Nuclear energy is a promising solution for climate change

But the clean-energy option will forever risk a catastrophe.

Fukushima, on the northeast of Japan's largest island, is vulnerable to earthquakes and tsunamis. From 1971, the area hosted the Daiichi nuclear plant. Based on global appraisals of tsunamis, the facility was built 10 metres above sea level. The commercial plant and others ensured nuclear energy supplied 30% of Japan's power needs.[1]

That is until an earthquake of magnitude 9.0 on the Richter scale struck in 2011. An ocean surge, which peaked offshore at 23 metres, was still 15 metres high when it swamped three reactors at the Daiichi plant. Radioactive material escaped for six days. More than 2,300 people died and over 100,000 were evacuated.[2] Japan was paralysed by what the chairman of a parliamentary inquiry described as "a profoundly man-made disaster".[3]

Tokyo reacted to the alarm of a public who watched on TV as the tsunami smashed into land. Within a year, only one of Japan's 54 nuclear reactors was operating.

Enthusiasm for nuclear power, which reached a peak of 17% of global energy production in 1996,[4] dimmed around the world.[5] Germany immediately decided to phase out its 17 nuclear plants by 2022. Only three remain but it looks like Europe's energy crisis could delay their closure. In the rest of Europe, the drive to nuclear power stalled such that Italy, Lithuania and nearby Kazakhstan have ditched nuclear while Finland in March opened the continent's first new nuclear plant in 15 years. The US has opened only one reactor (in 2016) since 1996.

Reduce one risk but still face another. That danger is climate change. The UN-overseen Intergovernmental Panel on Climate Change warned in April the world is "at a crossroads" in its quest to halve emissions by 2030 to limit the rise in the earth's temperature.[6] The obstacles? Voters oppose carbon taxes. Renewable energy is struggling to match fossil fuels as a source of 'baseload' power on reliability and cost. Declining investment in fossil fuels has boosted hydrocarbon prices. Russia's invasion of Ukraine in February further bolstered oil and gas prices while exposing Europe's reliance on Russian energy as a liability. 'Energy security' has gained renewed political significance.

What to do? A large part of the answer could be nuclear energy, which is generated in a process known as fission – when uranium or plutonium atoms are split to release heat that makes steam to spin turbines.[7] Even though radioactive waste is produced during fission that can last forever,[8] policymakers are talking of adding to the 439 reactors in operation across 32 countries (while another 54 reactors are being built) that still supply about 10% of the world's energy needs.[9]

The talk is generating action. The US in April announced a US$6 billion effort to prevent more closures among the country's 94 reactors sprinkled across 56 plants that make the US the world's largest generator of nuclear power. Since 2013, 12 US reactors have closed 'early' and another 11 reactors are scheduled to shut by 2025.[10] Nuclear power, first tapped in the US in 1958, has supplied about 20% of US electricity generation since 1990.[11]

Europe too is reemphasising nuclear. The UK in April said it would build as many as eight new nuclear plants by 2030.[12] In February before Ukraine was invaded, French President Emmanuel Macron said the world's second-most nuclear-powered country (56 reactors that supply 70% of the country's electricity) needed 14 new reactors by 2050.[13] Earlier the same month, the European Commission added nuclear energy to a list of sustainable energy sources that are valid replacements for fossil fuels.[14] In July, the European Parliament backed the EC decision.[15] Asia hosted all the world's new nuclear capacity in 2021 and more is coming.[16]

It's easy to see why leaders are attracted to nuclear energy. As long as countries can source uranium or plutonium, the nuclear option offers energy self-sufficiency and is the lowest-cost greenhouse-gas-free energy – one that is cheaper than all but the lowest-cost fossil fuels. OECD analysis, which assumes long-lasting nuclear plants will spread fixed costs and adds a carbon price of US$30 per tonne of CO_2 onto the cost of fossil fuels, estimates nuclear energy could cost as little as US$30 a megawatt hour compared with US$45 for gas and US$75 for coal.[17]

Two promising developments could make nuclear more appealing. The first is the coming of commercial mini-nuclear reactors.[18] These mini-reactors would produce between 300 megawatts (small) and 700 megawatts (medium) of power

compared with at least 1,000 MW electrical (MWe) produced by standard-sized reactors.

The advantages of mini-reactors are lower initial capital costs, less-complex design and that they take only four years to build rather than the decade needed for standard facilities. Mini-reactors can be built and shipped, thus are a better option for remote areas. They are safer because they require no manpower or electricity to shut down.[19] They produce less waste. They are cheaper to decommission. The International Atomic Energy Agency says there are about 50 designs for mini-reactors and four are close to being finished in Argentina, China and Russia.[20] Rolls-Royce says it can have 470 MWe mini-reactors connected to the UK grid by 2029.[21]

The second development is nuclear fusion. Whereas in nuclear fission an atom is split, fusion is combining atoms (using special hydrogen, deuterium and tritium as fuel). When fusion occurs, the difference in mass between nuclei and the newly formed heavier-but-lower-mass atom is released as energy. It takes special machines (tokamaks) or lasers to generate the intense heat and powerful magnetic forces required to produce an energy so powerful that one litre of fusion fuel matches 55,000 barrels of oil for energy.[22]

Breakthroughs are occurring in mimicking the energy source of the Sun and stars. In the UK in February, a fusion reactor produced a world record of 59 megajoules of heat energy over five seconds, more than double the previous record of 22 megajoules set in 1997.[23] In the US last September, a superconducting magnet needed in fusion broke magnetic field strength records during trials.[24] A month earlier in the US, laser light created enough heat to generate a record yield of laser fusion; 10 quadrillion watts of fusion power for 100 trillionths of a second.[25]

Aside from producing greenhouse-gas-free energy, fusion comes with two other notable advantages. One is that fusion eradicates the risk of a nuclear meltdown because, if disturbed, the process stops. The other is that no radioactive waste is produced. Fusion research is expensive, however, and advances whereby fusion reactors offer the world affordable power seem far off and might never happen.

That's the best hope too for the devastation that nuclear energy risks. Accidents that include Three Mile Island in the US in 1979, Chernobyl in the former Soviet Union in 1986 and Fukushima are blamed on human error. A possible calamity occurred in March when Russian shelling started a fire at the Zaporizhzhia nuclear plant in Ukraine, which with six reactors is Europe's largest. The incident highlighted the vulnerability of nuclear facilities to war, terrorism, suicidal rage or rogue states turning a nuclear plant into a military base, as Russia has now done with Zaporizhzhia.[26] Many say ageing nuclear facilities pose a threat. Nearby Germans have long had concerns about the state of the Tihange nuclear plant in Belgium. The regional German government has called for the plant to be closed.[27]

Nuclear energy's risk tied to the internet age is cybersecurity. The US and Israel in 2010 used Stuxnet malware to interfere with Iran's Natanz plant while a nuclear plant in Germany was reported to have suffered a "disruptive" cyberattack about a decade ago.[28] While the threat might be exaggerated by opponents of nuclear energy, it adds to political challenges of gaining public support for the nuclear option.[29]

Even with all the risks, nuclear energy is an established source of power that will gain traction as an answer for climate change, especially if more technological leaps are made. Nuclear energy might be most notable for how its adoption will vary across countries as communities judge their tolerance for the risks surrounding the most-promising energy solution to mitigate global warming.

To be sure, nuclear is not touted as the sole solution for climate change. Leaps in renewable technology or its economics could undermine the need for nuclear. But the reverse could apply too. The shift to more nuclear could take too long to contain the rise in the earth's temperature to 2 degrees Celsius. Nuclear energy, with its huge initial investment, might never match the lowest-cost fossil fuels, especially if plants are excessively regulated to soothe public concerns about safety. Some countries such as Australia and Germany are against nuclear though the energy crisis could change that.[30] Russia exports nuclear technology so its isolation might slow the industry's development. Any nuclear-building spree comes with risks and no doubt cost overruns (a problem too when upgrading ageing facilities). Against this, only three notable accidents in more than six decades is a fair safety record for any industry.

Energy security is what gives nuclear energy fresh appeal. Expect more policymakers to push for nuclear. It's just that the next nuclear mishap – and human error, even malevolence, almost guarantees one – might, Fukushima-style, set back the best option to mitigate climate change on every measure but safety.

HEAVIER BUT LESS MASS

Tokamak is a Russian acronym that stands for the 'toroidal chamber with magnetic coils' that was developed in the Soviet Union in the late 1960s. The machine contains a large doughnut-shaped vacuum chamber where a few grams of hydrogen fuel are heated to 150 million degrees Celsius to form a substance known as plasma. This substance allows electrons to roam between different nuclei so they can collide and fuse. The challenges include having sufficient plasma particle density to increase the likelihood that collisions occur and enough confinement time to hold the plasma, which has a propensity to expand, within a defined volume. Within the tokamak, magnetic fields are used to confine and control the plasma.[31]

The process is seeking to capitalise on the insights of UK physicist Arthur Eddington (1882-1944).[32] Eddington observed that four hydrogen atoms weigh more than one helium atom. He surmised that if four hydrogen nuclei were fused then some mass must be lost in the process. According to Einstein's famous equation E=MC2, that lost mass must become energy that amounts to the mass lost multiplied by the speed of light. Eddington's brilliance, as revealed in his book Internal constitution of the stars in 1925, was he deduced that hydrogen crashing into hydrogen to form helium under immense gravitational forces is how the Sun and stars produce energy (shine).[33]

The hope of many scientists nowadays is that nuclear fusion is the solution to climate change, even the world's energy needs. Many have tried since the explosion of a hydrogen bomb in 1952 to crack nuclear fusion as a source of power.

The world's biggest experiment underway to achieve nuclear fusion is the International Thermonuclear Experimental Reactor, or ITER, Project that groups China, the EU, India, Japan, Korea, Russia and the US.

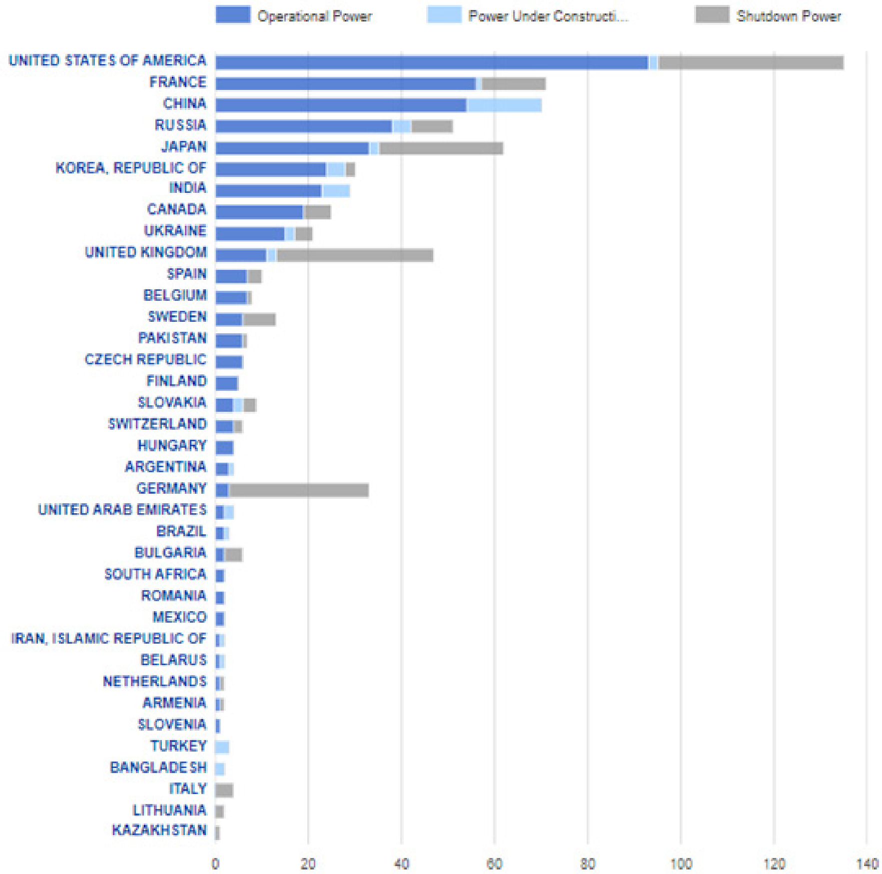
ITER's first plasma experiment is scheduled for 2025, 15 years after building the facilities began on a site in the south of France. With 10 times the plasma volume of the largest machine operating now, the ITER tokamak is designed to move on from small-scale fusion experiments.

The key quest is to get fusion to reach the point where the energy output from the fusion reaction matches the energy needed to create the conditions that sustain the fusion reaction. A later goal of ITER is to attain 10 times the energy output, which would mean that 50 megawatts of heating power could become 500 megawatts of fusion power.[34]

If scientists at ITER or elsewhere achieve these and other feats, nuclear fusion could well power the world. No breakthroughs away from ITER appear imminent while the ITER results won't be known for decades and might prove fruitless. In the meantime, nuclear fission conducted in mini-reactors might be the best option for those countries willing to risk using nuclear power to combat climate change.

By Michael Collins, Investment Specialist

Number of nuclear reactors by country



info@magellangroup.com.au +61 2 9235 4888