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Australian electricity options: nuclear

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Executive summary

- Nuclear electricity provides around a tenth of world electricity needs, with only a few other applications in the energy sector. It is the second largest source of low carbon electricity after hydro. However, recent capacity additions in OECD countries have been few, and growth is now outside OECD countries, dominated by China and India.

Australian electricity options are short briefings on the principal energy sources and storage options being debated in Australia, including: coal, natural gas, wind, nuclear, photovoltaics (PV) and pumped hydro energy storage (PHES).

The global COVID-19 pandemic and its economic consequences mean that statements and projections about future demand and pricing of energy options may no longer be reliable. Readers should note that some figures quoted in these briefings may pre-date the pandemic.

Nuclear energy production

Nuclear energy is deployed to produce electricity by harnessing the heat produced in the fission, or splitting, of radioactive isotopes of uranium or plutonium in a reactor. In the majority of cases, water is used to transfer heat to steam turbines. Reliable supplies of cooling water are essential to the operation of large-scale nuclear plants. Nuclear energy is also deployed in military applications, notably submarines for power and propulsion, but also other shipping, including aircraft carriers and icebreakers. Nuclear plants are generally characterised by large capacity and output, high capital cost, and long construction times, but relatively low operating costs and almost zero emissions to air from their operation.

Nuclear energy is used to produce electricity in 31 countries from some 450 nuclear reactors, providing around 10 per cent of global electricity. Production is concentrated in OECD countries, where nuclear provides almost one-fifth of total electricity output. More recently, new construction has been dominated by non-OECD countries, notably China, but also India and states of the former Soviet Union, accounting for a large share of the 52 reactors currently under construction.

Major nuclear power countries

The United States accounts for around one-third of global nuclear electricity, providing just under a fifth of US generation. The nation has almost 100 reactors, but most of these entered service more than 30 years ago. Only two reactors are being built, supported by measures enacted in the Energy Policy Act 2005.

Nuclear power peaked in Japan around a decade ago, providing nearly a third of electricity generation. However, after the devastating disaster at Fukushima in 2011, all plants were closed

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down. This resulted in severe electricity shortages, managed largely by increased imports of liquefied natural gas (LNG) and coal, demand management measures, plus enhanced solar generation. Subsequently, reactors are slowly re-entering service, but nuclear generation seems set to play a diminished, if still important role in Japanese electricity supply.

France produces around three-quarters of its electricity generation from 58 reactors, but again, the majority of its reactor fleet entered service before 1990. This generation enables France to be one of the world's largest net exporters of electricity. Only one new reactor is under construction at Flamanville, Normandy. With construction having started in 2007, the plant is well behind its projected schedule and well over budget. Construction of a similar plant was started in 2005 in Finland, and has yet to enter commercial service, and is also well over budget. In OECD Europe, only these two reactors, plus two smaller ones in Slovakia, and one in Turkey are being built. Germany, Europe's largest economy, produces around a seventh of its electricity from nuclear reactors, down from a quarter a decade ago, having closed a part of its fleet after Fukushima. Further plant closures have been foreshadowed, with all nuclear power plants to be shut down by the end of 2022. Solar and wind now generate more electricity than nuclear in that country.

China has a very active nuclear program as part of its rapid shift to diversify its electricity sector away from coal. However, its 48 reactors currently account for less than four per cent of electricity supply. Even with its current building program, this share is only expected to increase to around eight per cent of generation by 2030.

International Energy Agency (IEA) projections show that nuclear generation will broadly maintain its current share of global power markets, on the basis of non-OECD output growth—especially in China and India, which will account for around 90 per cent of the net growth. The declining contribution of nuclear power in advanced economies and its interaction with carbon emissions is examined in the 2019 IEA report *Nuclear Power in a Clean Energy System*.

Advantages and disadvantages

The key advantage of nuclear power is that its operation produces no greenhouse gases and no significant emissions of other air pollutants. However, power plant construction, transport of nuclear waste, and decommissioning does result in emissions. Despite this, whole-of-life analysis shows that nuclear power is much more 'greenhouse-friendly' than burning hydrocarbons such as coal, peat, oil and natural gas. For this reason, there have been calls to expand nuclear power to help mitigate climate change.

Disadvantages, apart from the high up-front cost mentioned above, centre around the safe storage and disposal of high-level radioactive waste, with only a few countries having built permanent repositories for this waste. The United States identified a site in the 1980s for such a repository in Nevada, but local opposition has slowed progress. Negative perceptions towards nuclear power, especially around the safety of waste and the possibility that an accident could release radiation into the environment, also persist in Australia.

Other nuclear technologies

Other nuclear technologies include fast breeder reactors (which produce more fuel than they use), thorium reactors (under research and development, notably in India), and the still-distant possibility of controlled, clean fusion power, which draws on the energy of fusing hydrogen nuclei. Smaller scale fission reactors are also being proposed.

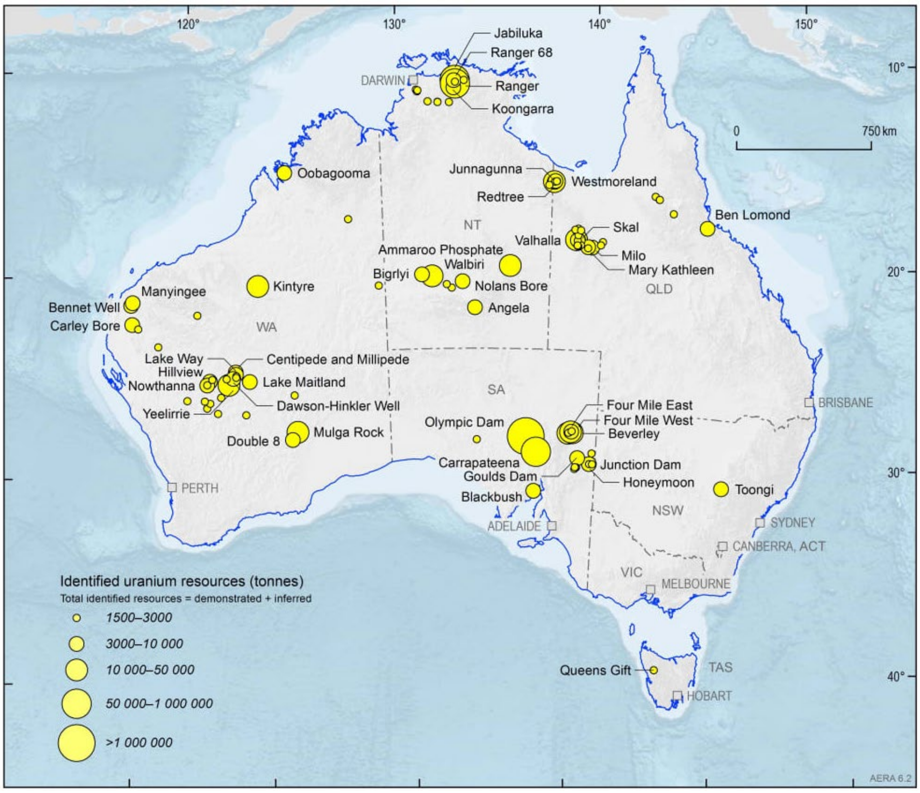
In the case of breeder reactors, a large scale prototype was built in southern France, but has been closed for some years in the face of major technical and mechanical problems. For fusion, decades of research have yet to lead to a useful power reactor. Experimental work continues in several locations, with the largest being a multinational experimental fusion facility in France (ITER), but

this is at least ten years away from demonstrating commercial feasibility of the technology. The ITER facility has not been designed to capture any energy produced as electricity, but as an experimental unit to test and demonstrate the technology. Smaller scale fission technologies are also under active research, but have yet to be demonstrated. Advanced reactor designs are the focus of the Generation IV International Forum collaboration (which Australia joined in 2016).

Prospects for Australia

Australia holds almost one-third of the world's proven uranium reserves, which has underpinned exports of around 7,000 tonnes per year. This represents about 10 per cent of global supply and makes Australia the third-largest uranium producer. Uranium ore is mined and processed into uranium oxide before being exported, with no enrichment into nuclear fuel undertaken in Australia. There are three operating uranium mines in Australia—Olympic Dam and Four Mile (South Australia) and Ranger (Northern Territory).

Australia's identified uranium resources



Source: Geoscience Australia, *Australian energy resources assessment*, 2018

Nuclear power production is currently not permitted under two main pieces of Commonwealth legislation—the *Australian Radiation Protection and Nuclear Safety Act 1998* (the ARPANS Act), and the *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act). These Acts expressly prohibit the approval, licensing, construction, or operation of a nuclear fuel fabrication plant; a nuclear power plant; an enrichment plant; or a reprocessing facility. There is also a range of other legislation, including state and territory legislation, which regulates nuclear and radiation-related activities.

In recent years, a number of inquiries have been undertaken into nuclear issues in Australia. The Australian Parliament House of Representatives Standing Committee on Environment and Energy held an inquiry into the prerequisites for nuclear energy in Australia and reported on 13 December 2019. The NSW Parliament conducted an inquiry into uranium mining and the potential of nuclear

power in NSW (report tabled in March 2020). The Victorian Parliament also has an inquiry into nuclear prohibition (submissions closed in February 2020). South Australia held a Royal Commission in 2015 and 2016 into expanding its nuclear industry.

Australia has one nuclear reactor at Lucas Heights (south of Sydney). It is one of over 200 research reactors located around the world and is used chiefly for the production of medical isotopes—it is not used to generate electricity. The facility produces tens of cubic metres of low and intermediate level radioactive waste each year. Despite efforts over some decades, a permanent repository has yet to be developed for this waste, which is currently held at Lucas Heights, Woomera, and other sites. Australia is currently working to establish a National Radioactive Waste Management Facility for the permanent storage of low-level waste from nuclear medicine and research activities and the temporary storage of intermediate-level waste. This is progressing under the *National Radioactive Waste Management Act 2012*. The Government has identified a site near Kimba in South Australia to host the facility and this selection has gone before Parliament in the National Radioactive Waste Management Amendment (Site Specification, Community Fund and Other Measures) Bill 2020.

In almost all OECD markets, new nuclear reactors have struggled to establish a business case in the last two decades (with the exception probably being South Korea). The long lead times and high capital costs, plus the technical and economic inflexibility of nuclear plants, have mitigated strongly against new construction unless there has been sufficiently strong policy support (such as for the proposed new reactor in the United Kingdom). New power plants over the last two decades in OECD countries have generally been gas fired (based on high-efficiency gas turbines) and more recently based on new renewable technologies, such as wind and solar, where costs have declined sharply and lead times are short and costs known more accurately.

Experience in other countries where nuclear reactors are introduced indicates that initially costs and lead times may exceed expectations. A skilled work force is required to construct, operate and maintain the facilities. In addition, any reactor construction in Australia would likely need to be in a coastal location to assure cooling water. In due course, a permanent repository for high-level reactor waste would need to be identified, constructed and operated, quite distinct from current efforts to develop a repository for low and intermediate level waste. The example of the United Arab Emirates, where a Korean consortium is building four reactors, may prove instructive in how a modern nuclear industry could function.

Further reading

International Atomic Energy Agency, 'Power Reactor Information System'

International Energy Agency, *World Energy Outlook*