Introduction: Sustainable Development and Securing Peace

The climate crisis is arguably the most pressing issue of the 21st century. Finding solutions to tackle this crisis is imperative for the continuation of the world and the functioning of society as we know it. The failure to do so will result in unprecedented consequences.[1] The climate crisis is driven by human-induced emissions of carbon dioxide (CO_2) and other greenhouse gases.[2] The majority of these emissions is caused by the world's hunger for energy.[3] Consequently, transforming the energy production to emission-free energy sources is of paramount importance in the effort to combat climate change.

Emission-free energy sources already exist today, including solar energy, wind energy, hydroelectric energy, geothermal energy and nuclear energy. These technologies, however, come with limitations. Both solar and wind energy depend on meteorological conditions, thus necessitating the technologically challenging process of storing electricity.[4] Hydroelectric and geothermal energy are limited to geographical conditions where there are suitable water bodies or sufficient geothermal activity. Nuclear energy, too, has its own downsides in light of safety and proliferation concerns as well as the unresolved question of how to deal with nuclear waste.

This is where nuclear fusion – or fusion for short – becomes important. Fusion is the process that powers the Sun and all other stars in our universe. Harvesting this energy has the potential to provide the world with a virtually unlimited source of energy. A bottle of water combined with less

1 *International Panel on Climate Change*, Sixth Assessment Report – Synthesis Report, 2022, at 68 ff.; *Sabine L. Perch-Nielsen/Michèle B. Bättig/Dieter Imboden*, Exploring the Link Between Climate Change and Migration, Climatic Change 91 (2008), 375–393; *J. Timmons Roberts*, Global Inequality and Climate Change, Society & Natural Resources 14 (2001), 501–509.

2 *International Panel on Climate Change*, Climate Change 2021: The Physical Science Basis, in: Sixth Assessment Report, Geneva: IPCC 2021, at 423 ff.

3 In 2022, global energy-related CO_2 emissions amounted to 36.8 Gt, *International Energy Agency*, CO2 Emissions in 2022, Paris: IEA 2023. On the different contributors to this number in a historic context, see *Zhu Liu/Zhu Deng/Steve Davis et al.*, Monitoring Global Carbon Emissions in 2022, Nature Reviews Earth & Environment 4 (2023), 205–206.

4 See Trevor M. Letcher (ed.), Storing Energy, Amsterdam: Elsevier 2022.

than a gram of lithium contains roughly as much fusion energy as can be generated by burning three tonnes of coal.[5] This energy source comes without the production of CO_2 or other greenhouse gases, as in fossil energy sources, and without the level of safety and waste concerns, as in nuclear fission energy. Additionally, fusion energy can provide a baseload supply of energy independent of meteorological or geographical conditions, unlike renewable energy sources. While fusion has been confined to academic research for decades, with continued promises of reaching a commercial scale within a few decades, recent times have shown substantial scientific breakthroughs,[6] as well as a significant increase in the number of start-ups and investor capital.[7] Fusion could be a key technology in solving the energy problem and playing a crucial role in the broader effort to combat climate change.

As has been emphasised by numerous scholars, the climate crisis represents a threat to peace.[8] The climate crisis will increase inequalities in socioeconomic development, can lead to a fight for resources and may cause large-scale migration movements.[9] As fusion plays a role in the fight against the climate crisis, fusion energy can contribute to peace. Indeed, fusion already served as a peace project between the United States and the

5 One liter of water contains roughly 10^{22} deuterium atoms, while one gram of natural lithium contains enough ^{6}Li to produce 10^{22} tritium atoms. Their fusion energy amounts to roughly 30 GJ, which correlates to 3 tonnes of brown coal with an energy density of 10 MJ/kg.

6 See for example *Michael Banks*, China's Experimental Advanced Superconducting Tokamak Smashes Fusion Confinement Record in: Physics World, https://physicsworld.com/a/chinas-experimental-advanced-superconducting-tokamak-smashes-fusion-confinement-record/#:~:text=This%20week%2C%20scientists%20working%20on,device%20located%20in%20Hefei%2C%20China., last accessed 17 July 2025; *Max-Planck-Institute for Plasma Physics*, JET Fusion Facility Sets a New World Energy Record in: https://www.mpg.de/18250857/jet-fusion-facility-new-world-energy-record, last accessed 17 July 2025; *U.S. Department of Energy*, DOE National Laboratory Makes History by Achieving Fusion Ignition (2022), https://www.energy.gov/articles/doe-national-laboratory-makes-history-achieving-fusion-ignition, last accessed 17 July 2025.

7 *Fusion Industry Association*, The Global Fusion Industry in 2024, Washington DC: FIA 2024.

8 *Katharine J. Mach/Caroline M. Kraan/W. Neil Adger et al.*, Climate as a Risk Factor for Armed Conflict, Nature 571 (2019), 193–197; *Vally Koubi*, Climate Change and Conflict, Annual Review of Political Science 22 (2019), 343–360; *Oli Brown/Robert McLeman*, A Recurring Anarchy? The Emergence of Climate Change as a Threat to International Peace and Security, Conflict, Security & Development 9 (2009), 289–305.

9 *Mach/Kraan/Adger et al.* (n 8).

Soviet Union during the Cold War in the 1980s.[10] However, as a nuclear technology, fusion also has military applications, especially with regard to nuclear weapons. Nuclear weapons are one of the greatest threats to peace.[11] Promoting a nuclear technology for sustainable development poses the risk of increasing the risk of nuclear proliferation, and in the worst case, nuclear war. Fusion intends to promote sustainable development in the fight against the climate crisis, while securing peace at the same time.

Law seeks to make these interests compatible. This introduction first explores how fusion as a technology to promote sustainable development stands in the broader context of international law (1), before focusing on the technology's role in international nuclear law (2), the legal regime that focuses on the specific risk-potential of nuclear technology. The introduction then proceeds to highlight the relevance of fusion in the context of nuclear weapons law (3), where the combined task of promoting sustainable development while preventing the further proliferation of nuclear weapons is prominent. The introduction concludes with a presentation of the outline of the book (4).

1 Fusion in International Law

Fusion is a technology that has the potential to play a significant role in the fight against the climate crisis. This transformative potential of fusion as a new energy source in realising an objective shared by the world community raises the question of fusion's role in the broader context of international law. As it is true for any energy source, the implications in international law are manifold and stretch into different sub-disciplines, emphasised by an increased focus of international law on various aspects of energy.[12]

As fusion may play a significant role in the context of the climate crisis and in finding solutions for climate mitigation, international climate law is of relevance. The United Nations Framework Convention on Climate Change (UNFCCC) has been in force for more than thirty years with

10 *Michel Claessens*, ITER: The Giant Fusion Reactor – Bringing a Sun to Earth, Cham: Springer 2020, at 19.

11 *John Mecklin*, Closer Than Ever: It Is Now 89 Seconds to Midnight in: Bulletin of the Atomic Scientists, https://thebulletin.org/doomsday-clock/2025-statement/, last accessed 17 July 2025.

12 *Jorge E. Viñuales*, Energy in International Law, Cambridge: Cambridge University Press 2022, at 1 ff.

almost universal adherence, aiming to stabilise "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[13] Again, energy is the largest source of greenhouse gases, emphasising the role of sustainable energy sources within the climate law regime, including fusion.

The role of new technologies is further emphasised in the 2015 Paris Agreement, which introduced the limit of an increase in the global average temperature to well below 2°C above pre-industrial levels, with efforts to limit it to 1.5°C, into an international agreement.[14] To achieve this goal, Article 10 emphasises the role of technology within climate mitigation and the reduction of greenhouse gas emissions. In 2023, the so-called Global Stocktake, adopted during COP28 in Dubai, has introduced the yet biggest focus on energy within the regime. There, the Parties to the Paris Agreement recognised the need to accelerate efforts globally towards net zero emission energy systems, to transition away from fossil fuels in energy systems and to accelerate zero-emission technologies, such as nuclear technologies.[15] Fusion can provide pathways to keeping the increase of global temperature within the limits of the UNFCCC and the Paris Agreement.

Fusion as a clean energy source also plays a role within the United Nations Sustainable Development Goals (SDGs). In 2015, the United Nations General Assembly adopted 17 Sustainable Development Goals as "a plan of action for people, planet and prosperity."[16] Goal 7 aims to ensure access to affordable, reliable, sustainable and modern energy for all. Fusion has the potential to provide a pathway to achieve these goals in all of these four aspects: Fusion as a modern energy source is expected to be affordable,[17] to be reliable as fusion power plants can provide baseload energy, to be sustainable by being climate-neutral, while avoiding the social implications of fossil and renewable energy sources, and also offering enormous economic potential. Furthermore, fusion contributes to Goal 13 – the goal addressing

13 Article 2 UNFCCC.
14 Article 2.1.a Paris Agreement.
15 Decision 1/CMA.5, at para. 28.
16 Preamble of A/RES/70/1, at para. 1.
17 *Slavomir Entler/Jan Horacek/Tomas Dlouhy et al.*, Approximation of the Economy of Fusion Energy, Energy 152 (2018), 489–497. It must be noted that there are high uncertainties both with regard to the costs of fusion power plants and the development of costs for renewable energy sources.

climate change –, by taking urgent action to combat climate change and its impacts.[18]

Once commercialised, fusion energy will become a focal point within the mitigation obligations under international climate law and sustainable development regimes.

Moreover, energy sources – including fusion – impact numerous other facets of international law. The impact starts from the relevance of large-scale energy projects within international investment law,[19] the potential to contribute to disputes brought before the International Court of Justice,[20] having major implications in human rights,[21] their role in shaping international environmental law,[22] and stretching as far as playing a crucial role in addressing violations of international law, such as Western reactions following the Russian aggression in Ukraine[23] or the relevance of access to oil in the United States' intervention in Iraq.[24]

18 On fusion's role within the SDGs, see also *E. G. Carayannis/J. Draper/I. A. Iftimie*, Nuclear Fusion Diffusion: Theory, Policy, Practice, and Politics Perspectives, IEEE Transactions on Engineering Management 69 (2022), 1237–1251.

19 See the vast majority of contributions in Karoly Tamas Olajos/Fusion For Energy (eds.), Fusion For Energy Contracting Professionals Roundtable Proceedings 2022–2023, Barcelona: European Commission 2023.

20 *International Court of Justice*, Gabčikovo-Nagymaros Project (Hungary/Slovakia), Judgment, ICJ Reports 1997, p. 7.

21 On Human Rights regarding access to energy, see *Marc Clemson*, Human Rights and the Environment: Access to Energy, New Zealand Journal of Environmental Law 16 (2012), 39–81; *Stephen R. Tully*, The Contribution of Human Rights to Universal Energy Access, Northwestern University Journal of International Human Rights 4 (2005), 518–548. However, energy (even renwables) can also be in conflict with human rights, see *Mary Finley-Brook/Curtis Thomas*, Renewable Energy and Human Rights Violations: Illustrative Cases from Indigenous Territories in Panama, Annals of the Association of American Geographers 101 (2011), 863–872.

22 *Anguel Anastassov*, The Sovereign Right to Peaceful Use of Nuclear Energy and International Environmental Law, in: Jonathan L. Black-Branch/Dieter Fleck (eds.), Nuclear Non-Proliferation in International Law – Volume I, The Hague: T.M.C. Asser Press 2014, 159–197.

23 For example, Germany was highly critised for its continued support of the gas pipeline Nord Stream 2 after the annexation of Crimea by Russia. On that, see *Tobias Bunde*, Lessons (to be) learned? Germany's Zeitenwende and European Security After the Russian Invasion of Ukraine, Contemporary Security Policy 43 (2022), 516–530.

24 *Eric Bonds*, Assessing the Oil Motive After the U.S. War in Iraq, Peace Review 25 (2013), 291–298; *John. S. Duffield*, Oil and the Decision to Invade Iraq, in: Jane Cramer/A. Trevor Thrall (eds.), Why Did the United States Invade Iraq?, London: Routledge 2011, 145–166.

2 Fusion in International Nuclear Law

Nuclear fusion, being a nuclear process, plays a specific role within the framework of international nuclear law, a subset of international law. Nuclear law and the regulation of nuclear energy are unparalleled in comparison to the regulation of other forms of energy.[25] Unlike with other energy sources, the dual-use characteristic of nuclear technology gives rise to questions of international security, as well as the safety and security of nuclear materials and facilities, which often take precedence over economic interests.[26] Furthermore, potential transboundary effects caused by accidents necessitate international legal approaches. The regime is characterised by a centralised approach, whereby international organisations exert a high level of authority under a comprehensive governance framework.[27] The International Atomic Energy Agency (IAEA), and to some extent the European Commission and the OECD, centralise the governance mechanisms of nuclear law.

Nuclear law is defined as "the body of special norms created to regulate the conduct of legal or natural persons engaged in activities related to fissionable materials, ionizing radiation and exposure to natural sources of radiation."[28] Given the radioactivity involved in fusion, the technology is subject to the regulations of nuclear law, which cover four pillars: safety, security, safeguards and civil liability.

These four pillars are designed to cover the specific risks and challenges posed by the inherent risks and dual-use nature of nuclear energy. Safety is the body of norms which aims to protect people and the environment from hazardous effects of nuclear facilities and materials.[29] These efforts are encapsulated in various conventions and standards, including the 1994 Convention on Nuclear Safety or the 1997 Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, and several IAEA Safety Standards. These instruments ensure that nuclear facilities are constructed, operated and decommissioned safely by establishing a comprehensive set of rules, procedures and institutions.

25 *Viñuales* (n 12), at 291.
26 Ibid, at 291, 303 f.
27 Ibid, at 293.
28 *Carlton Stoiber/Alex Baer/Norbert Pelzer et al.*, IAEA Handbook on Nuclear Law, Vienna: International Atomic Energy Agency 2003, at 4.
29 *International Atomic Energy Agency*, IAEA Nuclear Safety and Security Glossary, Vienna: IAEA 2022, at 139.

Security is the set of rules that protect the facilities and materials from external influence, especially with a view to preventing and detecting criminal acts.[30] This includes the 1979 Convention on the Physical Protection of Nuclear Material, as well as UN Security Council Resolutions 1373 and 1540. The overarching objective of these instruments is to prevent external influence on nuclear facilities and material, with a particular emphasis on preventing non-State actors from acquiring nuclear material. Safeguards regulate the verification that nuclear material and activities remains in peaceful uses with the 1968 Nuclear Non-Proliferation Treaty (NPT) as the cornerstone of the regime.[31] As will be discussed in the next chapters, the safeguards regime contains of a vast web of legal sources with a view to preventing the further spread of nuclear weapons. With regard to civil liability, there are special international regimes in place for the case that a nuclear accident occurs. These regimes introduce specific rules tailored to the potential large-scale consequences of such accidents.[32]

30 Ibid, at 140.

31 *International Atomic Energy Agency*, IAEA Safeguards Glossary, Vienna: IAEA 2022, at 18 ff.

32 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy, 1963 Vienna Convention on Civil Liability for Nuclear Damage, 1988 Joint Protocol Relating to the Application of the Vienna Convention and the Paris Convention. For an overview of the regime, see *Andrea Gioia*, Nuclear Accidents and International Law, in: Andrea de Guttry/Marco Gestri/Gabriella Venturini (eds.), International Disaster Response Law, The Hague, The Netherlands: T.M.C. Asser Press 2012, 85–102, at 98 ff.

Recent initiatives have seen governments,[33] the European Union[34] and the IAEA,[35] in addition to scholars,[36] commence efforts to regulate the safety of fusion. The question of how to regulate a future fusion facility remains a subject of ongoing discussion. Should the regulatory framework for nuclear fission power plants apply? Should a regime for radiological sources be implemented? Or should a specific regime for fusion be established? These questions are the focus of extensive research and debate.

Regarding nuclear security, the IAEA has begun to analyse the implications of fusion on this pillar.[37] The broad scope of the existing instruments has been found to already cover fusion without the need of any specific changes to the regime. The question of civil liability in the case of a fusion accident has been addressed by scholars[38] and is currently being discussed at the level of international organisations acting as depositaries for the

33 The United Kingdom has published first thoughts on fusion safety regulation, *Department for Energy Security & Net Zero*, Towards Fusion Energy 2023 – The Next Stage of the UK's Fusion Energy Strategy, London: 2023. The US Government has taken first decisions in 2023, https://www.nrc.gov/cdn/doc-collection-news/2023/23-029.pdf, last accessed 25 February 2025. Germany develops a regulatory framework for fusion until mid 2026, https://www.faz.net/aktuell/wirtschaft/energiewende-gesetzlicher-rahmen-zur-kernfusion-in-deutschland-geplant-19669987.html, last accessed 25 February 2025.

34 See for example *Commission European/Directorate-General for Research and Innovation/L. Eriksson et al.*, Exploring Regulatory Options for Fusion Power Plants, Brussels: Publications Office of the European Union 2021; The European Commission also set up an expert meeting on 23 April 2024, entitled "The EU Blueprint for Fusion Energy".

35 See for example *International Atomic Energy Agency*, IAEA World Fusion Outlook 2023 – Fusion Energy: Present and Future, Vienna: IAEA 2023, at 28 ff. The IAEA has also started to host meetings on safety regulation, e.g. the First Meeting Focusing on Safety and Regulation of Fusion in October 2023.

36 *J. Elbez-Uzan/L. Williams/S. Forbes et al.*, Recommendations for the Future Regulation of Fusion Power Plants, Nuclear Fusion 54 (2024), 1–10; *N. P. Taylor*, Safety and Licensing of Nuclear Facilities for Fusion, in: 2015 IEEE 26th Symposium on Fusion Engineering (SOFE)2015; *Didier Perrault*, Nuclear Safety Aspects on the Road Towards Fusion Energy, Fusion Engineering and Design 146 (2019), 130–134.

37 *International Atomic Energy Agency* (n 35), at 25.

38 *Claire Portier*, Le droit de la responsabilité à l'épreuve des activités de fusion nucléaire, Aix-en-Provence: Aix-Marseille Université 2022; *William E. Fork/Charles H. Peterson*, Fusion Energy and Nuclear Liability Considerations, Nuclear Law Bulletin 93 (2014), 43–62; *Steven McIntosh*, Nuclear Liability and Post-Fukushima Developments, in: International Atomic Energy Agency (ed.), Nuclear Law: The Global Debate, The Hague: T.M.C. Asser Press 2022, 249–269.

relevant treaties.[39] Similar to the question of safety, there are discussions as to whether the framework developed for fission is applicable to fusion and, if fusion were to be included, whether it would be proportionate given the technology's different risk profile. For example, fusion technology is inherently safe from runaway reactions, which caused the Chernobyl accident, and from meltdowns caused by decay heat such as the Fukushima-Daiichi accident. Furthermore, radioactive by-products and waste from fusion differ significantly from those of fission technology.[40]

With regard to safeguards, the fourth pillar, so far, no comprehensive legal study has been conducted. Safeguards represent a fundamental aspect of both nuclear non-proliferation and disarmament law. While technological aspects have been identified already a decade ago,[41] calls from experts to addressing the legal framework with regard to fusion have been left unanswered. This book aims at filling this gap and to provide an analysis of fusion energy within the context of nuclear weapons law.

3 Fusion in Nuclear Weapons Law

Fusion energy is of particular interest with regard to nuclear weapons law. Nuclear technologies, including fusion, are dual-use technologies, meaning they have both peaceful and military applications. While intended to support sustainable development and thus, contributing to the prevention of conflicts, fusion – like fission – could be used in a military context for the development of nuclear weapons. In response to the dual-use nature of nuclear technology, nuclear weapons law has developed a unique system for verifying compliance by vesting international and supranational organisations with an unprecedented level of authority. The study of the role

39 The OECD as depositary of the 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy has started a Working Group to discuss a potential inclusion of fusion into the treaty regime. The role of fusion within the 1963 Vienna Convention on Civil Liability for Nuclear Damage is also discussed within the IAEA as depositary, *International Atomic Energy Agency* (n 35), at 25.

40 *Sehila M. Gonzalez de Vicente/Nicholas A. Smith/Laila El-Guebaly et al.*, Overview on the Management of Radioactive Waste From Fusion Facilities: ITER, Demonstration Machines and Power Plants, Nuclear Fusion 62 (2022), 085001.

41 See for example *Alexander Glaser/Robert J. Goldston*, Proliferation Risks of Magnetic Fusion Energy: Clandestine Production, Covert Production and Breakout, Nuclear Fusion 52 (2012), 043004; *Giorgio Franceschini/Matthias Englert/Wolfgang Liebert*, Nuclear Fusion Power for Weapons Purposes, The Nonproliferation Review 20 (2013), 525–544.

of new technology in nuclear weapons law offers a distinctive perspective on a sub-regime of international law that operates in a distinct manner compared to other domains of international law.

This section will first explore the relevance of studying nuclear weapons law in general (3.1) as well as nuclear proliferation (3.2), before focusing on the specific interest of studying fusion energy in nuclear weapons law (3.3).

3.1 The Interest to Study Nuclear Weapons Law

Nuclear weapons law seeks to regulate the development, possession, transfer, and use of nuclear weapons, which are classified as weapons of mass destruction. While the use of weapons in general is governed by the legal frameworks of *jus ad bellum* (the law on the use of force) and *jus in bello* (international humanitarian law), only a limited number of weapon types are subject to specific international treaties. Some conventional weapons – such as anti-personnel mines[42] and cluster munitions[43] – are regulated through dedicated conventions, but these are exceptions rather than the norm.

In contrast, weapons of mass destruction are treated more extensively under international law. Biological[44] and chemical weapons[45] are comprehensively prohibited. However, nuclear weapons remain an outlier: there is no treaty that fully prohibits or comprehensively regulates them. Instead, the legal regime surrounding nuclear weapons is fragmented and focuses on three areas: non-proliferation, disarmament, and arms control. Each of these areas is governed by different instruments with varying legal obligations and differing levels of participation by States.

The focus of nuclear non-proliferation law is to prevent the further spread of nuclear weapons and, for nuclear weapon-states, to at least maintain the status quo of nuclear powers. In this regard, the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (NPT) is the most important instrument. Nuclear disarmament goes beyond non-proliferation and aims to establish a pathway to a world free of nuclear weapons. Nuclear arms

42 Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on Their Destruction.

43 Convention on Cluster Munitions.

44 Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction.

45 Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction.

control law includes highly detailed agreements and verification mechanisms between States possessing nuclear weapons to limit or reduce the amount, type, or yield of their respective nuclear weapons arsenals.

Nuclear weapons law is an area in which, despite its importance for the maintenance of international peace and security – the primary purpose listed in the UN Charter[46] – the United Nations is of secondary importance. While the organs of the United Nations, most notably the International Court of Justice (ICJ) and the Security Council, are often at the centre of international law discourse, it is other specialised international organisations and actors that dominate the field of nuclear weapons law. In international law, these two UN organs typically determine the compliance of States with international obligations. However, within the domain of nuclear weapons law, they assume a more marginal role. Such a deviation from standard scenarios in international law and the relevance of different actors renders the topic of nuclear weapons law an interesting area of research.

The question of compliance is always a controversial topic in international law. Given the absence of an equivalent to an executive power at the international level, verifying and enforcing international law is from time to time complicated. Indeed, one of the prominent criticisms of international law is precisely this absence of comprehensive powers to enforce compliance.[47] The assessment of compliance with the obligations assumed under nuclear weapons law is of the utmost importance. A breach of these obligations, which in the worst case could be the acquisition of a nuclear weapon, has the potential to cause irreversible consequences for the international security order.

The ICJ is the principal judicial organ of the United Nations,[48] yet its powers in the context of nuclear weapons law are limited given the courts limited jurisdiction. The ICJ has jurisdiction over a case only in three cases: Two or more disputing States present a case to the court (so-called *compromis*)[49], a State has accepted the ICJ's compulsory jurisdiction,[50] or a treaty

46 Article 1 para. 1 of the UN Charter.

47 On the seminal question of enforceability in international law, see *Gerald Fitzmaurice*, The Foundations of the Authority of International Law and the Problem of Enforcement, The Modern Law Review 19 (1956), 1–13.

48 Article 92 of the UN Charter.

49 Article 36 para. 1 ICJ Statute.

50 Article 36 para. 2 ICJ Statute.

establishes the ICJ's jurisdiction in a *compromissory clause*.[51] In the context of nuclear weapons law several issues arise. For instance, in the event of an alleged breach of the fundamental obligation of the Nuclear Non-Proliferation Treaty – specifically the development of a nuclear weapon by a non-nuclear weapon State –, it is very unlikely that the proliferating State would accept an *ad-hoc* jurisdiction by the ICJ. Moreover, the NPT does not include a *compromissory clause*. In addition, only 74 out of the 193 UN Member States have accepted the ICJ's compulsory jurisdiction, many of them with reservations, some of which are quite extensive.[52] Even if such a judgment were to be rendered, it would often be issued at a point where a nuclear weapons programme is at an advanced stage, making corrective measures difficult. Thus, the ICJ's authority in contentious cases regarding non-proliferation law is limited. In instances where the ICJ has been called upon to adjudicate on a contentious matter concerning nuclear weapons,[53] the issue of non-proliferation was not addressed. While the ICJ pronounced itself on the topic in the *Nuclear Weapons Advisory Opinion,*[54] this advisory opinion is neither binding nor did it specifically address the question of non-proliferation. The ICJ's capacity to adjudicate and pronounce itself in question regarding nuclear weapons law is limited and it does not play a role in ensuring compliance.

The second organ is the UN Security Council. In contrast to the ICJ, it has played a role in nuclear non-proliferation. While the Security Council has often been and still is blocked by the veto rights of its permanent

51 Article 36 para. 1 ICJ Statute. On compromissory clauses, see *Jonathan I. Charney*, Compromissory Clauses and the Jurisdiction of the International Court of Justice, American Journal of International Law 81 (1987), 855–887.

52 *Gary L. Scott/Craig L. Carr*, The ICJ and Compulsory Jurisdiction: The Case for Closing the Clause, American Journal of International Law 81 (1987), 57–76; *Stanimir A. Alexandrov*, Accepting the Compulsory Jurisdiction of the International Court of Justice with Reservations: An Overview of Practice with a Focus on Recent Trends and Cases, Leiden Journal of International Law 14 (2001), 89–124.

53 *International Court of Justice*, Obligations concerning Negotiations relating to Cessation of the Nuclear Arms Race and to Nuclear Disarmament (Marshall Islands v. India), Jurisdiction and Admissibility, Judgment, I.C.J. Reports 2016, p. 255; Obligations concerning Negotiations relating to Cessation of the Nuclear Arms Race and to Nuclear Disarmament (Marshall Islands v. Pakistan), Jurisdiction and Admissibility, Judgment, I.C.J. Reports 2016, p. 552; Obligations concerning Negotiations relating to Cessation of the Nuclear Arms Race and to Nuclear Disarmament (Marshall Islands v. United Kingdom), Preliminary Objections, Judgment, I.C.J. Reports 2016, p. 833.

54 *International Court of Justice*, Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion, ICJ Reports 1996, p. 226.

members,[55] the P5 – being also the only States recognised by the NPT as nuclear-weapon States – have historically found consensus in cases of enforcing nuclear non-proliferation. This commitment is evidenced by the Security Council's responses to Iraq's clandestine nuclear programme in the 1990s, as reflected in the establishment of UNSCOM under UNSCR 687, and its subsequent efforts to prevent the proliferation of nuclear weapons to non-state actors, as outlined in UNSCR 1540. These acts were all adopted under Chapter VII of the UN Charter, thereby conferring legal binding obligations upon all States. However, it is important to note that the Security Council, in isolation, is unable to ensure nuclear non-proliferation; rather, it functions as a pivotal actor within a complex network of other actors at a stage when a State has already engaged in a nuclear weapons programme.

In lieu of the main actors in international law, nuclear weapons law is a regime in which specialised international organisations exercise a significant degree of authority, directly interfering with the sovereignty of States. While there are cases in which an international organisation can directly oblige a Member State, such as the Security Council under Chapter VII of the Charter or (quasi-)judicial decisions from the ICJ or the World Trade Organization's Dispute Settlement Mechanism, or sometimes even individuals[56], such powers are rare. Instruments of international organisations frequently consist of non-binding recommendations[57] or mere information.[58]

55 Article 27 para. 3 of the UN Charter.

56 On the effect on individuals, see *Clemens A. Feinäugle*, The UN Security Council Al-Qaida and Taliban Sanctions Committee: Emerging Principles of International Institutional Law for the Protection of Individuals?, in: Armin von Bogdandy/Rüdiger Wolfrum/Jochen von Bernstorff/Philipp Dann/Matthias Goldmann (eds.), The Exercise of Public Authority by International Institutions, Berlin, Heidelberg: Springer 2010, 101–131.

57 See for example *Gefion Schuler*, Effective Governance through Decentralized Soft Implementation: The OECD Guidelines for Multinational Enterprises, in: Armin von Bogdandy/Rüdiger Wolfrum/Jochen von Bernstorff/Philipp Dann/Matthias Goldmann (eds.), The Exercise of Public Authority by International Institutions, Berlin, Heidelberg: Springer 2010, 197–226.

58 See for example *Erika de Wet*, Governance through Promotion and Persuasion: The 1998 ILO Declaration on Fundamental Principles and Rights at Work, in: Armin von Bogdandy/Rüdiger Wolfrum/Jochen von Bernstorff/Philipp Dann/Matthias Goldmann (eds.), The Exercise of Public Authority by International Institutions, Berlin, Heidelberg: Springer 2010, 377–403; *Joseph Windsor*, The WTO Committee on Trade in Financial Services: The Exercise of Public Authority within an Informational Forum, in, Berlin, Heidelberg: Springer 2010, 405–435.

Where there are concrete actions, they are usually limited to the role of the State within the international organisation,[59] such as the suspension of voting rights or access to funds, without having direct impact to a Member State's territory. While these instruments also show an exercise of authority,[60] the level of authority within nuclear weapons law is of another order of magnitude: An international organisation can send international civil servants to a State to verify its compliance with international legal instruments, at facilities often operated by private-owned entities. These civil servants might bring to light clandestine nuclear weapons programmes, potentially leading to (coercive) action by the IAEA or even the UN Security Council. The origin of this high level of authority is obvious: The dramatic and potentially irreversible consequences of a lack of compliance. Once a State has acquired nuclear weapons, any coercive actions to reinstate compliance is difficult, as such a State then has the elevated positions of nuclear deterrence and nuclear coercion.[61] The case of North Korea serves as a prominent example.

Such a high degree of authority is important to maintain international peace and security. In instances where the exercise of authority by international organisations is insufficient to prevent the proliferation of nuclear weapons, States may resort to unilateral measures including the use of force. The question of whether a (suspected) nuclear weapons programme is sufficient to justify military attacks under Article 51 of the UN Charter is a subject of a controversial debate.[62] Israel invoked the argument of self-defence against nuclear proliferation when it destroyed the Iraqi Osirak

59 See for example *Ute Mager*, The UNESCO Regime for the Protection of World Heritage, in: Armin von Bogdandy/Rüdiger Wolfrum/Jochen von Bernstorff/Philipp Dann/Matthias Goldmann (eds.), The Exercise of Public Authority by International Institutions, Berlin, Heidelberg: Springer 2010, 337–339.

60 See for example the influence of the OECD's PISA Policy to national policies, *Armin von Bogdandy/Matthias Goldmann*, The Exercise of International Public Authority through National Policy Assessment: The OECD's PISA Policy as a Paradigm for a New International Standard Instrument, International Organizations Law Review 5 (2008), 241–298.

61 More on these concepts below, Chapter 2 Section 1.1.

62 *Christian Henderson*, The Bush Doctrine: From Theory to Practice, Journal of Conflict & Security Law 9 (2004), 3–24; *Rachel A. Weise*, How Nuclear Weapons Change the Doctrine of Self-Defense Note, New York University Journal of International Law and Politics 44 (2011), 1331–1398; *Arman Sarvarian*, The Lawfulness of a Use of Force Upon Nuclear Facilities in Self-Defence, Journal on the Use of Force and International Law 1 (2014), 247–272.

reactor in 1981,[63] the Syrian Dair Alzour reactor[64] or attacked Iran's nuclear programme in 2025.[65] A similar argument was presented by the so-called *coalition of the willing* when it invaded Iraq in 2003.[66]

3.2 The Interest to Study Nuclear Proliferation

A central topic of this book is proliferation. Proliferation, in the context of nuclear weapons, refers to the spread and advancement of nuclear capabilities, and it shows in two dimensions: horizontal and vertical.[67]

Horizontal proliferation occurs when a non-nuclear-weapon State (NNWS) – a state that previously did not possess nuclear weapons – acquires nuclear weapons. This type of proliferation expands the number of states possessing such weapons. The proliferation of nuclear weapons has started in the 1940s during World War II. Following a letter sent by Albert Einstein to President Roosevelt and fueled by fears of a German nuclear weapon,[68] the United States initiated a nuclear weapons programme (the

63 *Istvan Pogany*, The Destruction of Osirak: A Legal Perspective, The World Today 37 (1981), 413–418.

64 Both attacks were carried out following the so-called Begin Doctrine, the Israeli policy to use force preventively to stop enemies from acquiring weapons of mass destruction. On the so-called "Operation Outside the Box" and the Begin Doctrine, see *Ori Wertman/Christian Kaunert*, Operation "Outside the Box": The Securitization of the Syrian Nuclear Reactor, in: Israel: National Security and Securitization: The Role of the United States in Defining What Counts, Cham: Springer International Publishing 2023, 123–148.

65 *Michael N. Schmitt*, Israel's Operation Rising Lion and the Right of Self-Defense in: Lieber Institute Articles of War, https://lieber.westpoint.edu/israels-operation-rising-lion-right-of-self-defense/, last accessed 17 July 2025.

66 See e.g. the Address given to the UN Security Council by the then US Secretary of State Colin Power, https://georgewbush-whitehouse.archives.gov/news/releases/2003/02/20030205-1.html, last accessed 25 February 2025.

67 *Tom Sauer*, Nuclear Arms Control, Harvard: Macmillan 1998, at 31; *Vitaly Goldansky*, Connection between Horizontal and Vertical Proliferation of Nuclear Weapons, in: Joseph Rotblat/Laszlo Valki (eds.), Coexistence, Cooperation and Common Security: Annals of Pugwash 1986, London: Palgrave Macmillan UK 1988, 21–36; *Sabine Bauer/Cormac O'Reilly*, The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO): Current and Future Role in the Verification Regime of the Nuclear-Test-Ban Treaty, in: Jonathan L. Black-Branch/Dieter Fleck (eds.), Nuclear Non-Proliferation in International Law: Volume II – Verification and Compliance, The Hague: T.M.C. Asser Press 2016, 131–150, at 142.

68 On 2 August 1939, Albert Einstein wrote a letter to President Roosevelt, indicating the risk that Germany was underway to develop a nuclear weapon. On the German

so-called Manhattan Project) in 1942, conducted the first nuclear weapons test (Trinity Test) on 16 July 1945 and dropped two nuclear weapons on Hiroshima on 6 August 1945 and Nagasaki on 9 August 1945.[69] Intelligence insights from the German *Uranprojekt* and the Manhattan Project aided the Soviet nuclear weapons programme, resulting in a first test in 1949.[70] The United Kingdom followed in 1952, France in 1960 and China in 1964. While many other States pursued nuclear weapons programmes during this time, the adoption of the Nuclear Non-Proliferation Treaty in 1968 halted many – but not all – of them.[71] Israel constructed nuclear weapons in the 1960s or 1970s,[72] India in the 1970s,[73] Pakistan in the 1990s,[74] and North Korea in the 2000s.[75] Between the 1970s and 1990s, South Africa possessed nuclear weapons as well but later dismantled them.[76] Today, nine States possess nuclear weapons: United States, Russia, United Kingdom, France, China, Israel, India, Pakistan and North Korea. In addition, Iran has had an

nuclear programme, see *Helmut Rechenberg*, 50 Jahre Kernspaltung: Transurane, Uranspaltung und das deutsche Uranprojekt, Physikalische Blätter 44 (1988), 453–459.

69 On the Manhattan Project, see *Bruce Cameron Reed*, The History and Science of the Manhattan Project, Berlin, Heidelberg: Springer 2019.

70 On the role of intelligence, see *Robert Chadwell Williams*, Klaus Fuchs, Atom Spy, Cambridge: Harvard University Press 1987. On the Soviet nuclear programme, see *John Beyer/Julian Cooper/Gerald Holden et al.*, The Soviet Union, in: Scilla McLean (ed.), How Nuclear Weapons Decisions are Made, London: Palgrave Macmillan UK 1986, 1–31.

71 On nuclear weapons programmes during the 1950s and 1960s, see below Chapter 2, Section 1.1.

72 The so-called Vela incident occurred on 22 September 1979 when US satellites detected an unidentified double flash. The most common interpretation is that a nuclear weapons test took place: *Lars-Erik De Geer/Christopher M. Wright*, The 22 September 1979 Vela Incident: Radionuclide and Hydroacoustic Evidence for a Nuclear Explosion, Science & Global Security 26 (2018), 20–54. This test is attributed to Israel: *Leonard Weiss*, Israel's 1979 Nuclear Test and the U.S. Cover-Up, Middle East Policy XVIII (2011), 83–95.

73 *Elisabeth Röhrlich*, Inspectors for Peace, Baltimore: John Hopkins University Press 2022, at 1 ff.

74 *Samina Ahmed*, Pakistan's Nuclear Weapons Program: Turning Points and Nuclear Choices, International Security 23 (1999), 178–204.

75 *Hans M. Kristensen/Matt Korda*, North Korean Nuclear Weapons, 2021, Bulletin of the Atomic Scientists 77 (2021), 222–236.

76 *Waldo Stumpf*, South Africa's Nuclear Weapons Program: From Deterrance to Dismantlement, Arms Control Today 25 (1995), 3–8.

advanced nuclear weapons programme.[77] Those States possess more than 12,000 nuclear weapons.[78]

Vertical proliferation, by contrast, refers to the qualitative and quantitative enhancement of nuclear weapons by states that already possess them – referred to as nuclear-weapon States (NWS).[79] This form of proliferation involves the development of new warhead designs, improvements in delivery systems such as missiles or submarines, increased weapon accuracy, greater destructive yields, yield to weight ratio, or the expansion of existing arsenals. The United States can be taken as an example: The Manhattan Project produced three relatively simple one-stage fission-only nuclear gravity bombs.[80] At the height of the Cold War in the mid-1980s, the United States possessed more than 27,000 nuclear weapons.[81] These weapons came in a variety of sizes and configurations. The US stockpile includes multi-stage thermonuclear weapons, gravity bombs, intercontinental ballistic missiles, submarine-launched ballistic missiles and weapons with and adjustable yield.[82]

NWS are investing massively in vertical proliferation. The United States is expected to invest more than one trillion dollars in modernising its nuclear weapons arsenal within the next quarter century, not including inflation.[83] The United Kingdom's programme to replace submarines which are equipped with nuclear weapons amounts to GBP 41 billion over 35 years.[84] Russia spends around USD 300 billion on the modernisation and

77 *Paul K. Kerr*, Iran and Nuclear Weapons Production, Washington DC: Congressional Research Service 2024. The current state of Iran's nuclear programme following the US-Israel attacks is unknown.

78 *Hans M. Kristensen/Matt Korda*, World Nuclear Forces, in: Stockholm International Peace Research Institute (ed.), SIPRI Yearbook 2024: Armaments, Disarmament and International Security, Stockholm: Stockholm International Peace Research Institute 2024, 271–376.

79 *Mark P. Hilborne*, The Non-Proliferation Treaty. Foundation of Disarmament Policy, in: Harsh V. Pant (ed.), Handbook of Nuclear Proliferation, London, New York: Routledge 2012, 251–260, at 251; *Victor W. Sidel*, Vertical Nuclear Proliferation, Medicine, Conflict and Survival 23 (2007), 249–258.

80 On different weapon technologies, see below Chapter 1, Section 4.

81 *Robert S. Norris/Hans M. Kristensen*, Global Nuclear Weapons Inventories, 1945–2010, Bulletin of the Atomic Scientists 66 (2010), 77–83.

82 *U.S. Department of Defense*, Nuclear Posture Review, Washington DC: U.S. Government 2022.

83 *Congressional Budget Office*, Approaches for Managing the Costs of U.S. Nuclear Forces, 2017 to 2046, 2017.

84 *Claire Mills/Esme Kirk-Wade*, The Cost of the UK's Strategic Nuclear Deterrent, London: House of Commons Research Briefing 2023.

expansion of its nuclear arsenal.[85] In this decade, France spends EUR 52 billion on modernising its nuclear arsenal.[86] In other numbers: All nine NWS spend combined almost USD 3,000 per second on maintaining and expanding their nuclear arsenals.[87]

Technological developments can influence both horizontal and vertical proliferation. New technologies may allow NNWS to acquire material or knowledge necessary to develop a nuclear weapon more easily. Such a scenario could pose a threat of horizontal nuclear proliferation. Such developments can also be utilised by NWS. New technologies may facilitate the production of material necessary for nuclear weapons, and thus facilitating the expansion of nuclear weapons arsenals. In such a scenario, a horizontal threat of NNWS acquiring nuclear weapons is also a vertical threat that NWS are consequently motivated to expand their arsenals. In addition, technologies developed for civilian use can also be beneficial for increasing the sophistication of a nuclear weapon. For example, they could allow for the construction of smaller more versatile weapons or bigger more destructive weapons. Moreover, new technologies may provide NWS with means to facilitate the maintenance of their arsenals.

3.3 The Interest and Scope of This Study

As fusion energy may play a significant role in the fight against the climate crisis, it is of particular interest how nuclear weapons law ensures that the use of fusion remains exclusively peaceful in order to help fully harnessing the potential of this technology. There is a tension between sustainable development and securing peace:[88] on the one hand, no application of nuclear weapons law might lead to a scenario in which fusion leads to the further proliferation of nuclear weapons. On the other hand, a regime that

85 *Julian Cooper*, How Much Does Russia Spend on Nuclear Weapons? in: SIPRI, https://www.sipri.org/commentary/topical-backgrounder/2018/how-much-does-russia-spend-nuclear-weapons, last accessed 17 July 2025.

86 https://www.bfmtv.com/economie/entreprises/defense/budget-des-armees-la-dissuasion-nucleaire-questionnee-a-l-assemblee-nationale_AD-202305240081.html, last accessed 25 February 2025.

87 *ICAN*, Surge 2023: Global Nuclear Weapons Spending, Geneva: ICAN 2024, at 4.

88 On the tension between nuclear energy to mitigate climate change and the risk of further proliferation, see Robert J. Goldston, Climate Change, Nuclear Power, and Nuclear Proliferation: Magnitude Matters, Science & Global Security 19 (2011), 130-165.

is not adapted to a specific technology, which is still in its infancy, may impose to burdens and costs, capable to limit the technology's potential. The regime of nuclear weapons law – developed for fission and its specific risk potential – is faced with the developed of a new technology with a different risk profile. Moreover, the regime of nuclear weapons law is characterised by many shortcomings, ongoing conflicts and an increased level of contestation. This book will analyse the role of fusion within the regime and explore how nuclear weapons law can find a convincing way forward.

The development of fusion energy will be of particular interest for non-proliferation and disarmament law as fusion technology can be used to develop nuclear weapons against existing obligations not to develop nuclear weapons and corresponding verification regimes. While nuclear weapons law also comprises arms control law, fusion is of less relevance for this domain of law. Arms control commitments are independent of the physical processes within a weapon and thus, the development of fusion energy only has a limited influence on the regime of nuclear arms control.[89] For example, one of the most relevant arms control instruments was the New START Treaty between the United States and Russia. This treaty limits the number of deployed missiles, warheads and bombers as well as launchers. Whether the warhead is powered by fission-only or a combination of fission and fusion or whether a bomber deploys a simple uranium bomb or a hydrogen bomb is of no relevance for the New START Treaty. Consequently, as fusion does not pose specific challenges to this are of law, this book does not engage in an analysis of arms control law.

4 Outline of the Book

In the evolving landscape of energy technology, the introduction of fusion energy presents a complex array of challenges and opportunities for the legal framework governing nuclear non-proliferation and disarmament. This book is the first comprehensive study of fusion within the context of the legal framework of nuclear weapons. It delves into these intricacies in five

89 It should also be noted that relevant international legal instruments in nuclear arms control have ceased to exist. On this, see *Philipp Sauter*, Russia's Withdrawal from New START – The End of a Cold War Relic, but Not the Beginning of a New Nuclear Arms Race (2023), in: Völkerrechtsblog, https://voelkerrechtsblog.org/russias-withdrawal-from-new-start/.

chapters, each addressing a distinct aspect of the fusion technology's implications on nuclear weapons law. The book's central objective is to provide a comprehensive analysis of how the legal framework of nuclear weapons can effectively regulate the peaceful use of fusion for energy production.

Chapter 1 sets the stage by exploring the technological aspect associated with nuclear fusion. The chapter will explain the basic concepts of physics necessary to understand the legal analysis that follows. It focuses on the differences between fusion and fission technologies as well as the functioning of nuclear weapons. The chapter further provides a detailed analysis of the proliferation potential of fusion.

Chapter 2 examines the legal background of nuclear weapons law. It examines the politics and interests of actors within the regime, supported by historic examples of the evolution of the regime. In addition, the chapter provides an overview of the institutional framework and the various legal sources which are of relevance for addressing fusion. It further explores the different regimes of nuclear non-proliferation and nuclear disarmament law. Additionally, the chapter analyses the role of law within the broader context of nuclear weapons.

Chapter 3 undertakes a critical examination of the existing framework of nuclear weapons law with respect to the proliferation concerns of fusion technology. It analyses the applicability of existing frameworks to fusion and identifies areas where the legal provisions may be too stringent or, conversely, insufficiently comprehensive. This analysis highlights the gaps and ambiguities within the legal structures that govern nuclear non-proliferation and disarmament, particularly as applied to fusion.

Chapter 4 proposes approaches to bridge the identified gaps by adapting the legal framework. It discusses evolutionary interpretation, which could offer flexibility in applying existing laws to fusion technology. The chapter further explores the role of exercising authority by the relevant actors involved in nuclear weapons law in adapting the regime for fusion. Furthermore, the chapter will explore where treaty changes are required and how they can be implemented.

Chapter 5 offers a forward-looking perspective on the potential for treaty changes in light of fusion technology's emergence and proposes the adoption of a Fusion Treaty that comprehensively covers all aspects of fusion regulation. This chapter discusses the rational of such a comprehensive approach and the structure of such a treaty.

The book concludes with a summary of the findings.