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Is Fusion Energy Proliferation Resistant?

By Alvin Chew and Andrew Ngo

SYNOPSIS

Nuclear fusion does not use or produce fissile materials, making it largely resistant to weapons proliferation and exempt from IAEA safeguards. However, tritium (used in fusion fuel) is subject to export controls. As fusion energy moves toward commercial deployment, Southeast Asia must engage early in evolving global regulatory frameworks.

COMMENTARY

Nuclear fusion, touted as the "holy grail" of clean and limitless energy, has made significant strides in recent years, with commercial deployment now considered a realistic prospect in the coming decades. Fusion energy promises to be different from its more contentious counterpart, nuclear fission, in that the former is believed to offer higher energy density and produce less hazardous waste. More importantly, fusion does not use or produce fissile materials, such as enriched uranium or plutonium, that serve as the primary materials for nuclear weapons.

Fusion, as a form of nuclear energy, will fall under the authority of the International Atomic Energy Agency (IAEA), which ensures that all nuclear technologies and applications are used solely for peaceful purposes. The IAEA Statute, which entered into force in 1957, was primarily established to promote the peaceful uses of nuclear energy. The IAEA was subsequently designated as the nuclear watchdog under the Non-Proliferation Treaty (NPT) framework, responsible for ensuring that all parties comply with their non-proliferation commitments.

With the urgent need to commercialise fusion energy, countries are looking for solutions to do away with the onerous safeguard protocols of the IAEA, or at the very least, develop novel regulatory approaches that will lead to the rapid deployment of fusion energy.

Nuclear Fusion Unlikely to be Weaponised

Under the NPT, every non-nuclear weapon state (NNWS) needs to complete safeguard agreements with the IAEA to establish protocols to account for nuclear materials in all their facilities. This was done on the understanding that the nuclear fission fuel cycle, either uranium or thorium, will produce fissile materials that can be used in nuclear warheads. As such, the Nuclear Suppliers Group (NSG) has a trigger list that places such fissile materials under international safeguards.

This is not the case for fusion, however. A fusion reactor does not produce any fissile materials. While it is theoretically possible for fusion to generate sufficient neutrons to produce fissile materials, this could only occur in a specially designed facility intended for that purpose. The normal fusion process, which takes place in a vacuum, does not carry the risk of generating fissile materials. Therefore, the IAEA released its first version of the *World Fusion Outlook* in 2023, which summarised that a fusion system does not utilise or produce fissile materials, and is therefore not subject to IAEA safeguards.

Tritium: A Controllable but Controlled Fuel

The fusion process entails using two light isotopes of hydrogen to produce energy, whereby the most efficient is the deuterium-tritium combination. Deuterium is abundant and can be readily extracted from seawater. In contrast, tritium is a radioactive isotope that exists only when cosmic rays interact with gases. Furthermore, its relatively short half-life of approximately 12 years means that tritium inventories diminish significantly over time through natural decay into helium-3.

The challenge in using tritium lies not in its scarcity but in its sourcing. The largest inventory of tritium comes as a by-product of pressurised heavy water reactors (PHWRs), a reactor technology that poses a proliferation risk. The international community considers the limited quantities of tritium from PHWRs manageable, given that fusion reactors are designed with a ‘breeding blanket’. Once ignition is achieved, the process is expected to be self-sustaining, as neutrons captured by the blanket breed additional tritium.

Tritium is not used directly in the making of nuclear bombs, but it is used to boost the yields in nuclear weapons. Hence, tritium is a tightly controlled product under national regulations and export control framework. Although fusion systems are exempted from the IAEA safeguards, the use of tritium as a fuel comes under Part 2 of the Nuclear Suppliers Group (NSG) Trigger List for export control of dual-use technologies.

Alternative Fuel Combination

To eliminate the use of radioactive tritium in fusion, some companies are looking at an alternative deuterium and helium-3 fuel mix. Unlike the conventional deuterium-tritium reaction, a deuterium-helium-3 reaction does not produce high energy neutrons that will generate fissile materials. However, this alternative combination is less efficient than using tritium as a fuel. Therefore, the deuterium-helium-3 combination will require significantly higher plasma temperatures compared to the favoured deuterium-tritium mix. As such, it poses a more challenging environment for fusion to take place in the reactor.

Another major hurdle is that helium-3 is exceptionally scarce on Earth. Therefore, fusion companies like Helion Energy will need to engineer their own supply of helium-3. While the Moon holds an abundance of helium-3, which lunar startups like Interlune aim to harvest, extracting resources from space remains economically and technologically speculative.

Implications for Southeast Asia

Although fusion systems are exempt from IAEA safeguards, it is very likely that tritium fuel will be subject to export control by the NSG. All countries in Southeast Asia are NNWS of the NPT and therefore, need to enter into safeguard agreements with the IAEA when importing tritium fuel. This could impinge on the prospect of full-scale commercialisation for fusion energy in the region.

The NPT serves as the cornerstone of the non-proliferation regime, providing the normative foundation on which bodies like the NSG operate. The safeguard mechanisms of the nuclear industry rely on the robustness of this multilateral export control regime. Southeast Asia has been a late entrant into the civilian nuclear fission market and has had to operate within the NSG framework accordingly.

For fusion, the field is still relatively nascent. If the region intends to establish a recognised position in the global fusion industry, it needs to engage with the NSG now, while global policy frameworks are still being shaped. For example, Singapore has recently announced a strategic agreement with Commonwealth Fusion Systems (CFS), a global leader in fusion energy, to develop technologies for a commercial fusion power plant. Singapore has also positioned itself as an Artificial Intelligence (AI) and supercomputing hub which will help to accelerate the realisation of fusion energy in the areas of materials, manufacturing and diagnostics. At this developing stage, it needs to engage in international discourses on the regulatory approaches for the type of fuel combinations to be used commercially.

Conclusion

Nuclear fusion offers a promising, cleaner energy source that falls outside traditional IAEA safeguards, as it neither uses nor produces fissile materials. However, export controls on tritium fuel could constrain commercial deployment for states without early access to evolving regulatory frameworks. For Southeast Asia, the window to shape, rather than merely accept, the global rules governing fusion energy is open now, but will not remain so indefinitely.

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