Can China break the 'cost curse' of nuclear power?

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Abstract

Escalating construction expenses threaten to derail global progress on atomic energy. China offers lesson on how to rein in costs.

Keywords—nuclear power, cost curse, China

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Can China break the 'cost curse' of nuclear power?

Once again, the world is betting on nuclear power. The United States aims to quadruple its nuclear capacity by 2050, and more than 30 countries have pledged to triple global capacity by mid-century. China has more than 30 reactors under construction, and France has announced plans to build 14 reactors. Technology giants, including Amazon, Google and Microsoft, are also investing in nuclear to power their energy-hungry data centres and lower their carbon emissions.

A central challenge remains: can development be done at a manageable cost? Historically, the industry has faced a 'cost escalation curse'(Rangel and Lévêque 2015; MIT 2018; Grubler 2010; Lovering, Yip, and Nordhaus 2016). Building more nuclear reactors has led to higher, not lower, costs per watt (see Figure 1), hampering their economic viability. By contrast, for solar and wind energy, mass production and steady technological improvement have driven costs down (Elia et al. 2020; Nemet 2019).

The cost of building nuclear power plants can soar because of a lack of standardized designs, rising material and labour costs, evolving regulations and technical complexity (Eash-Gates et al. 2020). But is this cost escalation inevitable? Here, we show that tailored regulations and policy can reverse the trend. Decades of nuclear energy development in China demonstrate that construction costs can be brought down through a combination of stable regulations and efforts to strengthen domestic supply chains.

China's success in curbing costs

Over the past two decades, China has been the main country to substantially and consistently expand its nuclear fleet, to 58 operating reactors in 2024. Since 2022, the

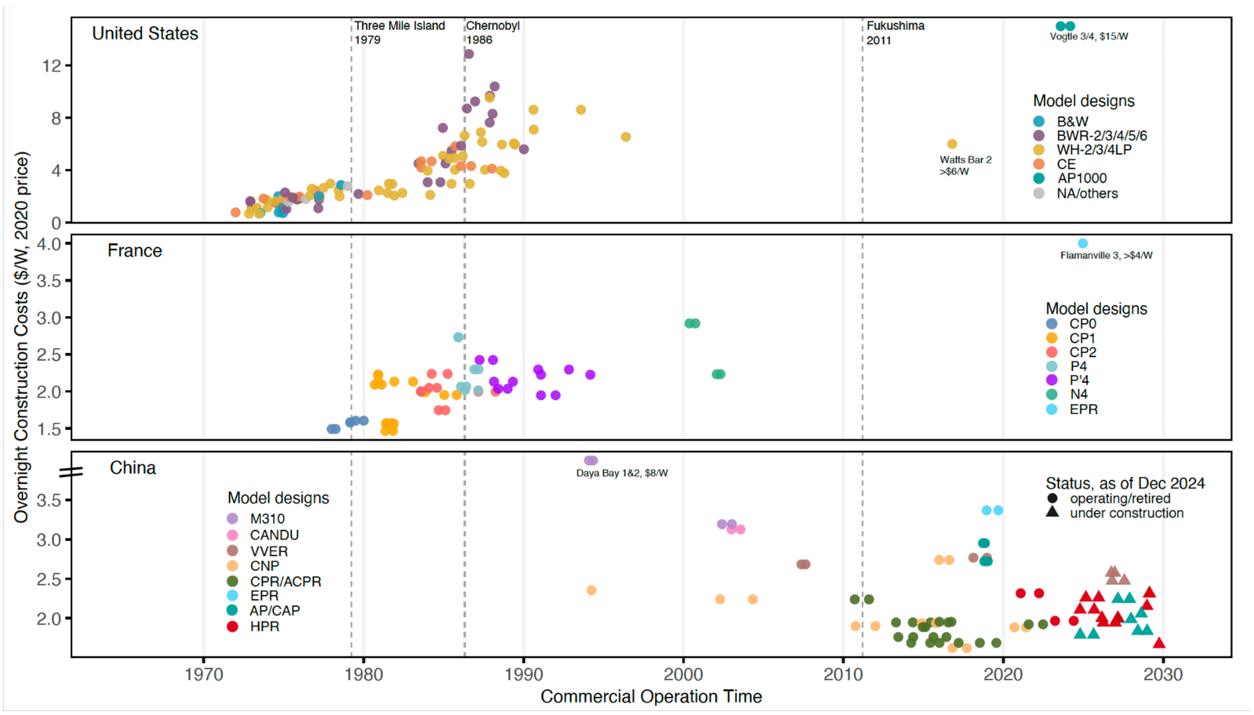

Figure 1: China has managed to rein in the expenses associated with commercial nuclear units. US nuclear costs rose sharply, in particular after the Three Mile Island accident in 1979, owing to a lack of standardization, rising labour and material costs and stricter regulations. Costs also increased in France as the country moved to larger and more complex reactor designs. Overnight construction costs are the cost of building a project as if it were completed overnight, without taking financing costs (interest during construction) into account. All costs are converted to their equivalent 2020 value. Direct cross-country cost comparisons should be interpreted with caution because of differences in exchange rates and inflation.

government has been approving around ten new reactors each year, putting China on track to surpass the United States and become the world's largest holder of nuclear power capacity by 2030. State-affiliated research centers have outlined a goal of quintupling China's current nuclear capacity by 2050.

We have compiled and analyzed a dataset on the construction costs of nuclear power plants in China using a wide range of publicly available sources. We focus on the cost of construction, because operating and fuel costs are relatively low and have remained stable (Grubler 2010; Dawson and Sabharwall 2017).

Our findings are striking. Whereas construction costs increased substantially between the 1960s and 2000s, by around tenfold in the United States and by at least twofold in France, they had halved in China by the early 2000s and have remained largely stable since.

Various strategies were used to keep technological costs down, such as building larger plants for scale efficiency and leveraging accumulated experience. But these alone fail to fully explain the cost reduction trend observed in China. Instead, The country has managed to contain nuclear costs through strategic development of domestic supply chains, stable regulatory frameworks, state-backed incentive policies, and effective construction management.

The key driver of cost reduction has been China's deliberate effort to build domestic capacity in civil nuclear power, which unfolded in three stages. From the 1990s to 2005, China imported foreign reactors to deploy immediately while gradually producing simple, conventional components domestically and using Chinese firms for civil engineering and construction to reduce costs. At the same time, it began researching and developing its own reactor design based on a French technology.

Between 2005 and 2010, these efforts to localize production advanced to include more complex, safety-critical components such as reactor cores. China ramped up capacity, building about 30 reactors using two domestically developed model types. After the Fukushima nuclear disaster in Japan in 2011 China accelerated the adoption of advanced safety features by collaborating with partners from the United States and France, while developing its own indigenous advanced reactor models.

Substituting expensive imports with domestically produced components substantially reduce cost (see Figure 2). Some Chinese-made nuclear components, such as tubes, ring cranes and charging pumps, cost half as much as their imported equivalents. However, for countries that import their nuclear technologies, domestic supply chain building must be strategic. For example, South Korea adopted a similar approach to China, which led to cost reductions (Lovering, Yip, and Nordhaus 2016; Sung and Hong 1999). By contrast, around the 1980s,France deviated from the tried-and-tested US reactor design in favour of a national version, which hindered standardization and caused construction costs to soar (Kavlak, McNerney, and Trancik 2018).

China's regulatory structure and policy environment also play an important part. A consistent, state-backed industrial policy has provided stable electricity tariffs and low-interest financing for state-owned nuclear power companies. Its centralized nuclear governance structure helps to ensure regulatory stability and coordinates reactor standardization across the country.

China's vast and expanding electricity market provides certainty for long-term demand and has driven investments in domestic nuclear power supply chains and workforces. The nation's high labour productivity and its abilities to "hire quickly, produce quickly,

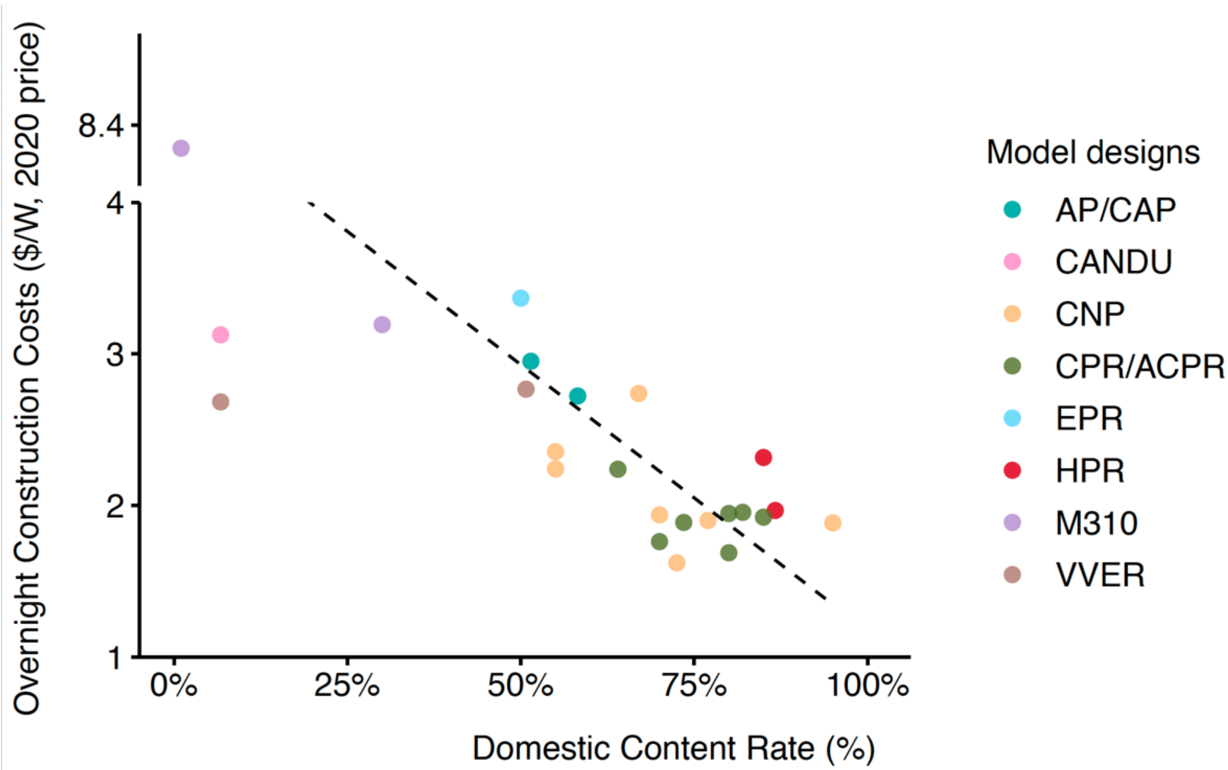

Figure 2: The effect of indigenization (domestic content rate) on unit overnight construction costs of Chinese operating nuclear power plants. Each dot represents a nuclear power plant (including multiple units), as costs and domestic content rates are typically reported at this level. The dashed line represents the fitted linear regression of domestic content rate against unit overnight construction costs.

and improve quickly"(Nemet 2019) have enabled effective project management. As a result, reactors in China are typically built in five to six years -–about half the time it takes in France or the United States.

Harmonize policies and standards

To jump-start further development of global nuclear power, efforts must to beyond today's asprational declarations. As the Chinese experience shows, concrete, long-term commitments to nuclear energy are needed alongside national clean energy targets. Such commitments needed to be backed by stable regulations, government subsidies and financing tools, and by long-term price certainty through mechanisms such as power purchase agreements–contracts between a power supplier and a buyer at an agreed price (Berthelemy et al. 2020).

The research community, industries and governments must work together to better understand the complex interplay between standardization of components, localization of supply chains and regulatory oversight. This should be informed by more transparent data, empirical evidence, and global best practices.

A stable, harmonized safety and licensing framework is essential to reduce regulatory uncertainty, and to gain public support. Safety remains a paramount concern for nuclear energy. Although accidents have become less frequent, the threat of a Fukushima-scale disaster persists (Wheatley, Sovacool, and Sornette 2017). Such an event could derail nuclear ambitions at a crucial moment for climate action.

Internationally, countries that export nuclear technology should collaborate with importing ones to identify components that can be manufactured locally and to invest in workforce training. The International Atomic Energy Agency can support entrants by sharing best practices and streamlining regulatory approaches, enabling timely and cost-effective deployment while maintaining safety standards, ensuring that nuclear technology is used only for peaceful purposes, and managing radioactive waste.

As countries rush to expand nuclear capacities, they must combine affordability with safety, scalability, investor confidence and public trust. Without this, nuclear power will remain an expensive bet the world can ill afford.

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