Singapore's Energy Dilemma: Would the Nuclear Option Help?

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Singapore's Energy Dilemma

Singapore's economic health hinges on two crucial imported resources—water and energy. While the importance of the first is seared in the public mind, the criticality of the second is appreciated only by a few. A disruption to our energy supply would have dire consequences on our economy as well as our defence capability.

More than 95 per cent of every joule of electricity is derived from natural gas. Of that, only a small proportion is transported here by LNG tankers. The bulk is piped from Indonesia and Malaysia. The existential threat of the latter has hardly been aired in public. Is the supply chain robust? Technical mishaps, sabotage, depletion of gas deposits, market pressures, and political backlash, resentment and discord with our neighbours next door are all potential threats.

Indonesia, Southeast Asia's largest economy, has morphed from an exporter to a net importer of oil. It is expected to be a net importer of natural gas by 2020 according to a 2017 article in Reuters. Malaysia inked a US$25 billion agreement to sell liquefied natural gas to China for 25 years. It also reached an agreement in October 2017 to sell 2.5 million tonnes of the same to Japan annually. The world's second and third largest economies are soaking up fossil energy like a sponge right at our doorstep. The prospect of one, if not both, pipelines running dry by about 2020 is too serious to ignore.

Singapore is constrained by a number of factors, which reduces the viability of solar and wind as baseload alternatives. The truth is that we cannot overly rely on these baseline alternatives. Instead, we need to take a quantum leap for energy diversification.

Our 193 km of shoreline is practically fully developed. Finding waterfront land to build more LNG gas terminals safely has become a challenge. The western shorelines where most of the power plants are sited are close to capacity, while the northeast coast line is too close to population centres as well as Changi Airport.

Gas cannot be easily stockpiled. It requires large tracks of land, even if below ground, making it impractical as a strategic reserve for a small city-state. This lack of a strategic reserve compromises the country's defence capability.

We need to accelerate our pace towards nuclear energy. The path to a nuclear power capability is long. Even if the government gives the thumbs up, it would be at least a decade before the first nuclear power plant comes online. "Let's wait for new nuclear technologies" is a common refrain even among experts. Although China and India have invested heavily in nuclear innovations, these new technologies are still in the experimental phase, and will take 10 years or more before commercialisation.

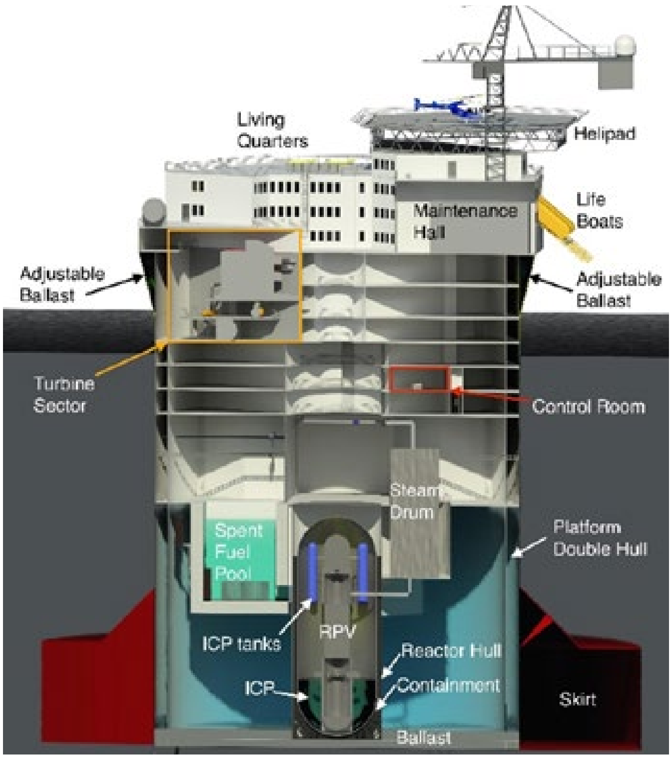
Every year of delay towards energy independence is a year of exposure risk to our economy. Fissile material is much more easily stockpiled than gas, and that enhances the resilience of our economy as well as our defence capability in a prolonged war.

There is a potential solution, which we believe has not been fully considered—an offshore nuclear power plant. The Massachusetts Institute of Technology (MIT) has worked on it for some years and one of the co-authors of this essay, Professor Jacopo Buongiorno, had shared it in a public talk supported by The HEAD Foundation on 16 January 2018, at the National University of Singapore.

Offshore Nuclear Power Plant

MIT's Offshore Nuclear Plant (ONP) concept offers the potential of a new, economically attractive model for construction, siting, operations and decommissioning of nuclear plants, which could be particularly suitable for application to Singapore.

▲ **Figure 1:** The proposed offshore Floating Nuclear Plant structure. Source: MIT News



▲ **Figure 2:** The nuclear reactor and related safety systems of the proposed offshore Floating Nuclear Power Plant. Source: MIT News

"The **truth** is that we **cannot overly rely on** these **baseline alternatives**. Instead, we **need** to take a **quantum leap** for **energy diversification**."

This concept integrates a nuclear reactor within an offshore platform. Several features produce an attractive design. First, the ONP can be entirely constructed in a shipyard and then towed to the site, where it can be anchored off the coast. The plant is connected to the grid via an underwater AC transmission line, such that the only structure on land is the electric switchyard. Therefore, land usage is reduced to virtually zero, making it particularly suitable for land-scarce countries like Singapore. Second, the ONP reactor is below the water line, with easy access to the ocean heat sink; the system is designed to require no external intervention in order to maintain reactor cooling during all postulated accidents, including a prolonged station blackout. Therefore, a Fukushima-type scenario is not possible. Third, the ONP's main structure is a simple cylindrical, partially submerged rig, with a low centre of gravity, offering an excellent compromise between cost and robustness with respect to waves, wind, collision and blast. The ONP concept can accommodate virtually any reactor and power cycle designs, with modifications to the size of the platform.

MIT is now developing the ONP-300, featuring a relatively small reactor designated according to its electric power rating of 300 MW. The water-tight underdeck hosts the reactor, the control room, the spent fuel pool, and other necessary facilities. The steam cycle, equipped with a standard steam turbo-generator, and the crew's living quarters are located right below the main deck. Cooling water is drawn from the bottom of the ocean and discharged slightly above ambient temperature at the surface.

The ONP design aims to exploit the advances and experience in the construction of large offshore structures in the oil and gas industry and naval shipyards. The shipyard model potentially allows decreasing construction time and cost compared to standard nuclear power plants. This fact is crucial in light of the need to reduce the capital cost of nuclear projects. Also, decommissioning is done in a centralised shipyard (just as it happens for the US Navy nuclear submarine and carrier fleets) so that the site can be returned to "green field" conditions after the platform is towed away. The ONP platform's weight and size are well within the capabilities of modern shipyards in Singapore and worldwide. Compared to terrestrial plants, the ONP concept eliminates about 95 per cent of the concrete used in a conventional nuclear power plant, thus reducing cost and removing a major potential source of delays during construction.

Concluding Remarks

The benefits of adopting nuclear energy to Singapore are numerous and substantial: (i) the electricity supply would become more reliable, resilient to disruption and independent of fossil fuel supplies from neighbouring countries; (ii) electricity prices would be stabilised for decades; (iii) the entire freshwater demand of Singapore could be met with desalinated water using a single 300-MW nuclear plant[1]; (iv) if all of Singapore's cars were converted to electric vehicles, their energy demand could be covered with only one more 300-MW nuclear plant[2]; and (v) the amount of CO_2 emissions into the atmosphere could be drastically reduced, thus making Singapore a leader in the fight against global warming.

In the longer term, Singapore could use nuclear energy also to generate hydrogen for fuel-cell cars or industrial processes. Lastly, if the ONP design were adopted, the construction of ONP platforms would constitute a sizeable business opportunity for Singapore's shipyards.

There are of course also challenges. For example, siting the ONP platforms away from shipping lanes and ensuring their security will not be trivial. Short- and long-term solutions for management of the high-level radioactive waste produced by the nuclear plants would have to be identified.[3] The development of an independent and effective nuclear regulatory agency, which will oversee the nuclear programme and provide the public with the confidence that nuclear risks are properly managed, will take time. Public acceptance itself will require strong engagement and transparent decision-making; in particular the benefits of nuclear will have to be weighed against its challenges in the public debate. ■

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1 This assumes a water demand of 1.7 million m3 per day and a reverse osmosis process operating at 3.5 kWh/m3.

2 This assumes 9.45 billion km travelled per year with an electric vehicle operating at 5.4 km/kWh.

3 Robust technical solutions (such as dry casks and underground repositories) are available. The primary challenge will be to design a licensing process that is socially acceptable.