Exploring small nuclear to plug the energy gaps

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Russia's invasion of Ukraine has in February 2022 sent shockwaves through world energy markets and triggered concerns over energy security, leading to renewed interest in nuclear power and the technology that underpins it.

The current situation echoes the 1973 oil crisis, when an oil embargo contributed to the largest contraction in the world's economy since the Great Depression[4]. This resulted in expansion in nuclear programmes, as nations affected by the embargo sought to break their dependence on foreign oil imports[1]. In 1974, for example, the French prime minister Pierre Messmer announced that all of France's electricity needs should be met by nuclear[5–7]. France installed 56 reactors over the next 15 years. Today, the country still generates most of its electricity from nuclear power and despite this not being original intention, has among the lowest CO_2 emissions from electricity production in Europe[8].

If we are to successfully combat climate change, nuclear may be a better alternative than increased oil prospecting. As fossil fuel prices rise, the cost of nuclear power, which was once deemed too high, is now competitive. Even countries that withdrew from nuclear after the 2011 Fukushima accident, such as South Korea and Japan, have stated their desire to recommit to the technology[9,10]. In light of this, could we see modern versions of the Messmer Plan being implemented?

In the near term, new reactors will be built from existing designs. These large, water-cooled reactors produce between 600 Megawatts electric (MWe) (Canada's CANDU reactor, for example), and 1650 MWe (France's EPR) and have excellent operational characteristics, with very low down time meaning they generate electricity more than 90% of the time and design lives of 60 years. But they take an average of nearly eight years to construct, with some projects taking much longer. Finland's Olkiluoto 3 reactor, for example, took 16 years to build[11]. The large up-front costs (in the order of billions of dollars) and long delay before seeing a return on investment has deterred investors seeking assets that can be built more quickly and cheaply.

Small modular reactors (SMRs), in contrast, aim to address these issues and could be deployed by the end of the decade. The SMR concept puts an emphasis on factory construction, enabling advanced manufacturing methods and a reduction in on-site construction and hence weather delays. These reactors target power levels of 200 to 500 MWe. By requiring construction times of half that of large reactors, SMRs reduce unit price to levels suitable for private investment – although multiple units will be required to produce the same output as a larger plant.

The main barrier to the success of SMRs lies in attracting sufficient orders to cover the cost of development and a factory. Even if this is achieved, siting and licensing may still be obstacles. Current regulatory systems are geared towards a small number of large projects, with each often taking years to be approved. This will need to be streamlined if the rapid development of an SMR fleet is to be practical.

SMRs can provide heat at 315°C, if it is extracted from the output of the reactor core, however doing this means there is less energy in the steam entering the power-station's turbine generators and the efficiency of electricity generation is reduced considerably. Consequently heat is more usually taken after the steam turbines at 100-200°C allowing heat to be provided with only a small hit to electrical generating efficiency.

This can still support processes such as desalination, paper production and drying. It is also suitable for domestic water heating through district-wide heating schemes.

There is a long history of nuclear district heating in countries such as Switzerland, Sweden, Canada and Eastern Europe, but their high infrastructure cost has deterred widespread use. It could become competitive, however, if gas prices fail to fall significantly. Recent projections for a scheme to heat Paris from large reactors estimated a cost of €42/MWh (US$44.86/MWh). This compares well to the current gas price of €79/MWh, which has fallen from a high of €105/MWh at the end of April. Cost could also be reduced further through the use of SMRs, which aim to allow siting closer to population centres, reducing the length and cost of the heat transmission network.

A new generation of high-temperature reactors are also currently being developed (as an example the Generation IV International Forum has 11 nations as active members), which suit applications such as iron smelting and efficient hydrogen production via steam electrolysis and thermochemical routes (the latter having been demonstrated at pilot scale already with Japan's high temperature test reactor).

Although new enthusiasm for nuclear power may be driven by the same factors of energy security and price as the oil shock of 1973, its ability to provide low-carbon electricity and process heat means it is perhaps an even more relevant choice for today's energy systems than it was back then. By doing more than just producing electricity, it can aid in deep decarbonisation by displacing oil and gas, which also reduces the geopolitical power that can be wielded by those who control its supply.

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