PATH TO NET ZERO – ROLE OF NUCLEAR ENERGY

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Nuclear energy provides an available and adaptable source of zero-carbon energy poised to play a significant role in the global drive to achieve net zero carbon emissions by 2050. Notwithstanding nuclear's promise, its detractors and some governments have announced plans to phase out their use of nuclear power. Even so, only large scale hydropower can rival nuclear power's ability to generate large amounts of dispatchable, virtually zero-carbon power. Further, the multitude and diversity of advanced reactor designs offer opportunities to decarbonise multiple industrial sectors. Yet according to the International Energy Agency (IEA), while nuclear energy remains the world's second largest low-carbon source of electricity, the global construction of new nuclear power plants lags behind the level needed to achieve the net zero emissions by a 2050 scenario[1].

In reaction to the conflict in Ukraine, governments across the world are reviewing their attitudes and policies towards nuclear power as a tool to mitigate the rising cost of oil and gas, and Europe is looking at nuclear energy to reinforce its energy security and reduce reliance on energy imports from Russia. Also, small modular reactors and advanced reactors have spurred renewed investor appetite for financing nuclear power plants.

This article looks at the current status of nuclear energy as an integral part of the global energy transition portfolio and the growing recognition, in particular in the UK and the USA, of the value of nuclear energy as a source of reliable, virtually carbon-free, baseload power.

GOVERNMENT POLICIES ON NUCLEAR ENERGY

Government policies toward nuclear power in OECD countries remain mixed. For example, the European Commission's recent decision to include nuclear energy in the EU taxonomy of environmentally sustainable activities met strong opposition from some EU member states. Germany and Belgium remain committed to phasing out nuclear power by 2022 and 2035 respectively. In contrast, French President Emanuel Macron recently announced the construction of at least six new reactors by 2050 (with the possibility of an additional eight if the country decides to utilise new advance reactor designs) and a 10-year extension to the lifespan of existing nuclear plants from 40 years to 50 years. This announcement changed France's previous policy to reduce France's dependence on nuclear power to 50% by 2035 – about 70% of France's electricity is currently from nuclear power.

In the UK, Delivering New and Advanced Nuclear Power was placed fourth in the government's Ten Point Plan for a Green Industrial Revolution, the Ten Point Plan. The UK government's recently announced[2] Energy Security Strategy aims to see up to 25% – ie 24GW, an increase from 14.5% in 2020[3] – of the UK's energy come from nuclear power by 2050. To achieve that goal, the UK government has announced the launch of a £120m Future Nuclear Enabling Fund and has set up a new government body – Great British Nuclear – to oversee the delivery of new projects including the construction of up to eight new nuclear reactors.

The newly enacted Nuclear Energy (Financing) Act 2022 makes regulated asset base funding the new mode for financing nuclear power stations in the UK. This approach reduces reliance on overseas developers for financing new nuclear projects and substantially increases the pool of potential private investors to include British pension funds, insurers and other institutional investors.

In the US, the recently enacted infrastructure bill provided funding to support existing nuclear generation along with additional funding to develop advanced reactors and using nuclear power to generate hydrogen using electrolysis.

CHALLENGES TO EXPANDING NUCLEAR POWER

Low enriched uranium-235 (5%) and, in the case of advanced reactors, high-assay, low-enriched uranium (HALEU) (<20%), is a commonly used fuel for the operation of nuclear reactors around the world. Russia is a major global supplier of both uranium products and uranium enrichment services. State Atomic Energy Corporation Rosatom supplies nuclear fuel to many of the world's reactors through its subsidiary TENEX. It has been widely reported that the US is considering imposing sanctions on uranium from Russia and that Russia also is considering banning uranium sales to the US. Such bans, if imposed, could present challenges to meeting the needs of existing reactors and the requirements of advanced nuclear technologies.

Traditional large-scale nuclear plants have high capital costs and can be slow to build given the engineering and technological complexity. Of course, spent fuel from nuclear plants is highly radioactive.. This raises concerns as to the long-term environmental consequences around achieving the safe management and disposal of spent fuel .

While France reprocesses spent fuel from its reactors to recycle the fissile materials into new fuel, most countries have no plans to reprocess spent fuel. Instead, many countries, including the UK and the US, are planning deep geological repositories, similar to the ONKALO facility being built in Olkiluoto, Finland, to dispose of spent fuel. With the exception of the ONKALO facility, considered a game changer[4] and scheduled to be completed by 2025, these facilities are decades away from being operational, if they are built at all. As a result, spent fuel will probably continue to be stored in temporary facilities in many countries. Furthermore, the risk of potential accidents and the severe consequences that can result from such accidents, such as the Chernobyl in 1986 and Fukushima in 2011 nuclear disasters, have demonstrated, remain a cause of concern.

Proponents of nuclear power point to the fact that it provides reliable low-carbon energy in high volumes for base load electricity. Newer reactor designs such as small modular reactors and advanced reactors can meet a wider range of energy needs beyond base load electrical generation. Further, many believe that achieving the deep decarbonisation required to keep the average rise in global temperatures to below 1.5°C (ie net zero), would be much harder, if not impossible, to achieve without an increased role for nuclear power, beyond maintaining existing generating plants[5].

While other renewable and low carbon energy sources such as wind and solar are popular, especially in public opinion, they depend on variable weather patterns that cannot be relied on for a stable, constant supply of base load energy. Nuclear energy also produces more electricity on less land than wind or solar – for example, a 1,000MW nuclear facility needs just over one square mile compared with 360 times (for wind) or 75 times (for solar) as much land area to produce the same amount of electricity[6]. An operating nuclear power plant produces virtually no greenhouse gas emissions during its operation, and over the course of its life cycle a nuclear power plant produces about the same amount of carbon dioxide-equivalent emissions per unit of electricity as wind, and one-third of the emissions per unit of electricity when compared with solar[7].

RECENT DEVELOPMENTS

Given the long build times for traditional large light-water reactors, the nuclear industry turned to developing small modular reactors. SMRs are much smaller than traditional reactors – producing about 300MW of electricity compared with more than 1GW for traditional plants. They are designed so that much of the nuclear plant can be fabricated in a factory and transported to site, shortening the construction time, and reducing construction risk by making them less capital-intensive. And because these units are modular, several SMRs can be installed at a single site, at the same time or in sequence to follow load growth, and can be managed as a single integrated system to enable much more flexible output and load following than traditional plants designed to operate at 100% power for many months.

The industry also is developing several different advanced reactor designs. These vary in size from micro reactors of about 10MWe to larger designs capable of producing 300MWe–500MWe. To varying degrees, these advanced designs use different fuel designs and coolants than existing reactors and offer a range of additional features and applications. Most employ passive safety designs that do not require human intervention or electrical power to safely shut down the reactor or maintain cooling once shut down. Some of these designs can store energy as heat to either produce electricity on demand or supply industrial process heat. The hope is that these advanced reactor designs will drive deep decarbonisation by providing heat and power to remote communities that currently rely on diesel generators and by providing heat and power for industrial needs.

RECENT DEVELOPMENTS IN THE UK AND USA

In the UK, the Nuclear Energy (Financing) Act 2022 (the 2022 act) introduced the regulated asset base (RAB) model as a means to fund future nuclear projects. The RAB model is a method that has been historically used in the UK to finance large-scale regulated infrastructure assets, for example it was the model used to finance Heathrow's Terminal 5.

The RAB model, as envisaged by the 2022 act, will require consumers to contribute to the cost of constructing a nuclear project by paying a certain amount towards such construction in their electricity bills. The model fundamentally differs from the contract for difference (CfD) approach that was used to finance Hinkley Point C, the nuclear power plant that is currently under construction in the UK.

Under the Hinkley Point C CfD, the developer agreed to pay the entire cost of constructing the plant, in return for an agreed fixed price, ie the strike price, for electricity output once the plant is online. That cost is ultimately funded by consumers, who will pay the difference between the wholesale electricity price and the final strike price, once that power station is completed and in operation. In contrast, the RAB model shares the construction cost with consumers from the start, reducing the amount of interest owed on loans to finance the construction. This ensures that the burden on consumers is much lower over the life of the plant while helping to attract private sector investment to nuclear projects.

The Ten Point Plan announced the launch of the Advanced Nuclear Fund of up to £385m to invest in the next generation of nuclear technologies. This includes up to £215m for SMRs to develop a domestic smaller-scale power plant technology design, and up to £170m for a research and development programme to deliver an advanced modular reactor demonstration by the early 2030s.

In the US, Congress passed the Nuclear Energy Innovation and Modernization Act or NEIMA in 2019. Among its provisions, NEIMA directed the US Nuclear Regulatory Commission (NRC) to develop "a technology-inclusive regulatory framework" for advanced reactors by the end of 2027. The NRC has been working with stakeholders to develop this framework. The new regulations aim to be technology inclusive by setting performance-based standards that are flexible and can be applied to all advanced reactor technologies. The NRC is releasing sections of its proposed regulatory language for public comment with a goal of publishing the final rules before the 2027 deadline.

More recently, the Infrastructure and Jobs Act (IJA), passed in November 2021, contained several programmes to support the existing nuclear fleet and encourage the development and deployment of SMRs and advanced reactor technologies. For the existing fleet, Congress recognized the need to maintain existing nuclear generation to meet greenhouse gas reduction goals and protect high-paying jobs in the nuclear industry. Thus, Congress created a Civil Nuclear Credit Program to provide financial support to reactors in competitive electricity markets at risk of closing for purely economic reasons. This programme will provide up to US$1.2bn in financial support over the next six years. The US Department of Energy (DOE) is taking steps to implement the programme but has not yet begun accepting applications.

For SMRs and advanced reactors, the IJA included additional funding for the DOE's Advanced Reactor Demonstration Program or ARDP. The ARDP is a cost-sharing programme to speed the demonstration of advanced reactors by partnering with the nuclear industry. The DOE has selected two advanced reactor designs – one molten salt reactor and one high-temperature gas-cooled reactor – for the programme. The DOE now has US$3.2bn in spending authority for this programme. The DOE also oversees a loan guarantee programme with more than US$40bn in lending authority. This programme has provided loan guarantees to the two new large light water reactors nearing completion in Georgia, and the DOE is accepting applications to provide funding for advanced reactors.

The IJA also included provisions to encourage the development of clean hydrogen – defined as hydrogen produced from renewables, nuclear, or fossil sources using carbon capture – as a fuel source. To do so, the IJA established a Clean Hydrogen Research and Development Program within DOE and appropriated US$9.5bn for clean hydrogen research. The IJA also appropriated US$8bn for DOE to establish four regional clean hydrogen hubs that would include a network of hydrogen producers, users, and connective infrastructure. At least one of these clean hydrogen hubs must produce clean hydrogen using nuclear power. While an advanced reactor could be used for this purpose, the existing fleet is also interested in supplying power and heat for electrolysis to produce clean hydrogen.

CONCLUSION

Globally, there are currently 441 active nuclear reactors in 32countries with total net electrical capacity of 393.54GW. The highest number of active reactors can be found in the US with 93, France with 56, China 54, Russia 38, and Japan 33, and the UK is 12th on the global list with 11 operational reactors. There are 51 new reactors currently under construction across 17 countries, which when completed will represent an additional total capacity of 53.64GW, the majority of which are being built in China with 15, India 6, South Korea 4, Russia 4, and Turkey 2, while Bangladesh, Japan, Slovakia, Ukraine, the UAE, the UK and US each have 2 reactors under construction[8]. Notably, Unit 2 of the Barakah nuclear power plant in the UAE achieved commercial operations in March 2022.

However, the IEA reports[9] that based on current trends and policy targets, nuclear capacity in 2040 will amount to 582GW – well below the level of 730GW required in the net zero emissions by 2050 scenario and that this gap widens even further after 2040 as older reactors are shut down and decommissioned. For example, all but one of the UK's six nuclear plants are scheduled to be switched off by 2030 and in the US, the majority of reactors will be retired in the 2030s and 2040s unless they seek another licence renewal.

Thus, the IEA concluded that an average yearly new nuclear capacity of 20GW is required between 2020 and 2050 to meet net zero goals. However, recent legal developments in the UK and US, advances in nuclear technology and the reconsideration of policy statements in light of Europe's re-assessment of its energy security needs indicate nuclear power's increasingly important role in the path to achieving net zero by 2050.

FOOTNOTES

1 - IEA (2021), Nuclear Power, IEA, Paris https://www.iea.org/reports/nuclear-power
2 - Published April 6 2022
3 - International Atomic Energy Agency, Power Reactor Information System (PRIS) database
4 - Finland's Spent Fuel Repository a "Game Changer" for the nuclear industry, says director-general Grossi https://www.iaea.org/newscenter/news/finlands-spent-fuel-repository-a-game-changer-for-the-nuclear-industry-director-general-grossi-says
5 - International Atomic Energy Agency, Climate Change and Nuclear Power 2020, Non-serial Publications, IAEA, Vienna (2020)
6 - Source: US Department of Energy, Office of Nuclear Energy
7 - International Atomic Energy Agency, Climate Change and Nuclear Power 2020, Non-serial Publications, IAEA, Vienna (2020
8 - Source: International Atomic Energy Agency, PRIS database
9 - IEA (2021), Nuclear Power, IEA, Paris https://www.iea.org/reports/nuclear-power ■