Chapter 6: Conclusion

Fusion energy, the power of stars, has the potential to revolutionise energy production and to play a significant role in combatting the climate crisis. By fusing the atomic nuclei of the hydrogen isotopes deuterium and tritium, future fusion power plants may produce tremendous amounts of energy without the production of greenhouse gases from a virtually unlimited source of energy. As such, fusion might play a significant role in mitigating climate change, the most pressing topic of this century. While fusion has yet to escape research facilities, both government-funded and private-funded projects are underway to achieving the goal of commercially available fusion energy within the next decade or two.

As fusion is a nuclear technology, it has applications in nuclear weapons programmes as it can play an auxiliary role. Fusion's proliferation potential is significantly lower compared to fission, but the risk is non-zero. Fusion can play a role in nuclear weapons programmes in three aspects. Firstly, a State may use a fusion reactor to produce fissile material for the fission part of nuclear weapons. As fusion reactions yield neutrons, which can be used to convert ^{238}U, the most abundant isotope of uranium (which is of no use for fission reactors and weapons), into ^{239}Pu, or the thorium isotope ^{232}Th into ^{233}U. Both materials can be used in nuclear weapons.

Secondly, modern nuclear weapons are multi-staged devices that utilise the energy released by a combination of fission and fusion reactions. The integration of deuterium-tritium fusion reactions in weapons increases the yield significantly and allows for the miniaturisation of weapons, making a variety of deployment systems possible, such as intercontinental missiles. The commercialisation of fusion power plants will increase the annual tritium production by many orders of magnitude, thereby increasing the availability of this crucial component of advanced nuclear weapons.

Thirdly, one specific fusion technology, namely laser-fusion or inertial confinement fusion, is currently only researched in military research facilities. The aim of these facilities is to simulate and to better understand the processes that take place within a thermonuclear weapon. These facilities were constructed with the purpose of replacing nuclear testing. The entry of inertial confinement energy into a commercial scale might lead to the spread of knowledge of the functioning of thermonuclear weapons, thus potentially facilitating the development in NNWS. It is the task of nuclear weapons law to allow for harvesting the benefits of the use of fusion energy, namely the potential to tackling the climate crisis, while at the same time preventing the further proliferation of nuclear weapons.

The international regime of nuclear weapons law intends to prevent or reverse the use of nuclear technology in nuclear weapons. Its sub-regimes of non-proliferation and disarmament comprise a number of institutions, treaties and other international instruments, with the aim of either preventing the further spread of nuclear weapons or prohibiting them. The regime seeks to enable the economic use of nuclear energy while at the same time limiting the risk associated with dual-use technology.

As nuclear weapons have demonstrated their destructive potential in two uses of nuclear weapons in Japan on 6 and 9 August 1945, in addition to the well over two thousand nuclear tests conducted since then, the destructive capacity and the security risks of nuclear weapons are irrefutable. Nevertheless, the possession of nuclear weapons plays a pivotal role in the geopolitical landscape, serving to perpetuate a hegemonic system and to extend the sphere of influence through nuclear coercion and nuclear deterrence.

In light of the threat to peace and security posed by both the possession and the further spread of nuclear weapons, States have almost universally vested a number of institutions with a significant level of authority through various international treaties. At the core of the non-proliferation regime is the 1968 Nuclear Non-Proliferation Treaty (NPT) and the International Atomic Energy Agency (IAEA). The NPT permits five States, namely the United States, the United Kingdom, Russia, France and China, to possess nuclear weapons, while all other non-nuclear weapon states (NNWS) are prohibited from possessing or developing nuclear weapons. In addition, the NPT includes provisions on technical assistance and on nuclear disarmament. The IAEA is entrusted with the responsibility to verify the compliance with the NPT by administering safeguards to nuclear material and nuclear technology. All NNWS have concluded Comprehensive Safeguards Agreements (CSA) with the IAEA, thereby specifying the extent of the Agency's authority. Furthermore, the majority of States has also concluded an Additional Protocol, thereby extending the IAEA's authority further, following the discovery of Iraq's clandestine nuclear weapons programme in the 1990s.

Moreover, there are further regimes specifying obligations with regard to non-proliferation and disarmament. In Europe, Euratom, in its capacity as a common supplier of nuclear material for peaceful uses, is subject to its own non-proliferation obligations and safeguards regime, which acts complementary to the IAEA. In addition, the majority of States, covering the majority of landmass on Earth, signed regional nuclear weapon-free zone (NWFZ) treaties which prohibit nuclear weapons and nuclear weapon related activities. Additionally, the Treaty on the Prohibition of Nuclear Weapons (TPNW) prohibits nuclear weapons for and in all of its State Parties. All of these treaties include a specific verification regime, but they are mostly based on the IAEA system. As all treaties refer to the IAEA's safeguards system, this regime is at the centre of nuclear non-proliferation law.

Safeguards are further complemented by export control regimes. These regimes are based on soft law instruments and are agreed upon in two intergovernmental fora: the Zangger Committee and the Nuclear Suppliers Group.

With regard to fusion, the regime of nuclear weapons law fails to reach its goal as there is a gap in its application to fusion. The regime intends to prevent the use of nuclear technology for nuclear weapons, yet the verification regime is largely inapplicable to fusion technology. As the NPT and the IAEA's safeguards system are focused on source and special fissionable material in fission facilities, the treaty provisions do not apply on verifying fusionable material or fusion facilities. The existing regime only applies to verifying the absence of fissile material in fusion facilities by environmental sampling and complementary access, if a State has adopted the Additional Protocol. As the verification mechanisms for non-nuclear weapon states in nuclear weapon free zones and TPNW Member States do not require the implementation of the Additional Protocol, there are further gaps in these regimes. Furthermore, safeguards under the Euratom Treaty do not apply to fusion as well. While export control regimes cover material used in fusion, the procedures required for exports do not match the intent as they require IAEA safeguards, which are largely not applicable to fusion. There are significant gaps between the regime's objective and its application to fusion.

Given the gap between the objective of the regime and the application of its verification mechanisms, there are several options for adapting the framework for its application to fusion. These approaches vary in terms of their legitimacy, effectiveness and proportionality.

Evolutionary interpretation by the IAEA's Secretariat of the term *facility* allows for the application of existing safeguards to fusion facilities in order to verify the absence of fissionable material, addressing one of three proliferation concerns. However, as the legitimacy of this interpretation might be questioned by States, a path to increased legitimacy are measures by different institutions. They might include decisions and actions by the IAEA's Board of Governors, the IAEA's Secretariat, decisions by NPT and TPNW Review Conferences and Meetings of State Parties, actions by UN organs such as the General Assembly and the Security Council as well as the Nuclear Suppliers Group. Each institution has its own means to further the development of safeguards for fusion.

In instances where such measures are insufficient, treaty changes are necessary to adopt the regime to fusion. Such changes are particularly crucial for incorporating tritium into the safeguards regime. In order to do so, existing legal instruments such as the IAEA Statute or the NPT would require amendments, as well as the Euratom Treaty or NWFZ Treaties. Another approach could be the adoption of a new treaty under an international tritium control system. Furthermore, modifications to the export control guidelines are necessary to ensure alignment between the objectives of export control procedures and the application of export controls.

The incorporation of fusion technology into the existing legal framework governing nuclear weapons law is a complex issue, given the challenges faced by the current legal regime. Firstly, fusion represents a novel technology with significant economic and societal potential, yet its role in nuclear weapons is comparatively limited in comparison to existing nuclear technologies. The integration of fusion into the system could potentially hinder the development of this technology and incur costs for both the operator and the IAEA. Secondly, any modifications to the current framework would fall within the purview of the broader NPT regime, which – despite the treaty's successes – has been subject to considerable criticism and has repeatedly demonstrated its inadequacies over the past several decades. The non-proliferation regime has been largely reactive, rather than proactive, and has been unsuccessful in preventing numerous countries from acquiring nuclear weapons since its inception. Additionally, certain states have disregarded their obligations under the treaty, including nuclear disarmament. The failure of numerous review conferences to even agree on non-binding outcome documents further reinforces the perception that treaty changes are unattainable. Additionally, there is a lack of political incentives for NNWS to accept a further interference with their sovereignty in a field which is as important as energy.

Such an incentive could be the adoption of a comprehensive treaty specifically developed for fusion and encompassing not only the nuclear weapons law dimension, but further aspects of fusion regulation as well. Such a Fusion Treaty could harmonise aspects of nuclear safety and nuclear security on an international level, thereby facilitating the development of commercial fusion technology by reducing regulatory differences between different States. Furthermore, the treaty could develop new approaches for risk-appropriate safeguards measures for a technology with a limited proliferation potential, while implementing lessons learnt from the NPT. A comprehensive Fusion Treaty would help promoting fusion technology and its quick deployment throughout the planet in order to tackle the climate crisis, while at the same time meeting the risk of further proliferation of nuclear weapons.

Yet, law can only do so much, as it is just one of a multitude of reasons why States do or do not engage in nuclear weapons. It is not only the development of a new technology or the legal response that will support a nuclear weapons programme, it is the political will of a State to acquire nuclear weapons which is the most decisive factor whether fusion will only tackle the climate crisis or will also contribute to the further proliferation of nuclear weapons.

To conclude this book, a quote of British physicist Sir Oliver Lodge reminds us of external factors that determine if the commercialisation of fusion, i.e. getting hold of tapping into the energy stored in hydrogen nuclei, will remain solely peaceful:

> *"The atomic weight of hydrogen is not exactly 1, but by careful measurement is found to be 1.0077. Who could imagine that in this slight discrepancy — which indeed needs some explanation to make intelligible — an immense store of possible energy is indicated, which some day, when we have learned how, may become accessible for good or ill to the human race? [...] And if ever the human race get hold of a means of tapping even a small fraction of the energy contained in the atoms of their own planet, the consequences will be beneficent or destructive according to the state of civilization at that time attained."*[916]

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916 *Oliver Lodge*, Putting the Atom to Work, Scientific American 130 (1924), 306, 358–359. The mass of atoms is measured in the unified atomic mass unit *u*, which is equal to about 1.66 x 10^{-27} kg. Following Einstein's mass-energy-equivalence $E=mc^2$, mass translates to energy. The deviation of the mass of hydrogen from exactly 1 u corresponds to an enormous amount of energy. In atoms with at least one proton and one neutron, the mass of an atom deviates from the mass of its constituents, as the binding energy between the particles corresponds to a mass which can be measured and – in the form of energy – can be set free.