate large-scale plants and they also require limited upfront capital investment.

Given their fixed costs, nuclear reactors are considered a base load power technology - a technology that must produce energy continuously 24/7 to be economical. However, the combination of adding more nuclear power and intermittent sources of renewable energy - such as solar and wind - will require even greater flexibility and adaptability within the grid to compensate for the difference between energy supply and demand at various times.

Currently, nuclear reactors adapt to electricity demand - called 'load following' - by modifying the reactivity within the core. By doing so, power output is reduced, with a waste of potential energy. It also places a thermo-mechanical stress on the plant whenever the power regime is changed. Unlike gas-fuelled power plants, there is not a relevant cost saving in operating a nuclear reactor at a lower power level due to the substantial fixed nature of nuclear costs.

In our research, we tested the idea of keeping the primary circuit at full power and following the load curve by using the power to cogenerate valuable by-products. Cogeneration is the use of a heat engine or power station to simultaneously generate electricity and other products.

We assessed the technical-economic feasibility of this approach when applied to Small Modular Reactors with two cogeneration technologies: algae-biofuel and desalinisation.

Our results show that the power required by an algae-biofuel plant is not sufficient to justify the load following approach. However, it was viable in the case of desalination. Our successive economic analysis demonstrates the economic viability of the desalination approach in several scenarios. In conclusion, the coupling of SMRs with a desalination plant is a realistic solution to perform efficient load following in nuclear power generation.

Obstacles to more SMRs

If SMRs could make a valuable contribution to the energy supply then the next step would be to assess the legal feasibility to make this approach a reality.

This of course sounds simpler than it is! Working with Tristano Sainati, one of my PhD students at the University of Lincoln, we concluded that the tailoring of the licensing process for SMRs, as part of a strong political commitment by several countries, is essential.

There is not a single international authority with power to make this happen and the various national regulatory bodies have limited ability to reshape their own licensing frameworks. A political commitment to SMRs would require a major set of legal reforms, deeply modifying the architecture and principles governing licensing processes. This is unlikely to happen in the short-term and represents one of the main obstacles preventing the widespread adoption of this promising technology."

More information: "Small Modular Reactors: Licensing constraints

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