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Mackenzie Greenchip Team

Nuclear renaissance revisited

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In these crazy times, there is one consistent economic force we should all internalize — the world urgently needs more power. When Donald Trump signed his childishly named "One Big Beautiful Bill" on July 4, it was filled with laws related to electricity production. Tax breaks for wind, solar and electric cars were slashed and replaced with support for natural gas, geothermal and nuclear. It was blatantly political, as was, to a certain extent, Joe Biden's Inflation Reduction Act (IRA). The US desperately needs a more pragmatic and long-lasting approach to electricity infrastructure. The Mackenzie Greenchip Team (Greenchip) sees nothing but higher prices and outages if policymakers don't up their game.

This note, however, will focus on one part of the bill — its unwavering support for a nuclear renaissance. We first wrote about nuclear in 2012, and again in 2022 in the heart of the European gas crisis. The most recent piece led with Boris Johnson pledging a massive nuclear power expansion, his final act as Prime Minister. Last month, Trump had a similar call to action, signing several nuclear-related executive orders, which target 10 new reactors by 2030. In both cases, it was political grandstanding: the West hasn't managed to build a reactor in under 15 years for decades. Yet the West needs nuclear to work again. Mostly, we need to rebuild the systemic scaffolding that makes it economically feasible to do so. And we need to internalize that nuclear — or any other technology — cannot alone solve our power crisis.

Revisiting the 2022 note provides a useful nuclear benchmark. There were 440 reactors operating globally that year — today the number remains exactly 440.[1] Global developments, however, have not been static. New plants have been coming online in Asia at about the same pace that old reactors are decommissioned in the West. China will commission 10 new reactors this year.[2]

Yet nuclear is losing its share of total global power production — since 2022, electricity production from nuclear has dropped from 10% to 9%.[3] This is because 80% of annual generation investment has gone to wind and solar in each of the past three years,[4] while nuclear has received very little of the total CAPEX pie. We cannot just build intermittent wind and solar without adequate baseload power: exactly what nuclear offers, and with a very low carbon footprint to boot. It's just not clear that we can afford it, particularly in the West. Greenchip believes the path to lower nuclear costs can be found in Asia, where countries like China, Japan and South Korea build reactors much more quickly and at half the cost.

This paper outlines our research into both economic and investment opportunities, starting with large scale reactors, then small modular reactors (SMRs), refurbishment and fusion.

Note: there are currently 220 research reactors, and about 160 naval vessels powered by nuclear today — this note will focus on electricity production.

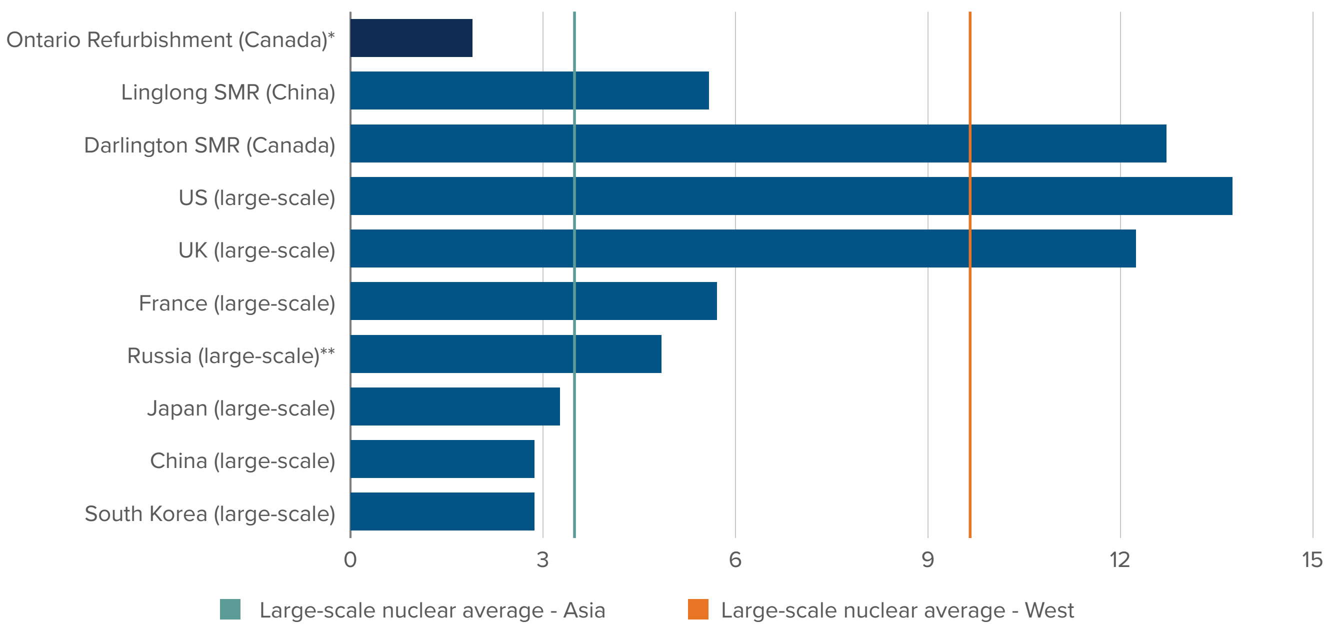
Large scale reactors

Large scale reactors vary in size, but they are generally around 1,000 megawatts — enough to power about 500,000 homes. For operating efficiency, multiple reactors are often clustered together in large power plants. In the West, these plants were mostly built in the 1960s, 70s and 80s. Since 1990, just six reactors have come online in the US, with only a few more in Europe. The last US reactors commissioned are called Vogtle 3 and 4, based in Georgia. They came online in 2022 and 2023 respectively — about 15 years after construction began. Together, the two units ended up costing over $30 billion USD,[5] or $13.6 billion USD/GW.

Hinkley Point, in South-West England, provides more evidence that Western nuclear is simply too expensive. The 3.2 gigawatt (GW) plant began construction in 2016. Originally scheduled to open in 2025, the commissioning date has drifted to 2031. While the estimated cost has soared from £24 billion to £46 billion,[6] or £14.3 billion/GW.

Note: on July 22nd, the British government announced a new 3.2GW nuclear plant at an estimated cost of $70.1 billion CAD.

FIGURE 1 – Average nuclear construction costs by country/project (2000-2023)
(in millions of $USD/MW)

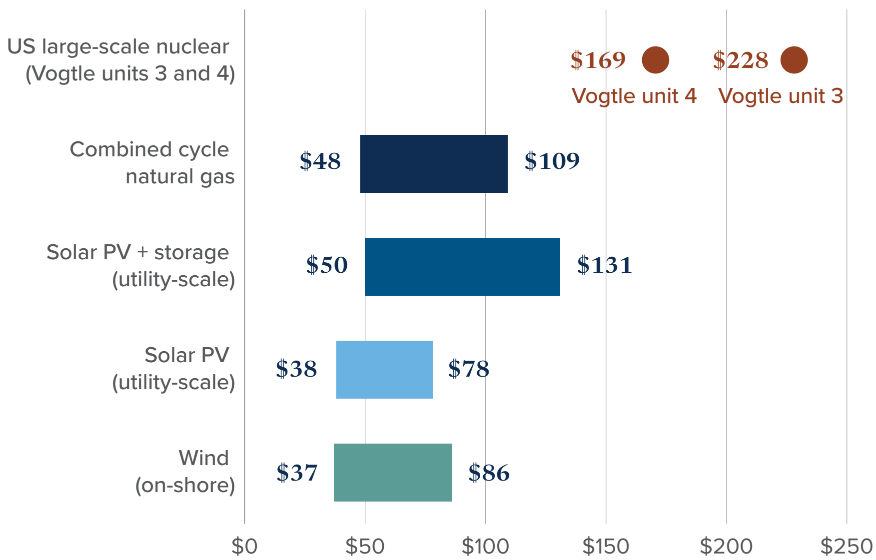


* Figure reflects a combined ~$26B CAD cost for Bruce and Darlington refurbishments across ~10 GW of capacity.
** Russia average reflects Greenchip's estimate based on data for Rosatom-led large-scale nuclear reactor builds in Russia (Novovronezh II), Turkey (Akkuyu), Egypt (El Dabaa), and Bangladesh (Roopur).

Sources: Britain Remade, The Economist. World Nuclear Association

To put these figures into perspective, we estimate it costs about $1 billion USD to build a gigawatt of large scale solar, $2 billion for a combined cycle gas plant, and $2-3 billion to build a 1 GW onshore wind farm. But construction costs are only part of the equation. To compare the economics of power, our industry uses a concept called Levelized Cost of Energy (LCOE), which calculates the total cost of producing electrons over the lifetime of an energy producing system. Assumptions are required, but LCOE is a much better way to compare the economics of generating technologies than capital costs alone. Annually, Lazard Freres publishes a well-regarded LCOE report (see Figure 2). Nothing in their recent reports suggests that a nuclear renaissance is around the corner.

FIGURE 2 – Levelized cost of energy (LCOE) comparison for generation technologies
(Range in USD/MWh)



Source: Lazard 2025 LCOE Report.

So, what can the West learn from the East to build reactors more quickly and at a lower cost? Greenchip has identified four key factors:

- First, countries like South Korea and China **use replicable designs** instead of the one-off, bespoke plants we build in the West.
- Second, they have **much shorter permitting approval timelines.**
- Third, public safety concerns in the 1950s and 60s led to over-engineered safety requirements in the West that don't always make reactors any safer — Asia uses **more pragmatic science-based specifications.**
- Finally, since the **development of nuclear plants in Asia is continuous**, equipment and other costs are optimized, and expertise is not lost.

A quick guide to MW vs. MWh

A MW (megawatt) is a measure of capacity, or how much electricity a power plant can produce at any given moment. Construction costs are typically quoted in $/MW.

A MWh (megawatt-hour) is a measure of energy generated or consumed over time. Electricity prices and LCOE are often compared in $/MWh (the cost to produce one unit of energy over time).

Why we need both:

- $/MW helps compare how expensive a plant is to build.
- $/MWh tells you how expensive its electricity will be to produce and sell.

The biggest cost in nuclear plant construction is financing. As such, shrinking the development timeline is the easiest way to reduce overall costs. In that light, addressing the four factors described above provides a more certain path to improved economics for the West. We seem more focused on technological breakthroughs or grand executive orders — this is a mistake.

Small modular reactors

Interestingly, the promise of improving small modular reactors (SMRs) economics largely falls on the same four factors. An SMR is loosely defined as a reactor between 100MW and 300MW in size — smaller than traditional reactors but not as small as the name implies. To date, Greenchip has identified over 50 SMR companies, most of them private. Some employ unconventional technologies, most claim significant economic, operating and safety improvements over large scale. While some of these startups have already failed, we should hope at least a few will eventually succeed.

In our 2022 nuclear note, we highlighted the potential for cost effectiveness given the simpler, standardized and repeatable modular designs of SMRs. Some technologies, like using thorium for fuel and/or using molten salt instead of heavy water or graphite to control reactions, look promising on paper. Site flexibility, given that SMRs may theoretically require less real estate than traditional nuclear, is another attribute. Nevertheless, the first series of SMR developments so far suggest competitive economics remains elusive.

In January of 2025, the IEA estimated that SMRs need to reach a $4.5 million USD/MW price point to see rapid global uptake.[7] If you believe the numbers, China has come closest to this threshold. The Linglong One SMR cost about $5.6 million USD/MW,[8] about 20% above the IEA's stated tipping point.

Other countries are further away. For example, Argentina is building an SMR called the CAREM-25. It is significantly delayed with an estimated final cost of $15 million USD/MW.[9] Ontario Power Generation (OPG) in Canada has one of the most ambitious SMR projects in the world. OPG plans to install four GE Hitachi BWRX-300 SMRs, for a total capacity of 1.2 GW. These are traditional boiling water reactors, about a third of the size of Vogtle's. Unit 1 is estimated to cost $6.1 billion CAD. While this figure includes about $1.6 billion CAD of infrastructure costs that could eventually be shared with the final three reactors, the most recent estimate of total project cost is a whopping $20.9 billion CAD.[10] That would be approximately $13 million USD/MW.

There is not much evidence yet that SMRs can be built much faster than large-scale reactors. Developments in China, Russia and Argentina, originally projected to have three- to four-year construction timelines, are now estimated to take 12-13 years to complete.[11] Elongated timelines are kryptonite to final project costs.

We acknowledge that these are "first-of-a-kind" projects, and as such, they should take longer and cost more to build. Mass production, efficient installation, and technological innovation promise that economic viability is theoretically still achievable, but we're not there yet.

Nuclear refurbishment

While much of the recent market enthusiasm has been directed towards new nuclear development, reactor refurbishment may offer the best return on investment in the sector today. Rebuilding existing reactors is both low risk and cost effective. Recent datapoints from the Ontario refurbishment program support this conclusion. Cost estimates for refurbishing the six reactors at the Bruce Power Plant are firming around $1.45 million USD/MW.[12] While the four reactors being refurbished at Darlington are now estimated to cost about $2.7 million USD/MW.[13] This is approximately one-fifth of the cost of building Vogtle or the Darlington SMRs on a per MW basis. And these refurbishments should buy Ontario another 30 years of plant operation. Considering the age of the global fleet, the refurbishment opportunity looks extremely attractive to us. It also reinforces our long-standing view that nuclear, despite its challenges, has a role to play in the energy transition.

Investment opportunities in nuclear

In 2008, Greenchip decided to include nuclear power generation in our investment universe*. It was not an easy decision. Nuclear had been the target of environmentalists for decades. We still have not solved the waste problem (other than burying it) and there is always the potential for a catastrophic event. Weighing the environmental benefits of transitioning fossil combustion to low carbon electrification, the need for baseload power to enable more wind and solar, and the relatively impressive safety record of nuclear, we concluded that some nuclear was warranted.

With that decided, where would we want to invest? The front end of nuclear power stack includes uranium producers and processors. Once built, reactors require constant inspection, maintenance work and increasingly refurbishment. At the back end, spent fuel gets reprocessed and/or requires waste management services. At some point all reactors need decommissioning. All these points of contact provide investment opportunity.

As is often the case for our team, Greenchip finds better risk-adjusted return opportunities in the so-called "picks and shovels" — equipment and other derivative plays that enable nameplate technologies like nuclear to work. Currently, we hold **Kazatomprom**, the most efficient and lowest cost uranium miner in the world. We have three construction and engineering firms in the portfolio, two of which have contracts along the nuclear value chain, including refurbishment: British-based **Balfour Beatty** and Canadian-based **Aecon**. **Hitachi**, another one of our holdings, designs both large- and small-scale nuclear reactors, while **Neo Performance** is involved in the processing of the precursor material in nuclear fuel rod manufacturing. Our best-performing stock over the past two years, **Siemens Energy**, is more concentrated in gas and wind turbines and transmission equipment, but some of its products find their way into nuclear plants. Our largest holding, **Veolia**, has a significant nuclear waste management business. Finally, we have **three copper miners**, whose product is essential for generator turbines and electric cables throughout.

In all, **10 of the current 42 portfolio holdings** in the Mackenzie Greenchip Global Environmental All Cap Fund have exposure to the nuclear supply chain.

We like our peripheral exposure to nuclear power. A full-blown nuclear renaissance would be great for several Greenchip holdings, but attractive business outcomes are possible without one. There are over 50 companies in Greenchip's investment universe with exposure to nuclear and we will continue scouring opportunities in this space.

Why we should all root for nuclear alongside other low carbon electricity technologies

From 2000 to 2023, global power demand grew consistently at just under 3% a year — most of that was in emerging markets. This changed in 2024 when global power demand took a notable step up. Most energy think-tanks now believe 4% annual growth is the new norm.[14] We concur. Industrial electrification, electric heating and cooling, electrified transportation and, of course, AI, all have voracious power requirements. Four percent may not seem like much, but it means **electricity supply needs to double in less than 20 years**. This is a monumental challenge for us all. It took the world 125 years to build the existing electricity system and much of it is already past its operating lifespan. No one technology can meet the scale of this challenge. As such, we should thank President Trump for his nuclear support, yet at the same time, we can admonish him for undermining other low carbon technologies — the Republican Party's energy policy looks incredibly short-sighted to us. The drivers of the "great" energy transition are apolitical.

* The Greenchip team's proprietary investment universe consists of approximately 2,000 companies that meet its investment criteria and are actively evaluated for potential inclusion in the portfolio.

A concluding note on fusion – the nuclear dream that remains decades away

Fusion, the forcing together of light atoms, typically isotopes of hydrogen, to release energy in a controlled environment (versus the splitting of heavy atoms) has remained the pipedream of the nuclear industry for decades. In late May, members of the Greenchip team met with a professional engineer who had spent the last five years focused on advanced fusion. His ability to simplify the incredibly complicated science behind fusion technologies was, well, genius.

This is how he described the current state of fusion: "There are six key milestones[15] we need to overcome for fusion to be commercialized. The first five are technical, the last is economic – can we produce power at competitive prices? To date, we have been able to overcome only a few of them. But it's a bit like the game of whack-a-mole. Achieve one milestone, like neutron containment, and the others become impaired."

It was a fascinating lunch. In the end, we concluded that overcoming all six milestones concurrently was unlikely in our lifetimes. Fusion is an investment opportunity best left to big government and the bravest of venture capitalists.

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