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International Atomic Energy Agency
Background Guide 2023

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Dear Delegates,

Welcome to the 2023 National Model United Nations New York Conference (NMUN•NY)! We are pleased to introduce you to our committee, the International Atomic Energy Agency (IAEA). The topics under discussion are:

1. Nuclear Waste Management
2. Strengthening Safeguards for the World's Nuclear Facilities

Members of our dais this year include:

Benjamin Wrigley, Director, works as an Energy Analyst in Koblenz, Germany.

Ruth Spickermann, Assistant Director, is pursuing a Bachelor's degree in Political Science, Sociology and Law at the University of Erfurt, Germany.

Joli McSherry, Director, is a digital communication strategist focused on civil service, issue advocacy, and social impact work. Born and raised on her family farm in southern New Mexico, Joli is based out of Washington, D.C.

Kieran Leigh, Assistant Director, is a Parliamentary Assistant to a Minister in the British Government. He studied Politics and International Relations at the University of Nottingham and the University of South Florida.

This Background Guide serves as an introduction to the topics for this committee. However, it is not intended to replace individual research. We encourage you to explore your Member State's policies in depth and use the Annotated Bibliography and Bibliography to further your knowledge on these topics. In preparation for the Conference, each delegation will submit a Position Paper by 11:59 p.m. (Eastern Time) on 1 March 2023 in accordance with the guidelines in the Position Paper Guide and the NMUN•NY Position Papers website.

Two resources, available to download from the NMUN website, serve as essential instruments in preparing for the Conference and as a reference during committee sessions:

1. NMUN Delegate Preparation Guide - explains each step in the delegate process, from pre-Conference research to the committee debate and resolution drafting processes. Please take note of the information on plagiarism, and the prohibition on pre-written working papers and resolutions. Delegates should not start discussion on the topics with other members of their committee until the first committee session.
2. NMUN Rules of Procedure - include the long and short form of the rules, as well as an explanatory narrative and example script of the flow of procedure.

In addition, please review the mandatory NMUN Conduct Expectations on the NMUN website. They include the Conference dress code and other expectations of all attendees. We want to emphasize that any instances of sexual harassment or discrimination based on race, gender, sexual orientation, national origin, religion, age, or disability will not be tolerated. If you have any questions concerning your preparation for this committee, please contact the Peace and Security Department, Citlali Mora Catlett (Conference A) and Eileen Austin (Conference B), at usg.ps@nmun.org.

We wish you all the best in your preparations and look forward to seeing you at the Conference!

Benjamin Wrigley, Director
Ruth Spickermann, Assistant Director
Conference A

Joli McSherry, Director
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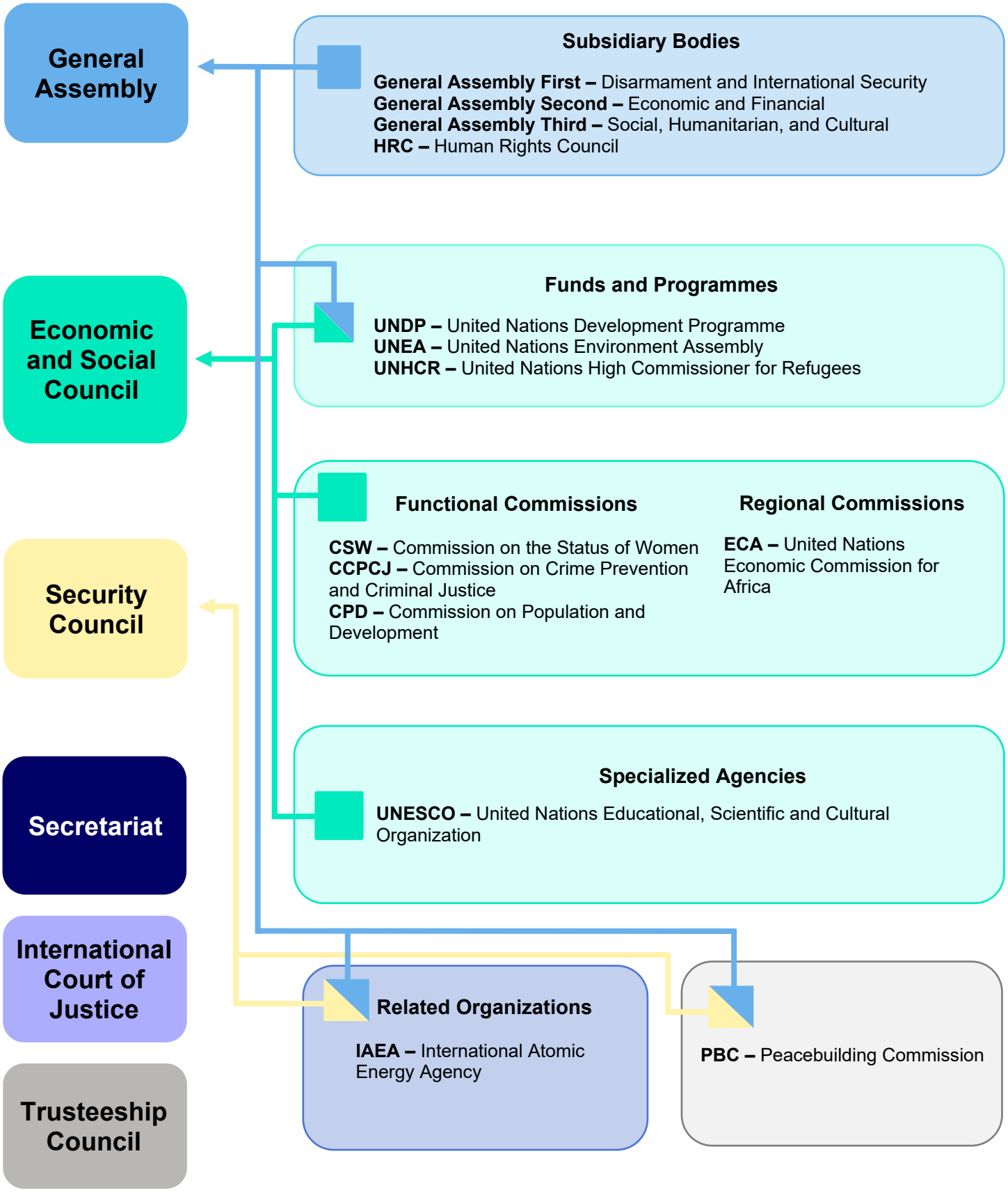
Conference B

Table of Contents

United Nations System at NMUN•NY

This diagram illustrates the UN system simulated at NMUN•NY. It shows where each committee "sits" within the system to demonstrate the reportage and relationships between entities. Examine the diagram alongside the Committee Overview to gain a clear picture of the committee's position, purpose, and powers within the UN system.



Committee Overview

Introduction

The International Atomic Energy Agency (IAEA) is an independent intergovernmental organization working closely with the United Nations (UN), which was founded "in response to the deep fears and expectations resulting from the discovery of nuclear energy."[1] The primary aim of the IAEA is to guarantee the peaceful use of nuclear material.[2] The agency faces dual challenges: to advance nuclear technology and spread knowledge on effective and sustainable usage of nuclear energy while simultaneously preventing the usage of nuclear material for atomic weapons and non-peaceful purposes.[3]

The work of the IAEA is crucial in the development of nuclear security standards that allow the peaceful use of nuclear technologies and guarantee the protection of human health and the environment.[4] As the IAEA continues its work toward the realization of the Sustainable Development Goals (SDGs) through its day-to-day operations, implementation of the Peaceful Uses Initiative (PUI), or the Zoonotic Disease Integrated Action project to respond to COVID-19, the agency's focus remains addressing current security challenges and ensuring the continued political will of its members.[5] Other programmatic work of the IAEA continues apace, including the PUI, which was launched in 2010 and aims to finance unfunded projects in the area of peaceful usage of nuclear technologies as well as to provide additional financial support to projects that foster technical cooperation.[6]

Mandate, Function, and Powers

According to article two of the *IAEA Statute* (1956), the IAEA aims to "accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" and thus, the primary role of the IAEA is to ensure that atomic energy is used for safe, secure, and peaceful purposes.[7] The mandate is further defined by the provisions of the *Treaty on the Non-Proliferation of Nuclear Weapons* (NPT) (1968), which establishes binding international law concerning the non-proliferation of nuclear weapons, the disarmament of existing nuclear weapons systems, and the advancement of peaceful nuclear technology, thereby defining the tasks and responsibilities of the IAEA.[8]

Whilst the following list is not exhaustive, the mandate of the IAEA can be summarized as:

- The IAEA **will generally**: assist with and surveil the peaceful use of atomic energy through the provision of research and technical assistance; make provisions about the standards for materials, services, equipment, and facilities to conduct research and produce nuclear power.[9] The IAEA encourages and assists in the exchange of information, training, and the interchange of scientists, and can acquire the facilities, plants, and equipment necessary to conduct its tasks and responsibilities.[10] The IAEA has the power to examine facilities and equipment, which includes the right to send inspectors to Member State facilities and to request progress reports from those states.[11] Furthermore, the IAEA has the power to require information on health and

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[1] Fischer. *History of the International Atomic Energy Agency: The first Forty Years*. 1997. pp. 1-3; New Zealand Ministry of Foreign Affairs and Trade. *United Nations Handbook 2022-23*. 2022. pp. 378-384.
[2] International Atomic Energy Agency. *IAEA Statute*. 1989.
[3] Llukmani. International Atomic Energy Agency. *General Conference: Day 5 Highlights*. 2021; International Atomic Energy Agency. *Atoms for Peace and Development: How the IAEA supports the Sustainable Development Goals*. 2015.
[4] International Atomic Energy Agency. *The IAEA Mission Statement*. 2022.
[5] Kamishima. IAEA Bulletin. *Ten years of the IAEA Peaceful Uses Initiative*. 2020.
[6] Ibid.
[7] International Atomic Energy Agency. *IAEA Statute*. 1989. art. III.
[8] United Nations, General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (A/RES/2373 (XXII))*. 1968.
[9] International Atomic Energy Agency. *IAEA Statute*. 1989. art. III A.
[10] Ibid. art. III A.
[11] Ibid. art. XII.

safety standards, and the production and recovery of fissionable materials.[12] In case of non-compliance with IAEA provisions, the agency can take further sanctioning steps including the suspension or termination of IAEA assistance or the withdrawal of material and equipment provided by the agency.[13]

- The IAEA **will not generally**: certify a Member State's compliance with safeguards or try to predict a Member State's future intentions regarding their nuclear program.[14] The IAEA is not a police force with enforcement powers when it comes to safeguard inspections and does not make decisions about actions to be taken against the Member States not complying with safeguards.[15]

Additional functions of the IAEA are set out in article three of the NPT, which obliges States parties to accept safeguard provisions, which should be negotiated between the Member State and the IAEA in accordance with the provisions outlined in the *IAEA Statute* and the NPT.[16] The IAEA is responsible for supervising and ensuring compliance to the established safeguard provisions, including the prevention of the misuse of nuclear material for non-peaceful usage, such as nuclear weapons or other explosive nuclear devices, and the supervision of the production, possession, and usage of fissionable material.[17] Finally, the *IAEA Statute* establishes the IAEA's reporting requirements to UN bodies, including annual reports to the General Assembly, reports to the Security Council as needed, and reports to other organs regarding matters within the fields of those bodies.[18]

Governance, Structure, and Membership

The General Conference, attended by all IAEA Member States, is the highest policy body of the IAEA and meets annually.[19] The General Conference discusses and makes decisions on matters within the scope set in the *IAEA Statute*, including the election of the Board of Governors, the approval of applications for membership, the appointment of the Director-General, and the decision upon changes made to the *IAEA Statute*.[20] Additionally, the General Conference has the power to suspend Member States, consider the annual report of the IAEA, vote on the budget suggested by the Board of Governors, adopt reports submitted to the UN, and approve agreements made between the IAEA and the UN or other organizations.[21]

The Board of Governors, which consists of 35 representatives of IAEA Member States and is elected by the General Conference, meets five times annually and makes recommendations to the General Conference concerning the IAEA's accounts, actions, and budget, as well as considers applications for IAEA membership.[22] The Board also prepares the annual report of the IAEA on the activities and actions of the agency, which is presented to the General Conference each year.[23] Overall, the Board is responsible for carrying out the functions of the IAEA as outlined in the Statute and according to its responsibilities to the General Conference.[24]

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[12] Ibid. art. III A.
[13] Ibid. art. III A.
[14] Priest. IAEA Bulletin. *IAEA safeguards and the NPT: Examining interconnections*. 1995. pp. 10-11.
[15] Ibid. pp. 10-11.
[16] United Nations, General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (A/RES/2373 (XXII))*. 1968.
[17] Ibid.
[18] International Atomic Energy Agency. *IAEA Statute*. 1989. art. III.
[19] International Atomic Energy Agency. *General Conference*. 2022.
[20] International Atomic Energy Agency. *IAEA Statute*. 1989. art. V.
[21] Ibid. art. V.
[22] International Atomic Energy Agency. *Board of Governors*. 2022.
[23] International Atomic Energy Agency. *IAEA Statute*. 1989. art. VI.
[24] Ibid. art. VI.

Annotated Bibliography

Fischer. *History of the International Atomic Energy Agency: The First Forty Years*. 1997. Retrieved 5 August 2022 from: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1032_web.pdf

This publication covers the first forty years of the IAEA's history and describes the foundation and developments of the agency during that period. The publication particularly focuses on the foundation of the agency and the difficulties the IAEA faced during the Cold War. The publication provides an in-depth and comprehensive oversight of the challenges and achievements of the agency during the first forty years after its creation. Even though the publication is quite old and lacks the development of the last twenty years, it is a helpful and rich source to learn about the first years of the agency and the challenges during the Cold War and post-Cold War period.

International Atomic Energy Agency. *IAEA Statute*. 1989. Retrieved 5 August 2022 from: https://www.iaea.org/sites/default/files/statute.pdf

Adopted in 1956, the Statute is the founding document of the IAEA that outlines and describes the terms and conditions of the establishment and the functioning of the agency. The Statute includes objectives, functions, rules for memberships, and further regulations concerning the structure and the work of the IAEA. The Statute is the ideal source to get familiar with the agency's mandate, responsibilities, functions, powers, and possibilities. This source is a good starting point for delegates' research and provides a basis for the knowledge necessary to continue research on the substantive work and actions of the agency.

International Atomic Energy Agency. *Atoms for Peace and Development: How the IAEA supports the Sustainable Development Goals*. 2015. Retrieved 5 August 2022 from: https://www.iaea.org/sites/default/files/sdg-brochure_forweb.pdf

The report explains very well the connection between the responsibilities and tasks of the IAEA and the Sustainable Development Goals. The agency shows how nuclear energy can contribute to advancing the goals, and how their projects and initiatives can advance many areas to make them become reality. This publication is a good way to help delegates connect the IAEA's work not purely to nuclear and energy security, but also to often overlooked humanitarian and development aims. The diversification of the IAEA's work is well illustrated and should motivate delegates to perceive the agency as more than just a supervisor of the distribution of nuclear weapons and nuclear energy usage.

United Nations, General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (A/RES/2373 (XXII))*. 1968. Retrieved 5 August 2022 from: http://www.undocs.org/en/A/RES/2373(XXII)

The Treaty on the Non-Proliferation of Nuclear Weapons *is one of the most important treaties leading and defining the IAEA's responsibilities, mandate, and powers. The treaty depicts a major achievement of the agency and significantly advanced the combat against the spread of nuclear weapons. The treaty provides delegates with the necessary knowledge of the current legal situation regarding the proliferation of nuclear weapons and shows possible gaps and necessary improvements that delegates should discuss and negotiate on.*

Bibliography

Fischer. *History of the International Atomic Energy Agency: The First Forty Years*. 1997. Retrieved 5 August 2022 from: http://www-pub.iaea.org/MTCD/publications/PDF/Pub1032_web.pdf

International Atomic Energy Agency. *IAEA Statute*. 1989. Retrieved 5 August 2022 from: https://www.iaea.org/sites/default/files/statute.pdf

International Atomic Energy Agency. *Atoms for Peace and Development: How the IAEA supports the Sustainable Development Goals*. 2015. Retrieved 5 August 2022 from: https://www.iaea.org/sites/default/files/sdg-brochure_forweb.pdf

International Atomic Energy Agency. *Board of Governors*. 2022. Retrieved 5 August 2022 from: https://www.iaea.org/about/policy/board/

International Atomic Energy Agency. *General Conference*. 2022. Retrieved 5 August 2022 from: https://www.iaea.org/about/policy/gc/

International Atomic Energy Agency. *The IAEA Mission Statement*. 2022. Retrieved 5 August 2022 from: https://www.iaea.org/about/mission

Kamishima. IAEA Bulletin. *Ten years of the IAEA Peaceful Uses Initiative*. 2020. Retrieved 5 August 2022 from: https://www.iaea.org/sites/default/files/6140406.pdf

Llukmani. International Atomic Energy Agency. *General Conference: Day 5 Highlights*. 2021. Retrieved 5 August 2022 from: https://www.iaea.org/newscenter/news/general-conference-day-5-highlights-24-september-2021

New Zealand Ministry of Foreign Affairs and Trade. *United Nations Handbook 2022-23*. 2022. Retrieved 11 October 2022 from: https://www.mfat.govt.nz/assets/Peace-Rights-and-Security/Our-work-with-the-UN/UN-Handbook-2022-23.pdf

Priest. IAEA Bulletin. *IAEA safeguards and the NPT: Examining interconnections*. 1995. Retrieved 5 August 2022 from: https://www.iaea.org/sites/default/files/publications/magazines/bulletin/bull37-1/37103480913.pdf

United Nations, General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (A/RES/2373 (XXII))*. 1968. Retrieved 5 August 2022 from: http://www.undocs.org/en/A/RES/2373(XXII)

1. Nuclear Waste Management

Introduction

Radioactive substances have numerous peaceful applications, ranging from power generation to treating cancer.[25] All of these applications produce radioactive waste, which needs to be managed in a way that protects people and the environment.[26] In the context of this guide, radiation refers only to ionizing radiation, which consists of particles and waves with enough energy to change atoms into ions.[27] In accordance with its mandate, the International Atomic Energy Agency (IAEA) is authorized to establish safety standards to ensure the safety and protection of health, life, and properties when dealing with radiation.[28] This includes the safe management of nuclear waste.[29]

Radioactive waste is defined in the *IAEA Safety Glossary* (2019) as a material that has no further use and "contains, or is contaminated with, radionuclides at activity concentrations greater than clearance levels" allow.[30] While material that is less radioactive than the clearance level is considered physically radioactive, it only bears negligible hazards.[31] The IAEA uses the terms radioactive waste and nuclear waste interchangeably.[32] The central issue with nuclear waste is its radioactivity, as this property can cause it to be harmful to its surroundings for thousands of years.[33] In high doses, radiation causes radiation sickness and death, while exposure to lower doses can cause several health issues, including cancer.[34] To determine the timespan in which radioactive materials emit radiation, the amount of time it takes for half of the radioactive material to emit radiation and thereby transform into another atom is measured.[35] This time period is called half-life and it differs for every radioactive atom, spanning from fractions of a second to thousands of years.[36]

Radioactive waste management covers a broad range of administrative and operational activities concerning the processing, transport, storage, and disposal of radioactive waste.[37] In this context, disposal of radioactive waste implies that it is placed in a location with no intention of retrieving it, whereas storage refers to depositing waste in a location with the intention of retrieving it at a later time.[38] The IAEA identifies six classes of radioactive waste with different waste management requirements regarding containment and isolation.[39] These classes include: low-level waste (LLW), which needs to be contained for periods of up to a few hundred years; intermediate-level waste (ILW), which needs to be stored for extended periods in depths of up to a few hundred meters; and high-level waste (HLW), which

[25] International Atomic Energy Agency. *IAEA Safety Standards Series No. SF-1: Fundamental Safety Principles*. 2006. p. 1.
[26] International Atomic Energy Agency. *Radioactive waste and spent fuel management*. 2022.
[27] National Cancer Institute. *Accidents at Nuclear Power Plants and Cancer Risk*. 2022.
[28] International Atomic Energy Agency. *IAEA Statue*. 1989. art. III, nr. 6.
[29] International Atomic Energy Agency. *Radioactive waste and spent fuel management*. 2022.
[30] International Atomic Energy Agency. *IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection 2018 Edition*. 2019. p. 186.
[31] Ibid. p. 186.
[32] International Atomic Energy Agency. *Getting to the Core of Radioactive Waste*. 2011. p. 8.
[33] International Atomic Energy Agency. *IAEA Safety Standards Series No. SSR-5: Disposal of Radioactive Waste: Specific Safety Requirements*. 2011.
[34] National Cancer Institute. *Accidents at Nuclear Power Plants and Cancer Risk*. 2022.
[35] Encyclopedia Britannica. *Half-life*. 2020.
[36] Ibid.
[37] International Atomic Energy Agency. *IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection 2018 Edition*. 2019. p. 187.
[38] International Atomic Energy Agency. *IAEA Safety Standards Series No. SSR-5: Disposal of Radioactive Waste: Specific Safety Requirements*. 2011. p. 3.
[39] International Atomic Energy Agency. *IAEA Safety Standards Series No. GSG-1: Classification of Radioactive Waste: General Safety Guide*. 2009. p. 5.

has high levels of radioactivity, generates a significant amount of heat, and needs to be disposed of deep underground.[40]

In 2022, the IAEA published that as of 2016 it is estimated that 392,000 tons of heavy metal used in nuclear technology, including uranium, have been produced since the first nuclear power plants began operating in the 1950s.[41] The IAEA stated that approximately 32.4% of the heavy metal has been reprocessed and can be used further as fuel for nuclear reactors.[42] Further estimates assume that there are currently 29,000 m³ of solid radioactive waste in storage or disposal.[43] If placed on a soccer pitch, this volume would roughly take up the space of a three-meter-tall building.[44] Most of the very-low-level and low-level waste has been disposed of, while only 5% of ILW and none of HLW, which makes up about 0.1% of all solid radioactive waste, is in disposal.[45] Even though ILW and HLW make up a small percentage of the waste volume, they approximately hold 95% of the radioactivity making it very hard to dispose of.[46]

International and Regional Framework

Article three of *The Statute of the International Atomic Energy Agency* (1956) sets out the IAEA's responsibility to establish standards and best practices for the peaceful use of radioactive materials.[47] This article further specifies that the IAEA is the main body for addressing the management of nuclear waste and that Member States should adhere to the IAEA guidelines.[48] International regulation of how radioactive materials are used is necessary because the negative impacts of mishandled radioactive waste will be felt beyond the borders of the Member State in which they originated.[49] The IAEA has published its overall approach, regulations, and guidelines in the *IAEA Safety Standards* series.[50] The overall philosophy taken to ensure safety is outlined in the Fundamental Safety Principles.[51] The remaining guides are categorized into safety requirements, which outline firm regulations necessary for the protection of people and the environment, and safety guides, which offer recommendations on best practices to ensure the highest safety standards.[52] These IAEA publications cover a wide range of different topics on nuclear safety, including medical applications, uranium production, energy generation, and the proper management of radioactive waste.[53]

The *2030 Agenda for Sustainable Development* (2030 Agenda) is a fundamental international framework that was agreed upon in 2015 to promote development that is economically, socially, and environmentally sustainable.[54] The 2030 Agenda contains 17 Sustainable Development Goals (SDGs) covering different aspects of sustainability, including SDG 3 (good health and well-being), SDG 7 (clean and affordable energy), and SDG 13 (climate action).[55] Sustainable use of nuclear technology requires that the waste

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[40] Ibid. pp. 5-6.
[41] Harper et al. Academic Press. *Uranium*. 2008; World Nuclear Association. *Outline History of Nuclear Energy*. 2020; World Nuclear Association. *Radioactive Waste Management*. 2022.
[42] World Nuclear Association. *Radioactive Waste Management*. 2022.
[43] Ibid.
[44] Ibid.
[45] Ibid.
[46] International Atomic Energy Agency. *Status and trends in spent fuel and radioactive waste management*. 2022. p. 10.
[47] International Atomic Energy Agency. *The IAEA Mission Statement*. 2022; International Atomic Energy Agency. *IAEA Statue*. 1989. art. III.
[48] International Atomic Energy Agency. *IAEA Statue*. 1989. art. III.
[49] International Atomic Energy Agency. *IAEA Safety Standards Series No. SF-1: Fundamental Safety Principles*. 2006. p. 1.
[50] International Atomic Energy Agency. *Safety standards*. 2022.
[51] Ibid.
[52] Ibid.
[53] Ibid.
[54] United Nations, Department of Economic and Social Affairs. *Do you know all 17 SDGs?* 2022.
[55] International Atomic Energy Agency. *Sustainable Development Goal 7: Affordable and clean energy*. 2022; International Atomic Energy Agency. *Sustainable Development Goal 13: Climate action*. 2022; International

produced by these activities is managed sustainably, therefore SDG 12 (ensure sustainable consumption and production patterns) includes the "environmentally sound management of chemicals and all wastes throughout their life cycle" as one of its targets.[56] This includes nuclear waste, which requires particular expertise to manage and dispose of sustainably.[57]

Given that nuclear waste has the potential to be weaponized, its proper management also falls under the remit of the *Treaty on the Non-Proliferation of Nuclear Weapons* (NPT) (1968).[58] This treaty is the primary international agreement for ensuring the peaceful use of nuclear technology while preventing the proliferation of atomic weapons.[59] While the IAEA itself is not a party to the treaty, article three does task the IAEA with verifying whether states are in adherence with the treaty, and IAEA standards are an important element in determining whether the treaty is being respected by its parties.[60]

Role of the International System

The IAEA hosts numerous conferences to help share progress in the field of nuclear waste management between stakeholders and assist them in strengthening their approaches to disposing of radioactive waste.[61] One such conference was the Conference on Sustainable Solutions in Radioactive Waste Management in November 2021.[62] To facilitate discussion, abstracts and papers were submitted on seven interrelated aspects of radioactive waste management, including integrated waste management and the socio-economic aspects of radioactive waste management programs.[63] During the conference, many speakers acknowledged that the vast majority of radioactive waste produced was being disposed of responsibly, but that facilities required for proper disposal of HLW were not yet built.[64] The first operational deep geological repository worldwide will soon be completed in Finland.[65]

IAEA does not only publish standards for the proper handling of nuclear waste, but also works with various organizations and governments to help them to be implemented.[66] One way in which IAEA has done this is through the creation of the *Joint Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management*, which was agreed upon in 1997.[67] This agreement was the first legal instrument to address nuclear waste through an international framework.[68] By signing this legal framework, each of the 88 parties to this agreement committed to ensuring IAEA safety standards on all forms of radioactive waste.[69] They further agreed to submit reports detailing measures taken to

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Atomic Energy Agency. *IAEA Conference on Sustainable Solutions in Radioactive Waste Management Opens*. 2021.

[56] United Nations, Department of Economic and Social Affairs. *Ensure sustainable consumption and production patterns*. 2022.

[57] International Atomic Energy Agency. *Nuclear knowledge management*. 2022.

[58] World Nuclear Association. *International Nuclear Waste Disposal Concepts*. 2020.

[59] International Atomic Energy Agency. *The NPT and IAEA safeguards*. 2021; United Nations, General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (A/RES/2373 (XXII))*. 1968.

[60] Ibid.

[61] International Atomic Energy Agency. *International Conference on Radioactive Waste Management: Solutions for a Sustainable Future*. 2021.

[62] International Atomic Energy Agency. *IAEA Conference on Sustainable Solutions in Radioactive Waste Management Opens*. 2021.

[63] Ibid.

[64] Ibid.

[65] Ibid.

[66] International Atomic Energy Agency. *The IAEA Mission Statement*. 2022.

[67] International Atomic Energy Agency. *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (INFCIRC/546)*. 1997; International Atomic Energy Agency. *The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. 2022.

[68] International Atomic Energy Agency. *The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. 2022.

[69] International Atomic Energy Agency. *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (INFCIRC/546)*. 1997.

implement these standards, which will be peer-reviewed by other Member States at review meetings taking place approximately every three years.[70] Feedback on these reports is given by the IAEA and other Member States so that progress can be monitored and suggestions for improvement can be made.[71]

Peer-reviewing is also used within the IAEA's Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS).[72] Through this IAEA program, IAEA-appointed experts provide independent peer reviews of national programs assessing the handling of radioactive waste.[73] They come from different IAEA Member States and are experts in different aspects of nuclear waste management.[74] The missions take place at the request of the government of a Member State and usually take one or two weeks.[75] Each review results in a report containing suggestions on how nuclear waste management can be handled more safely and efficiently.[76] Methods that are found to be particularly effective are added to the ARTEMIS database for good practices to be widely shared with other organizations looking to improve the management of nuclear waste.[77]

The IAEA works with other bodies in the UN system to promote the proper management of radioactive waste.[78] Among them is the General Assembly First Committee, which regularly passes resolutions on this topic, the most recent being General Assembly resolution 76/35 on "Prohibition of the Dumping of Radioactive Wastes", adopted in December 2021.[79] This resolution emphasizes the dangers of badly managed radioactive waste, such as an increased risk of developing cancer.[80] It further calls on Member States to prevent dumping of such waste in any way that could infringe on the sovereignty of other Member States.[81] It also encourages Member States to join the *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*, emphasizing its importance.[82]

An important contribution made by the IAEA toward the sustainable management of nuclear waste is the range of coordinated research projects (CRPs) it supports.[83] The IAEA provides funding for a three- to five-year collaboration between 10 to 15 research institutes on a particular topic.[84] A new CRP, Performance Assessment of Storage Systems for Extended Durations, was established in April 2022, which looks at the implementation of storage systems for radioactive waste and particularly on how to assess the performance of existing facilities of which some are over 50 years old.[85]

As well as other UN bodies, the IAEA also cooperates with actors outside the UN system to accomplish its objectives.[86] One example of this is the Status and Trends in Spent Fuel and Radioactive Waste

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[70] International Atomic Energy Agency. *The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management: An Overview*. 2022.
[71] International Atomic Energy Agency. *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (INFCIRC/546)*. 1997.
[72] International Atomic Energy Agency. *Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS)*. 2022.
[73] Ibid.
[74] International Atomic Energy Agency. *Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (Artemis) Mission to Germany*. 2019.
[75] Ibid.
[76] International Atomic Energy Agency. *Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS)*. 2022.
[77] International Atomic Energy Agency. *ARTEMIS good practices*. 2022.
[78] International Atomic Energy Agency. *United Nations system*. 2022.
[79] United Nations, General Assembly. *Prohibition of the dumping of radioactive wastes (A/RES/76/35)*. 2021.
[80] Ibid.; World Nuclear Association. *Radioactive Waste - Myths and Realities*. 2022.
[81] United Nations, General Assembly. *Prohibition of the dumping of radioactive wastes (A/RES/76/35)*. 2021.
[82] Ibid.
[83] International Atomic Energy Agency. *Coordinated Research Activities*. 2022.
[84] International Atomic Energy Agency. *IAEA Factsheet: IAEA Coordinated Research Activities*. 2019: International Atomic Energy Agency. *How CRPs work*. 2022.
[85] Gastl. International Atomic Energy Agency. *New CRP: Performance Assessment of Storage Systems for Extended Durations*. 2022.
[86] International Atomic Energy Agency. *Partnerships*. 2022.

Management project, which is a collaboration with the European Commission (EC), the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD NEA), and the World Nuclear Association.[87] This project provides an overview of programs regarding the management of spent fuel and radioactive waste and uses data to estimate the stocks of spent fuel and radioactive waste worldwide.[88] These estimations are compared with earlier ones to draw conclusions on the long-term development of nuclear waste globally.[89] By comparing estimated inventories of radioactive waste between 2013 and 2016, the IAEA was able to conclude that the total amount of solid waste in storage or disposal has increased by about 7%, which is in line with the increase of waste being produced over that time span.[90] The majority of this increased waste was very low-level waste.[91]

There are also regional frameworks dedicated to properly managing nuclear waste, including the European Union's (EU) Radioactive Waste and Spent Fuel Management Directive.[92] This directive requires EU Member States to create national programs detailing how all nuclear waste generated within their territory will be managed and disposed of, including an independent regulatory body and sufficient funding.[93] To monitor progress, this directive requires Member States to submit reports on its implementation to the EC every three years.[94] EU Member States are also required to assess their progress and to allow these assessments to be peer-reviewed at least once every 10 years.[95]

To represent stakeholders in the global nuclear industry, the World Nuclear Association was founded in 2001.[96] This organization represents nuclear plant operators, construction companies, and service companies in the nuclear energy industry at international meetings and workshops, including at the 2021 Conference on Sustainable Solutions in Radioactive Waste Management.[97] It also gathers information on best practices for the nuclear energy industry and provides training programs through the World Nuclear University.[98]

Current Options for the Disposal and Processing of Radioactive Waste

To protect against the harmful properties of radioactive waste, it should be contained and isolated from the environment.[99] There are different options for the disposal of each kind of radioactive waste.[100] LLW can typically be disposed of in near-surface facilities.[101] Near-surface facilities in caverns store nuclear waste at a depth of tens of meters below the surface.[102] These facilities can be disrupted by environmental changes, such as the formation of glaciers or floods.[103] Near-surface facilities are typically used for waste with short half-lives, such as LLW and short-lived ILW, since these types of waste do not require to be stored for long periods of time and the facilities do not need to resist environmental changes over centuries.[104]

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[87] International Atomic Energy Agency. *Status and Trends in Spent Fuel and Radioactive Waste Management*. 2022. p. 1.
[88] Ibid. p. 1.
[89] Ibid. p. 54.
[90] Ibid. p. 55.
[91] Ibid. p. 55.
[92] European Commission. *Radioactive waste and spent fuel*. n.d.
[93] Ibid.
[94] Ibid.
[95] Ibid.
[96] World Nuclear Association. *Our Mission*. 2022.
[97] Ibid.
[98] Ibid.
[99] International Atomic Energy Agency. *Status and trends in spent fuel and radioactive waste management*. 2022. p. 26.
[100] World Nuclear Association. *Storage and Disposal of Radioactive Waste*. 2021.
[101] Ibid.
[102] Ibid.
[103] Ibid.
[104] Ibid.

HLW needs to be disposed of in deep geological repositories because of the high-level and long-lived radioactivity, as well as the subsequent hazards for people and the environment.[105] This method requires suitable locations that are accessible and provide a stable environment with no groundwater flow in depths between 250 meters and 1000 meters.[106] The focus of most efforts so far has been on mined repositories.[107] Here packaged waste is placed in tunnels or caverns and then surrounded by materials that provide an additional barrier.[108] The activity level of HLW is so high that it generates heat, which has to be considered by waste management facilities.[109] Finland is close to beginning the operation of the first disposal facility for HLW worldwide, while other countries are still looking for locations to safely operate such a facility.[110]

Deep borehole disposal is another option for geological isolation.[111] A borehole to a depth of up to 5000 meters is drilled into basement rock, waste canisters are then placed into the lower 2000 meters of the borehole, and the upper 3000 meters are sealed.[112] To implement deep borehole disposal, significant research and development needs to be done to design and approve suitable canisters and explore drilling technology.[113] Deep borehole disposal has a high potential for managing small inventories of waste, but there is still a need for further testing and development.[114] The concept of deep borehole disposal has been explored in several countries, but it is more expensive than deep geological disposal and has faced significant economic challenges.[115] To support Member States in implementing borehole disposal, the IAEA has provided a the 2009 report, *IAEA Safety Standards Series No. SSG-1: Borehole Disposal Facilities for Radioactive Waste: Specific Safety Guide*, and also launched a research project in 2019 to develop a framework for borehole disposal.[116]

Spent fuel is generated by nuclear reactors and, if not reprocessed, it is considered HLW.[117] Currently, states can implement an open-cycle or a closed-cycle strategy when handling spent fuel.[118] In the open-cycle strategy, spent fuel is considered waste and is disposed of.[119] In the closed-cycle strategy, spent fuel is considered a potential resource for energy in the future.[120] Unused plutonium and uranium can be recovered through reprocessing, and thereby 25-30% more energy from the original uranium can be gained.[121] This not only conserves fuel but also reduces the volume of HLW to about 20%.[122] The remaining waste from reprocessing has a lower level of radioactivity and the levels fall much more rapidly after about 100 years, which means the waste needs to be stored for shorter amounts of time and it is not

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[105] International Atomic Energy Agency. *Status and trends in spent fuel and radioactive waste management*. 2022. p. 31; World Nuclear Association. *Radioactive Waste Management*. 2022.
[106] World Nuclear Association. *Storage and Disposal of Radioactive Waste*. 2021.
[107] Ibid.
[108] Ibid.
[109] International Atomic Energy Agency. *Status and trends in spent fuel and radioactive waste management*. 2022. p. 27.
[110] Schultz. Deutsche Welle. *Finns say yes to nuclear waste*. 2022.
[111] World Nuclear Association. *Storage and Disposal of Radioactive Waste*. 2021.
[112] Ibid.
[113] Uroić et al. *Discussion on Deep Borehole Disposal of Spent Nuclear Fuel*. 2022. p. 13.
[114] Chapman. Energies. *Who Might Be Interested in a Deep Borehole Disposal Facility for Their Radioactive Waste?* 2019.
[115] World Nuclear Association. *Storage and Disposal of Radioactive Waste*. 2021.
[116] International Atomic Energy Agency. *IAEA Safety Standards Series No. SSG-1: Borehole Disposal Facilities for Radioactive Waste: Specific Safety Guide*. 2009. p. 2; Marcke. International Atomic Energy Agency. *New CRP: Developing a Framework for the Effective Implementation of a Borehole Disposal System (T22002)*. 2019.
[117] International Atomic Energy Agency. *Status and trends in spent fuel and radioactive waste management*. 2022. p. 27.
[118] Ibid. p. 27.
[119] Ibid. p. 27.
[120] Ibid. p. 27.
[121] World Nuclear Association. *Processing of Used Nuclear Fuel*. 2020.
[122] Ibid.

as hazardous for people and the environment.[123] With newer nuclear reactors, the large stockpiles of depleted uranium can become a fuel source in the future, making nuclear energy less reliant on uranium mining.[124] Uranium mining bears hazards for the workers as well as the environment, as highly radioactive gas is released during the process.[125] However, reprocessing is more expensive than mining uranium and the current options for reprocessing produce a highly radioactive mix that could be weaponized.[126] Therefore, many countries choose an open-cycle strategy.[127] While a few countries operate their own reprocessing facilities, some countries, like Italy or the Netherlands, have opted to have reprocessing services provided by other countries.[128] The process is performed under strict controls, since highly radioactive materials need to be transported between different countries and is usually based on a bilateral agreements.[129]

Knowledge Sharing to Address Nuclear Waste

In the field of nuclear technology, it is important to share and maintain knowledge and capabilities.[130] Given that nuclear waste management facilities need to be operated for long timespans, they can be affected by knowledge loss over these long periods.[131] The IAEA has emphasized the importance of sharing knowledge and experiences and passing them on to future generations.[132] In order to find ways to transfer knowledge of nuclear waste programs, the OECD NEA launched an initiative on the Preservation of Records, Knowledge and Memory (RK&M) Across Generations.[133] Its final report, published in 2019, outlines different ways to pass on knowledge on waste disposal sites.[134] These preservation approaches include, among others, time capsules, markers above and below the ground, as well as international regulations and agreements.[135] The report recommends the combination of different mechanisms with different characteristics in terms of location, actors, contents, and transmission modes to ensure the transfer of knowledge to allow future generations to make informed decisions on radioactive waste they will have to manage.[136] The report emphasizes the need for further learning and building an international preservation network to further develop and implement the ideas and methods outlined in this report.[137]

The handling of radioactive waste can be challenging for countries without domestic knowledge, therefore the IAEA supports countries in implementing suitable approaches.[138] The IAEA's Technical Cooperation Programme is its main mechanism for transferring nuclear technology to Member States.[139] This program supports Member States in addressing their needs while considering their individual situation and facilitating cooperation between Member States.[140] The IAEA established several technical cooperation projects under the African Regional Cooperative Agreement for Research, Development and Training related to Nuclear Science and Technology (AFRA), which support African countries in improving the

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[123] Ibid.
[124] Ibid.
[125] World Nuclear Association. *Uranium Mining Overview*. 2022.
[126] Day. Reuters Events. *High costs, proliferation concerns feed doubts over waste recycling*. 2021.
[127] Ibid.
[128] International Atomic Energy Agency. *Status and trends in spent fuel and radioactive waste management*. 2022. p. 29.
[129] Ibid. p. 27.
[130] International Atomic Energy Agency. *Nuclear knowledge management*. 2022.
[131] Ibid.
[132] International Atomic Energy Agency. *Status and trends in spent fuel and radioactive waste management*. 2022. p. 65.
[133] Organisation for Economic Co-operation and Development, Nuclear Energy Agency. *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Final Report of the RK&M Initiative*. 2019.
[134] Ibid. p. 14.
[135] Ibid. pp. 94-95.
[136] Ibid. p. 14.
[137] Ibid. pp. 96-97.
[138] Yusuf. International Atomic Energy Agency. *Streamlining Storage: IAEA Conducts Training in Radioactive Waste Management in Africa*. 2020.
[139] International Atomic Energy Agency. *About the TC programme*. 2022.
[140] Ibid.

existing infrastructure and fostering technical cooperation among them.[141] In 2020, the IAEA held a training course in Uganda under AFRA using a new concept for the management of disused and sealed radioactive sources.[142] This new concept involves a facility with all essential elements to process low-activity radioactive sources comprised of two standard shipping containers.[143] A group of international experts observed the course and also reviewed the facility against international standards and best practices.[144]

The IAEA offers many different training courses and capacity-building programs in several different areas, including radiation, transport, and waste safety.[145] The IAEA works together with its regional training centers and Member States to develop national strategies for education and training in line with safety standards.[146] Nine regional IAEA training centers around the world host education and training events, develop standardized training materials, and provide expertise to Member States to establish and implement national strategies for education and training in radiation, transport, and waste safety.[147] One such regional training center is the Greek Atomic Energy Commission, which operates as a IAEA Regional Training Centre in Europe.[148] They not only organize seminars, scholarships, and scientific visits but also offer a post-graduate education program, which provides education for young scientists in the field of radiation protection and safety principles.[149]

Conclusion

Used correctly, nuclear material can play a significant role in helping to reduce emissions of carbon dioxide and in treating serious health conditions, including cancer.[150] However, these activities do produce nuclear waste, some of which can remain dangerously radioactive for thousands of years.[151] Properly managing and disposing of this waste is a challenge which requires investments and technical expertise.[152] The IAEA is working closely with other bodies in the international community to ensure that every state can make peaceful use of nuclear material and dispose of its waste without putting the environment or public health at risk.[153]

Further Research

When considering how to approach responsible nuclear waste management, there are several questions for delegates to consider: Why are there currently no suitable facilities for the final disposal of HLW? What can be done to make closed-cycle strategies more economically viable? Many countries that could benefit the most from a greater use of nuclear technology are also those in the most need of greater expertise. What can IAEA and the international community do to improve current approaches to sharing and preserving expertise for future generations?

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[141] International Atomic Energy Agency. *Africa*. 2022.
[142] Yusuf. International Atomic Energy Agency. *Streamlining Storage: IAEA Conducts Training in Radioactive Waste Management in Africa*. 2020.
[143] Ibid.
[144] Ibid.
[145] International Atomic Energy Agency. *Education and training in radiation, transport and waste safety*. 2022.
[146] Ibid.
[147] International Atomic Energy Agency. *Regional training centres*. 2022.
[148] Greek Atomic Energy Commission. *EEAE: IAEA Regional Training Centre in Europe*. 2015.
[149] Ibid.
[150] International Atomic Energy Agency. *Status and trends in spent fuel and radioactive waste management*. 2022. p. 1.
[151] International Atomic Energy Agency. *IAEA Safety Standards Series No. SSR-5: Disposal of Radioactive Waste: Specific Safety Requirements*. 2011.
[152] International Atomic Energy Agency. *Nuclear knowledge management*. 2022.
[153] International Atomic Energy Agency. *The IAEA Mission Statement*. 2022.

Annotated Bibliography

International Atomic Energy Agency. *IAEA Safety Standards Series No. SF-1*: *Fundamental Safety Principles*. 2006. Retrieved 2 August 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1273_web.pdf

The IAEA has a set of fundamental principles, which inform how it approaches all its activities and are included in this document. The standards were established in the mid-1990s by the IAEA in response to a complete overhaul of their safety standards. The new set of standards includes best practices on different aspects of nuclear safety including engineering, operations, transport, and waste. These standards also contain guidance on their implementation and in assessing the effectiveness of already implemented measures. By reading this document, delegates will gain a better understanding of how the IAEA operates, its guidelines, and how it has set the guidelines that make up a large part of the international framework on the management of nuclear waste.

International Atomic Energy Agency. *Status and Trends in Spent Fuel and Radioactive Waste Management*. 2022. Retrieved 20 June 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1963_web.pdf

This publication collects and summarizes the global status of nuclear waste inventories and the management of this waste. It addresses achievements and challenges in the field of nuclear waste management and provides future estimates. The publication was developed with data from Member States and gives a comprehensive overview of all aspects of nuclear waste management. Delegates can use this source to get an overview of all the aspects of nuclear waste management that the IAEA covers.

Organisation for Economic Co-operation and Development, Nuclear Energy Agency. *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Final Report of the RK&M Initiative*. 2019. Retrieved 7 August 2022 from: https://www.oecd-nea.org/jcms/pl_15088/preservation-of-records-knowledge-and-memory-across-generations-final-report

This report provides a guide for the preservation of knowledge on radioactive waste repositories. It gives a general outline of the topic and discusses the history, ethical considerations, and various mechanisms for preservation strategies. Delegates will find a thorough report on the situation and possibilities for the preservation of knowledge over many generations.

United Nations, General Assembly. *Prohibition of the dumping of radioactive wastes (A/RES/76/35)*. 2021. Retrieved 28 July 2022 from: https://undocs.org/en/A/RES/76/35

Nuclear waste is a topic that is addressed by many different international actors. It is therefore important to understand how these other actors, particularly UN actors, work with the IAEA to promote proper nuclear waste management. This resolution provides a good example of how the General Assembly is continuing to work to address the issue. It also helps place the work of the IAEA into context within the wider UN system. By reading this source, delegates will receive a greater understanding of the current priorities of the UN and how different UN bodies can work together to address important international issues.

World Nuclear Association. *Storage and Disposal of Radioactive Waste*. 2021. Retrieved 25 June 2022 from: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx

This website discusses the different options for the disposal of radioactive waste. It gives a thorough overview of the most common options and mentions other ideas that have been explored in the past. In addition, this webpage offers many examples of different disposal facilities in several countries. Delegates will gain a more detailed understanding of the different disposal options and how they may be implemented by taking a closer look at this website.

Bibliography

Chapman. Energies. *Who Might Be Interested in a Deep Borehole Disposal Facility for Their Radioactive Waste?* 2019. Retrieved 28 July 2022 from: https://www.mdpi.com/1996-1073/12/8/1542/htm

Day. Reuters Events. *High costs, proliferation concerns feed doubts over waste recycling*. 2021. Retrieved 10 September 2022 from: https://www.reutersevents.com/nuclear/high-costs-proliferation-concerns-feed-doubts-over-waste-recycling

Encyclopedia Britannica. *Half-life*. 2020. Retrieved 7 August 2022 from: https://www.britannica.com/science/half-life-radioactivity

European Commission. *Radioactive waste and spent fuel*. n.d. Retrieved 8 September 2022 from: https://energy.ec.europa.eu/topics/nuclear-energy/radioactive-waste-and-spent-fuel_en

Gastl. International Atomic Energy Agency. *New CRP: Performance Assessment of Storage Systems for Extended Durations*. 2022. Retrieved 9 September 2022 from: https://www.iaea.org/newscenter/news/new-crp-performance-assessment-of-storage-systems-for-extended-durations-passed-crp-t13019

Greek Atomic Energy Commission. *EEAE: IAEA Regional Training Centre in Europe*. 2015. Retrieved 12 October 2022 from: https://eeae.gr/en/info-point/education-and-training/eeae-iaea-regional-training-centre-in-europe

Harper et al. Academic Press. *Uranium*. 2008. Retrieved 9 September 2022 from: https://www.sciencedirect.com/science/article/pii/B9780080454054004341

International Atomic Energy Agency. *IAEA Statue*. 1989. Retrieved 25 July 2022 from: https://www.iaea.org/sites/default/files/statute.pdf

International Atomic Energy Agency. *Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (INFCIRC/546)*. 1997. Retrieved 19 July 2022 from: https://www.iaea.org/sites/default/files/infcirc546.pdf

International Atomic Energy Agency. *IAEA Safety Standards Series No. SF-1*: *Fundamental Safety Principles*. 2006. Retrieved 2 August 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1273_web.pdf

International Atomic Energy Agency. *IAEA Safety Standards Series No. GSG-1: Classification of Radioactive Waste: General Safety Guide*. 2009. Retrieved 31 July 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1419_web.pdf

International Atomic Energy Agency. *IAEA Safety Standards Series No. SSG-1: Borehole Disposal Facilities for Radioactive Waste: Specific Safety Guide*. 2009. Retrieved 10 October 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1418_web.pdf

International Atomic Energy Agency. *Getting to the Core of Radioactive Waste*. 2011. Retrieved 8 September 2022 from: https://www.iaea.org/sites/default/files/18/10/radioactivewaste.pdf

International Atomic Energy Agency. *IAEA Safety Standards Series No. SSR-5: Disposal of Radioactive Waste: Specific Safety Requirements*. 2011. Retrieved 6 August 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1449_web.pdf

International Atomic Energy Agency. *Framework and Challenges for Initiating Multinational Cooperation for the Development of a Radioactive Waste Repository*. 2016. Retrieved 10 October 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1722_web.pdf

International Atomic Energy Agency. *Nuclear Knowledge Management Challenges and Approaches*. 2018. Retrieved 2 August 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/STIPUB1838web.pdf

International Atomic Energy Agency. *IAEA Factsheet: IAEA Coordinated Research Activities*. 2019. Retrieved 10 September 2022 from: https://www.iaea.org/sites/default/files/19/09/iaea-coordinated-research-activities.pdf

International Atomic Energy Agency. *IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection 2018 Edition*. 2019. Retrieved 31 July 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1830_web.pdf

International Atomic Energy Agency. *Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) Mission to Germany*. 2019. Retrieved 10 September 2022 from: https://www.iaea.org/sites/default/files/documents/review-missions/final_artemis_report-germany.pdf

International Atomic Energy Agency. *IAEA Conference on Sustainable Solutions in Radioactive Waste Management Opens*. 2021. Retrieved 5 August 2022 from: https://www.iaea.org/newscenter/news/iaea-conference-on-sustainable-solutions-in-radioactive-waste-management-opens

International Atomic Energy Agency. *International Conference on Radioactive Waste Management: Solutions for a Sustainable Future*. 2021. Retrieved 10 September 2022 from: https://www.iaea.org/sites/default/files/21/03/cn-294-flyer.pdf

International Atomic Energy Agency. *The NPT and IAEA safeguards*. 2021. Retrieved 16 August 2022 from: https://www.iaea.org/bulletin/the-npt-and-iaea-safeguards

International Atomic Energy Agency. *About the TC programme*. 2022. Retrieved 3 August 2022 from: https://www.iaea.org/services/technical-cooperation-programme/about

International Atomic Energy Agency. *Africa*. 2022. Retrieved 11 October 2022 from: https://www.iaea.org/services/technical-cooperation-programme/africa

International Atomic Energy Agency. *ARTEMIS good practices*. 2022. Retrieved 10 September 2022 from: https://www.iaea.org/services/review-missions/integrated-review-service-for-radioactive-waste-and-spent-fuel-management-decommissioning-and-remediation-artemis/good-practices

International Atomic Energy Agency. *Coordinated Research Activities*. 2022. Retrieved 9 September 2022 from: https://www.iaea.org/services/coordinated-research-activities

International Atomic Energy Agency. *Education and training in radiation, transport and waste safety*. 2022. Retrieved 3 August 2022 from: https://www.iaea.org/services/education-and-training/training-courses/training-radiation-transport-waste-safety

International Atomic Energy Agency. *How CRPs work*. 2022. Retrieved 2 August 2022 from: https://www.iaea.org/services/coordinated-research-activities/how-crps-work

International Atomic Energy Agency. *Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS)*. 2022. Retrieved 1 August 2022 from: https://www.iaea.org/services/review-missions/integrated-review-service-for-radioactive-waste-and-spent-fuel-management-decommissioning-and-remediation-artemis

International Atomic Energy Agency. *Nuclear knowledge management*. 2022. Retrieved 31 July 2022 from: https://www.iaea.org/topics/nuclear-knowledge-management

International Atomic Energy Agency. *Partnerships*. 2022. Retrieved 1 September 2022 from: https://www.iaea.org/about/partnerships

International Atomic Energy Agency. *Radioactive waste and spent fuel management*. 2022. Retrieved 7 August 2022 from: https://www.iaea.org/topics/radioactive-waste-and-spent-fuel-management

International Atomic Energy Agency. *Regional training centres*. 2022. Retrieved 3 August 2022 from: https://www.iaea.org/services/training/regional-centres-radiation-transport-waste-safety

International Atomic Energy Agency. *Safety standards*. 2022. Retrieved 20 July 2022 from: https://www.iaea.org/resources/safety-standards

International Atomic Energy Agency. *Status and Trends in Spent Fuel and* Radioactive *Waste Management*. 2022. Retrieved 20 June 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1963_web.pdf

International Atomic Energy Agency. *Sustainable Development Goal 7: Affordable and clean energy*. 2022. Retrieved 10 September 2022 from: https://www.iaea.org/about/overview/sustainable-development-goals/goal-7-affordable-and-clean-energy

International Atomic Energy Agency. *Sustainable Development Goal 13: Climate action*. 2022. Retrieved 10 September 2022 from: https://www.iaea.org/about/overview/sustainable-development-goals/goal-13-climate-action

International Atomic Energy Agency. *The IAEA Mission Statement*. 2022. Retrieved 31 July 2022 from: https://www.iaea.org/about/mission

International Atomic Energy Agency. *The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management*. 2022. Retrieved 1 August 2022 from: https://www.iaea.org/topics/nuclear-safety-conventions/joint-convention-safety-spent-fuel-management-and-safety-radioactive-waste

International Atomic Energy Agency. *The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management: An Overview*. 2022. Retrieved 1 September 2022 from: https://www.iaea.org/sites/default/files/22/04/22-00989.pdf

International Atomic Energy Agency. *United Nations system*. 2022. Retrieved 1 September 2022 from: https://www.iaea.org/about/partnerships/united-nations-system

Marcke. International Atomic Energy Agency. *New CRP: Developing a Framework for the Effective Implementation of a Borehole Disposal System (T22002)*. 2019. Retrieved 10 October 2022 from: https://www.iaea.org/newscenter/news/new-crp-developing-a-framework-for-the-effective-implementation-of-a-borehole-disposal-system-t22002

National Cancer Institute. *Accidents at Nuclear Power Plants and Cancer Risk*. 2022. Retrieved 1 August 2022 from: https://www.cancer.gov/about-cancer/causes-prevention/risk/radiation/nuclear-accidents-fact-sheet

Organisation for Economic Co-operation and Development, Nuclear Energy Agency. *Preservation of Records, Knowledge and Memory (RK&M) Across Generations: Final Report of the RK&M Initiative*. 2019. Retrieved 7 August 2022 from: https://www.oecd-nea.org/jcms/pl_15088/preservation-of-records-knowledge-and-memory-across-generations-final-report

Schultz. Deutsche Welle. *Finns say yes to nuclear waste*. 2022. Retrieved 5 October 2022 from: https://www.dw.com/en/finns-say-yes-to-nuclear-waste/a-62779844

United Nations, Department of Economic and Social Affairs. *Do you know all 17 SDGs?* 2022. Retrieved 10 October 2022 from: https://sdgs.un.org/goals

United Nations, Department of Economic and Social Affairs. *Ensure sustainable consumption and production patterns*. 2022. Retrieved 6 September 2022 from: https://sdgs.un.org/goals/goal12

United Nations, General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (A/RES/2373 (XXII))*. 1968. Retrieved 4 August 2022 from: http://www.undocs.org/en/A/RES/2373(XXII)

United Nations, General Assembly. *Prohibition of the dumping of radioactive wastes (A/RES/76/35)*. 2021. Retrieved 28 July 2022 from: https://undocs.org/en/A/RES/76/35

Uroić et al. *Discussion on Deep Borehole Disposal of Spent Nuclear Fuel*. 2022. Retrieved 9 September 2022 from: https://www.researchgate.net/profile/Zelimir-Veinovic/publication/361184548_Discussion_on_Deep_Borehole_Disposal_of_Spent_Nuclear_Fuel/links/62a1d5b9c660ab61f86fd0e4/Discussion-on-Deep-Borehole-Disposal-of-Spent-Nuclear-Fuel.pdf

World Nuclear Association. *International Nuclear Waste Disposal Concepts*. 2020. Retrieved 8 September 2022 from: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/international-nuclear-waste-disposal-concepts.aspx

World Nuclear Association. *Outline History of Nuclear Energy*. 2020. Retrieved 7 September 2022 from: https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx

World Nuclear Association. *Processing of Used Nuclear Fuel*. 2020. Retrieved 29 July 2022 from: https://world-nuclear.org/information-library/nuclear-fuel-cycle/fuel-recycling/processing-of-used-nuclear-fuel.aspx

World Nuclear Association. *Storage and Disposal of Radioactive Waste*. 2021. Retrieved 25 June 2022 from: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-waste/storage-and-disposal-of-radioactive-waste.aspx

World Nuclear Association. *Our Mission*. 2022. Retrieved 1 August 2022 from: https://world-nuclear.org/our-association/who-we-are/mission.aspx

World Nuclear Association. *Radioactive Waste Management*. 2022. Retrieved 8 August 2022 from: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-waste-management.aspx

World Nuclear Association. *Radioactive Waste - Myths and Realities*. 2022. Retrieved 2 October 2022 from: https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-wastes-myths-and-realities.aspx

World Nuclear Association. *Uranium Mining Overview*. 2022. Retrieved 12 October 2022 from: https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/uranium-mining-overview.aspx

Yusuf. International Atomic Energy Agency. *Streamlining Storage: IAEA Conducts Training in Radioactive Waste Management in Africa*. 2020. Retrieved 7 August 2022 from:

https://www.iaea.org/newscenter/news/streamlining-storage-iaea-conducts-training-in-radioactive-waste-management-in-africa

2. Strengthening Safeguards for the World's Nuclear Facilities

Introduction

The science of atomic radiation was developed in the first half of the 20th century, with the bulk of its progress occurring during the development of the atomic bomb.[154] After atomic bombs were used against the Japanese cities of Hiroshima and Nagasaki at the end of World War II, attention shifted to peaceful development and applications of nuclear energy, such as making steam and electricity.[155] In 1953, the United States established the Atoms for Peace program and largely shifted the focus of its national nuclear activity toward nuclear energy development.[156] Created against the backdrop of the Cold War and the existential threat posed by a nuclear arms race, the program laid the foundation for an international commitment to the pursuit of peaceful nuclear technology.[157] This also led to the establishment of the International Atomic Energy Agency (IAEA) to oversee commitments made by the international community to prevent the proliferation of nuclear weapons and promote the safe development of nuclear science.[158]

Nuclear energy produces around 10% of the world's electricity.[159] Nuclear power plants operate in 32 countries worldwide, and many more can access this low-carbon energy source through regional transmission grids.[160] Applications of nuclear technology extend far beyond civil electricity production, and non-stationary power reactors are now essential to sectors including food and agriculture, consumer products, industry, transport, and scientific research.[161] Rather than being used to generate power, these reactors operate as neutron sources for research and training, materials testing, and producing radioisotopes for medicine and industry.[162] Naturally decaying atoms, or radioisotopes, possess numerous practical applications to modern-day life.[163] For example, everyday consumer products, including smoke detectors, watches and clocks, and non-stick materials, require properties of radioisotopes in their design.[164] Radioactive materials are used for inspecting the integrity of metal welds and infrastructure in many industries.[165] Nuclear technology is also used in sustainable development infrastructure such as desalination facilities, which provide access to safe drinking water in water-stressed areas.[166]

The IAEA inspects the world's nuclear facilities and verifies their compliance with international safety standards and nuclear non-proliferation agreements.[167] To carry out its duties, the IAEA maintains a robust framework of safeguards that facilitate its oversight and verification practices.[168] The use of safeguards is at the center of all global nuclear non-proliferation activities, as they combat the illicit diversions of nuclear material for military use and help build confidence among nuclear weapons states and non-nuclear weapons states (NNWS).[169] The IAEA embeds safeguards across all binding

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[154] World Nuclear Association. *Outline of Nuclear Energy*. 2020.
[155] Ibid.
[156] International Atomic Energy Agency. *Atoms for Peace Speech*. 2022.
[157] Ibid.
[158] International Atomic Energy Agency. *Factsheets and FAQs – Nuclear Safety*. 2011.
[159] World Nuclear Association. *The Many Uses of Nuclear Technology*. 2021.
[160] Ibid.
[161] Ibid.
[162] World Nuclear Association. *Radioisotopes in Industry*. 2022.
[163] Ibid.
[164] World Nuclear Association. *The Many Uses of Nuclear Technology*. 2021.
[165] Ibid.
[166] World Nuclear Association. *Nuclear Desalination*. 2021.
[167] International Atomic Energy Agency. *Factsheets and FAQs – Nuclear Safety*. 2011.
[168] International Atomic Energy Agency. *Safeguards Explained*. 2022.
[169] Ibid.

agreements surrounding peaceful nuclear energy use.[170] These safeguards are technical measures to independently verify Member States' compliance with all non-proliferation and safety commitments.[171]

International and Regional Framework

The global non-proliferation regime is built upon norms established by the *Charter of the United Nations* (1948).[172] The Charter recognizes the principle of diverting as few of the world's resources as possible to arms production and manufacturing, underscoring the inextricable relationship between disarmament and development.[173] All arms reduction measures, including safeguards, are essential tactics to achieve objectives laid out in the *2030 Agenda for Sustainable Development* (2030 Agenda) (2015).[174] Ensuring the security and safe use of fissile material applies to the scope of its Sustainable Development Goals (SDGs) due to the existential nature of nuclear technology's implications, including those on public health, economic stability, and environmental preservation.[175]

The 1980 *Convention on the Physical Protection of Nuclear Material* (CCPNM) codifies the international legal obligations that protect nuclear material for peaceful purposes.[176] The CCPNM supports the physical protection of nuclear material during international transport and encourages Member States to impose criminal penalties for unlawful possession of nuclear materials.[177] Its scope has since been broadened by its 2005 amendment to cover the protection of nuclear facilities and the further criminalization of illicit trafficking and sabotage-related offenses.[178] The system of nuclear safeguards in place to ensure nuclear material is being developed in adherence to legal standards is guided by the 1957 *Statute of the IAEA*.[179] Article III gives the IAEA the power to establish and apply safeguards to any bilateral or multilateral agreement on atomic energy and the breadth of a Member State's national nuclear program upon that state's request.[180] To facilitate this, article X asks Member States to make any services, equipment, or facilities available to the IAEA to assist the IAEA in fulfilling its objectives and functions.[181] The IAEA is then responsible for carrying out its rights and responsibilities toward safeguards applications as outlined in article XII, including the examination of equipment and facilities, observing health and safety measures, requiring maintenance and production of operating records, calling for and receiving progress reports, and requiring the deposit of excess fissionable materials recovered as a byproduct of licit development.[182]

The *Treaty on the Non-Proliferation of Nuclear Weapons* (NPT), adopted in 1968, is the first and only multilateral non-proliferation framework to mandate IAEA safeguards.[183] Considered the cornerstone of the global non-proliferation regime, the NPT lays the groundwork for all subsequent multilateral disarmament pursuits.[184] The treaty is designed to further the goals of nuclear disarmament and promote the peaceful application of nuclear technology.[185] 191 Member States have signed onto the legally binding treaty, including the five nuclear-weapon states: the United States of America, the Russian

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[170] Ibid.
[171] Ibid.
[172] United Nations Conference on International Organization. *Charter of the United Nations*. 1945.
[173] International Atomic Energy Agency. *Safeguards Explained*. 2022.
[174] Ibid.
[175] International Atomic Energy Agency. *IAEA Statute*. 1989. p. 6
[176] International Atomic Energy Agency. *Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment*. 2022.
[177] Ibid.
[178] Ibid.
[179] International Atomic Energy Agency. *IAEA Statute*. 1989. p. 6.
[180] Ibid. pp. 7-8.
[181] Ibid. p. 22.
[182] Ibid. pp. 25-26.
[183] Rockwood. International Atomic Energy Agency. *Legal Frameworks for IAEA Safeguards*. 2013. p. 4.
[184] United Nations, General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (A/RES/2373 (XXII))*. 1968.
[185] Ibid.

Federation, the United Kingdom of Great Britain and Northern Ireland, France, and China.[186] However, all States parties to the treaty have the right to withdraw should any of its commitments conflict with their national interests.[187]

The NPT creates a safeguards system to prevent the diversion of nuclear material for military use.[188] IAEA safeguards are also referenced as a confidence-building measure for States parties to the NPT and to verify compliance with its various commitments.[189] Article III of the NPT is dedicated to applying safeguards in compliance with the *Statute of the IAEA* and the IAEA safeguards system.[190] Under this article, all NNWS parties to the NPT are required to negotiate Comprehensive Safeguard Agreements (CSAs) with the IAEA.[191] States with nuclear weapons and non-signatories to the NPT may conclude similar agreements voluntarily.[192] To structure the budget necessary to implement the NPT, article IV of the NPT commits States parties to contribute funding on an individual or collaborative basis as they are able to do so.[193]

After the NPT entered into force, the IAEA Board of Governors established a committee to advise on the contents of safeguards agreements being conducted between the IAEA and NNWS parties to the NPT.[194] The Safeguards Committee concluded in 1972 with a document to provide a basis for negotiating safeguards agreements, *The Structure and Content of Agreements between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons* (INFCIRC/153).[195] It requires Member States to submit an initial report to the IAEA on all operational and non-operational national nuclear facilities and fissile material upon establishing a comprehensive safeguards agreement.[196] The IAEA is then responsible for verifying whether a facility is constructed and operated as reported by the participating Member State.[197] In 1997, the *Model Protocol to the Agreements between States and the International Atomic Energy Agency for the Application of Safeguards* (Model Additional Protocol) was approved by the Board of Governors to set a standard for additional protocols conducted by states and other parties to safeguards agreements.[198]

Role of the International System

As the primary global nuclear inspectorate, the IAEA works with Member States and stakeholders to promote the peaceful development and use of nuclear technologies.[199] The IAEA Board of Governors gives final approval to all safeguards agreements.[200] Approved safeguards agreements are then administered by the IAEA Department of Safeguards, which oversees nuclear material analysis, installation and maintenance of safeguards equipment, inspection logistics, and other data analysis and technical support.[201] One IAEA program designed to help carry out this work is the Integrated Regulatory

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[186] Ibid.
[187] Ibid.
[188] Ibid.
[189] Ibid.
[190] Ibid.
[191] Ibid.
[192] International Atomic Energy Agency. *Safeguards legal framework*. 2022.
[193] United States Department of State, Bureau of International Security and Nonproliferation. *The IAEA Peaceful Uses Initiative and the NPT*. 2019.
[194] Rockwood. International Atomic Energy Agency. *Legal Frameworks for IAEA Safeguards*. 2013. p. 12.
[195] Ibid. p. 12.
[196] International Atomic Energy Agency. *The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/153)*. 1972. p. 3.
[197] Ibid. p. 3.
[198] International Atomic Energy Agency. *Department of Safeguards*. 2022.
[199] International Atomic Energy Agency. *Board of Governors*. 2022.
[200] Ibid.
[201] International Atomic Energy Agency. *Department of Safeguards*. 2022.

Review Service (IRRS).[202] This team of senior regulatory experts conducts missions to review all regulatory functions and responsibilities of Member States' nuclear programs.[203] IRRS missions help improve national nuclear and radiation safety infrastructure and adherence to IAEA standards and international good practices.[204]

The IAEA has also established the Peaceful Uses Initiative (PUI) to contribute to the SDGs and provide the agency with greater flexibility to respond to shifts in Member States' national policies or priorities.[205] The PUI channels donor funding to projects that address the practical needs of Member States, including public health, infrastructure development, water resource management, food security, and environmental protection.[206]

In addition to the IAEA, several principal organs of the United Nations (UN) system address issues surrounding nuclear non-proliferation and safeguards applications.[207] The Security Council is mandated to maintain international peace and security, with Member States obligated to comply with all decisions made by the council.[208] The General Assembly First Committee considers all matters of disarmament and international security related to efforts produced across the UN system.[209] The First Committee promotes cooperative measures intended to strengthen stability through disarmament, including the use of nuclear safeguards.[210] The United Nations Office for Disarmament Affairs was established upon the recommendation of the General Assembly to provide substantive and organizational support for disarmament efforts across the UN system.[211]

The IAEA has a broad range of partners outside the UN to support its nuclear safeguards system, including civil society organizations, philanthropic foundations, academic institutions, and private companies.[212] Non-governmental organizations (NGOs) are key to enabling information sharing across the nuclear disarmament field.[213] For example, the Arms Control Association (ACA) is an organization working to build a broader public understanding of effective arms control policies through reliable and accessible information.[214] The organization provides policymakers, the media, and interested public with authoritative analyses across the global disarmament landscape.[215] ACA publishes "Arms Control Today", a monthly peer-reviewed journal on non-proliferation and international security.[216] Other NGOs and research institutions with similar operations include the Brookings Institution, the Bulletin of Atomic Sciences, and the Federation of American Scientists.[217]

These NGOs build a strong network of cross-sector expertise, helping the IAEA adapt its programming and processes to the evolving global environment.[218] To leverage this information network, the IAEA hosts a Symposium on International Safeguards for its stakeholders to convene and pursue solutions to

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[202] International Atomic Energy Agency. *IAEA Mission Sees Commitment to Nuclear Safety in Argentina, Recommends Areas for Improvement*. 2022.
[203] Ibid.
[204] Ibid.
[205] International Atomic Energy Agency. *Peaceful Uses Initiative*. 2022.
[206] United States Department of State, Bureau of International Security and Nonproliferation. *The IAEA Peaceful Uses Initiative and the NPT*. 2019.
[207] United Nations, Office for Disarmament Affairs. *United Nations Disarmament Yearbook 2017: Part II*. 2018. p. 201.
[208] United Nations, Security Council. *United Nations Security Council*. n.d.
[209] United Nations, General Assembly. *Disarmament and International Security (First Committee)*. n.d.
[210] Ibid.
[211] Ibid.
[212] Guillen. International Atomic Energy Agency. *IAEA Forges New Partnerships in Support of Safeguards*. 2021.
[213] Arms Control Association. *About the Arms Control Association*. n.d.
[214] Ibid.
[215] Ibid.
[216] Ibid.
[217] Global Security Institute. *NGO Links*. 2022.
[218] Guillen. International Atomic Energy Agency. *IAEA Forges New Partnerships in Support of Safeguards*. 2021.

current challenges.[219] In addition to the symposium's role in strengthening nuclear verification activity, the IAEA has established formal partnerships with five organizations to date: the Institute of Nuclear Materials Management, the European Safeguards Research and Development Association, Rosatom Technical Academy, the Center for Energy and Security Studies, and the Verification Research, Training and Information Center.[220]

Leveraging Innovations for Safeguard Applications

The IAEA is obligated to monitor and consider advancements in relevant technologies when fulfilling its responsibilities, including those related to applying and upholding nuclear safeguards.[221] Through the biennial Emerging Technologies Workshop (ETW), the Department for Safeguards engages with diverse stakeholders who are experts in their field to detect and assess the potential impact that technologies under development may have on its mission and implement this understanding to improve preparedness.[222] These stakeholders include academics, representatives from private sector firms that have deployed cutting-edge technology in their respective industries, and experts from NGOs committed to peacebuilding.[223] The IAEA takes a proactive approach to emerging technologies by also recognizing their potential to create unprecedented challenges to safeguarding the peaceful use of atomic energy and making it an operational priority to leverage novel technologies to improve organizational effectiveness.[224]

The 2020 ETW focused on the challenges and opportunities technological advancements bring to nuclear research and development.[225] For example, the IAEA actively promotes the development of new, more sustainable nuclear reactors that have greater efficiency than current models, supporting the critical global transition to low-carbon energy production.[226] The IAEA has worked with the Generation IV International Forum to focus research and development on six promising reactor technologies.[227] This innovation has many anticipated benefits but also creates obstacles to the safeguarding process.[228] For example, the small size of this technology makes it difficult for IAEA inspectors to physically scrutinize reactors deployed in inaccessible and remote areas and increases the number of locations where unauthorized activities could occur.[229] There is also concern that constructing these reactors may outpace the IAEA's ability to implement equally innovative safeguarding solutions.[230] This challenge is made more difficult due to a misalignment of motivation among stakeholders, such as prioritizing project costs and delivery time over facilitating the IAEA's safeguarding obligations.[231]

Emerging technologies must also be considered for their potential to be modified and exploited for unauthorized purposes.[232] One example is additive manufacturing, often referred to as 3D-printing, which has removed barriers to manufacturing materials for the nuclear industry and enabled components to be

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[219] Ibid.
[220] Ibid.
[221] International Atomic Energy Agency. T*he Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/153)*. 1972. p. 2.
[222] International Atomic Energy Agency. *Emerging Technologies Workshop: Insights and Actionable Ideas for Key Safeguards Challenges*. 2020. p. 5.
[223] Ibid. p. 5.
[224] Ibid. p. 5.
[225] Ibid.
[226] Donovan. International Atomic Energy Agency. *Next Generation Nuclear Reactors: IAEA and GIF Call for Faster Deployment*. 2020.
[227] Ibid.
[228] International Atomic Energy Agency. *Emerging Technologies Workshop: Trends and Implications for Safeguards*. 2017. pp. 19-23.
[229] Ibid. pp. 19-23.
[230] Ibid. pp. 19-23.
[231] Ibid. p. 19.
[232] Ibid. p. 28.

produced more locally.[233] This advancement has unintentionally enabled illicit parties to circumvent obstacles to proliferation by allowing them to print advanced structures that could assist the development of nuclear technologies with minimal specialist knowledge.[234] Similarly, improvements in the strength of high-powered commercial lasers mean that they could potentially be repurposed to enrich uranium.[235] Their small footprint reduces the likelihood of malicious users being detected.[236]

These challenges are emerging when the IAEA's safeguarding workload is significantly increasing already.[237] The number of nuclear facilities being constructed worldwide is rising and, at the same time, many older facilities are beginning the decommissioning process.[238] This context reinforces the need for resilience through innovation - to do more with less.[239] Although new technologies have the potential to make the safeguarding process more complex, the IAEA's proactive approach to leveraging emerging technology for safeguard purposes presents an opportunity to mitigate the potential downsides to innovation.[240]

The IAEA verifies state nuclear activity through Member State self-reporting, information collected from physical site visits by IAEA inspectors, and data gathered from publicly available sources.[241] As in other areas of life, technological advances will considerably impact the need for inspectors to be physically present at sites, with new cameras and sensors enabling large quantities of data to be gathered and analyzed remotely.[242] New multi-sensor high-resolution commercial satellite technology provides significant opportunities to detect information relevant to safeguarding in real time.[243] Within IAEA-monitored sites, 3D cameras fitted with light detection and ranging devices can also improve the robustness of unauthorized access detection systems through enhanced movement tracking.[244] One example is the Laser Curtain for Containment and Tracking system, which produces a continuously monitored "virtual box" around safeguarded items.[245] If unusual activity is detected within this area, an alarm alerts IAEA inspectors so the intrusion can be further investigated to ensure compliance.[246]

The integrity of nuclear material accountancy can be further improved by combining existing and emerging technologies with Distributed Ledger Technology (DLT).[247] DLT is a method of storing a database across multiple locations where no single user can alter its content.[248] It helps record nuclear material transactions' details in real time and increases confidence in supply chains.[249] These surveillance

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[233] Watson et al. International Atomic Energy Agency. *Nuclear Power Supply Chain New Avenues of Success as Global Markets Shift*. 2021.
[234] International Atomic Energy Agency. *Emerging Technologies Workshop: Trends and Implications for Safeguards*. 2017. pp. 16-17.
[235] Ibid. pp. 16-17.
[236] Ibid. p. 18.
[237] International Atomic Energy Agency. *Safeguards in Practice*. 2022.
[238] Ibid.
[239] International Atomic Energy Agency. *Enhancing Capabilities for Nuclear Verification: Resource Mobilization Priorities*. 2022. p. 3.
[240] International Atomic Energy Agency. *Report: Symposium on International Safeguards, Building Future Safeguards Capabilities*. 2018. p. 21.
[241] International Atomic Energy Agency. *Information Collection and Evaluation*. 2022.
[242] International Atomic Energy Agency. *Report: Symposium on International Safeguards, Building Future Safeguards Capabilities*. 2018. p. 20.
[243] International Atomic Energy Agency. *Development and Implementation Support Programme for Nuclear Verification 2022-2023*. 2022. pp. 63-64.
[244] Ibid. p. 128.
[245] Sequeira et al. Institute of Nuclear Materials Management. *Laser Curtain for Containment and Tracking*. 2021. p. 1.
[246] Ibid. p. 1.
[247] International Atomic Energy Agency. *Emerging Technologies Workshop: Insights and Actionable Ideas for Key Safeguards Challenges*. 2020. pp. 18-20.
[248] Ibid. pp. 18-20.
[249] Ibid. pp. 18-20.

technologies are linked with artificial intelligence, machine learning, and deep learning techniques to analyze ever-increasing volumes of data.[250]

Improving Cooperation with Authorities Responsible for Safeguards Implementation (SRAs)

Adequate safeguards require cooperation between Member States and the IAEA.[251] To facilitate this, state's systems of accountancy for and control of nuclear material (SSACs) are a vital component of CSAs.[252] State or regional authorities (SRAs) are responsible for implementing robust safeguards at the national level, including establishing and running SSACs to maintain accurate records of what nuclear materials a state has, when it has them, for what purpose, and in what location.[253] Individual SSACs also contain details of the processes necessary for practical nuclear accounting, such as the requirement for stringent licensing conditions in the import and export of nuclear materials, the need to submit relevant design information to the IAEA, and facilitating access to data pertinent to safeguarding.[254] As required by CSAs, this accounting and reporting system needs to be enshrined in Member States' domestic law and ensures nuclear materials are not diverted from peaceful purposes.[255] This is important because IAEA inspectors have jurisdiction to compel access to records, reports, and relevant premises.[256]

Worldwide, almost 500 nuclear power plants are currently in operation or under construction, as well as more than 400 research and ship-based reactors.[257] This is in addition to secure nuclear waste facilities, post-accident sites such as Chernobyl in Ukraine, and countless other commercial nuclear devices such as MRI scanners.[258] The scale of the regulatory challenge is such that IAEA relies upon SRAs to effectively carry out its function, with the overall success of their safeguard mission broadly dependent on SSACs.[259]

Launched in 2020, the Comprehensive Capacity-Building Initiative for SSACs and SRAs (COMPASS) provides Member States with the opportunity to benefit from the IAEA's institutional safeguards knowledge.[260] Through a collaborative approach, those taking part will initially receive an assessment of its safeguard provisions, which will form the basis of a bespoke support package with defined success indicators.[261] Although each case is unique, opportunities for collaboration include legal and regulatory advice, staff training, specialist equipment, and technical support.[262] The program takes five years to complete, and seven Member States have so far signed up for the program's pilot stage.[263] In addition to SRAs benefiting from expert evaluation and recommendations, this increased cooperation provides an opportunity for the IAEA to discover and circulate best practice information across the wider safeguard community.[264]

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[250] International Atomic Energy Agency. *Report: Symposium on International Safeguards, Building Future Safeguards Capabilities*. 2018. p. 20.
[251] International Atomic Energy Agency. *Safeguards Implementation Practices Guide on Establishing and Maintaining State Safeguards Infrastructure*. 2018. p. 3.
[252] Ibid. p. 3.
[253] Ibid. p. 3.
[254] Ibid. p. 3.
[255] Ibid. p. 3.
[256] Ibid. p. 75.
[257] World Nuclear Association. *Nuclear Power in the World Today*. 2022.
[258] Ibid.
[259] International Atomic Energy Agency. *Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards (GC (65)/16)*. 2021. p. 11.
[260] International Atomic Energy Agency. *IAEA Bulletin: IAEA and the NPT*. 2021. pp. 6-7.
[261] Ibid. p. 7.
[262] Ibid. p. 7.
[263] International Atomic Energy Agency. *Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards (GC (65)/16)*. 2021. p. 11.
[264] International Atomic Energy Agency. *IAEA Safeguards and SSAC Advisory Service (ISSAS) Guidelines*. 2021. p. 2.

Conclusion

IAEA is responsible for facilitating the implementation of nuclear safeguards to ensure that nuclear technologies are used for peaceful purposes.[265] This is achieved by ensuring that the oversight and verification of nuclear activities are central to international agreements.[266] To further strengthen its safeguard regime, IAEA takes a proactive approach to emerging technologies by monitoring potential threats to its safeguarding mission and seeking opportunities to apply novel technologies for the same purpose.[267] While the IAEA is already improving its capabilities in a drive to do more with less, it is still significantly reliant upon Member States carrying out its SSACs effectively.[268] With their workload rapidly increasing alongside technological advances and the demand for low-carbon energy rising, strengthening safeguards is likely to be central to the IAEA's future success.[269]

Further Research

As delegates research the topic, they should consider the following: what unique challenges do emerging technologies pose? How can the international community address the uncertainty surrounding emerging technology, especially regarding fissile material? How can novel technologies be quickly adopted and applied to existing safeguards agreements? How can civil society, philanthropists, the private sector, and academia contribute to strengthening safeguards applications? How can the IAEA be more proactive in boosting the efficiency and effectiveness of SRAs? Where should the IAEA focus its limited resources in the context of ever-increasing safeguard challenges?

Annotated Bibliography

International Atomic Energy Agency. *IAEA Safeguards Glossary 2001 Edition*. 2002. Retrieved 22 June 2022 from: https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf

Published and distributed by the IAEA, this glossary builds an understanding of specialized terminology relevant to safeguards applications. The 2001 Edition improves upon the previous glossary published in 1987, which was an update to the first IAEA Safeguards Glossary *(1980). The document contains 13 sections, each addressing a specific topic relevant to IAEA safeguards. While the document has no legal status and is not intended to influence any interpretation or negotiation of safeguards agreements or additional protocols, delegates will find the glossary a helpful reference document during their research to gain a broader understanding of how the IAEA facilitates integrated safeguards across the international community.*

International Atomic Energy Agency. *Emerging Technologies Workshop: Insights and Actionable Ideas for Key Safeguards Challenges*. 2020. Retrieved 25 June 2022 from: https://www.iaea.org/sites/default/files/20/06/emerging-tehnologies-workshop-290120.pdf

This report summarizes the 2020 Emerging Technologies Workshop held by the IAEA to develop strategies to address the challenges and opportunities emerging technologies present for nuclear verification. The document concludes with critical insights from the workshop, providing a succinct list of observations and priorities drawn from the stakeholder landscape. This report can help delegates develop a more robust understanding of the recurring themes and obstacles across efforts to strengthen safeguards.

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[265] International Atomic Energy Agency. *Safeguards Explained*. 2022.
[266] Ibid.
[267] International Atomic Energy Agency. *Emerging Technologies Workshop: Insights and Actionable Ideas for Key Safeguards Challenges*. 2020. p. 5.
[268] International Atomic Energy Agency. *Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards (GC (65)/16)*. 2021. p. 11.
[269] World Nuclear Association. *Nuclear Power in the World Today*. 2022.

International Atomic Energy Agency. *Conference of the Parties to the Amendment to the Convention on the Physical Protection of Nuclear Material*. 2022. Retrieved 26 June 2022 from: https://www.iaea.org/events/acppnm2022

This outcome document was produced after the 2022 Conference of the Parties to the Amendment to the Convention on the Physical Protection of Nuclear Material. Convened to review the implementation of the Convention, the 2022 Conference is among the more recent efforts to address the adequacy of safeguards agreements. The outcome document offers delegates a comprehensive view of current norms surrounding safeguards applications and the broad scope of challenges posed by future development, such as emerging technologies and growing demand for safeguard applications.

Rockwood. International Atomic Energy Agency. *Legal Frameworks for IAEA Safeguards*. 2013. Retrieved 22 July 2022 from: https://www.iaea.org/sites/default/files/16/12/legalframeworkforsafeguards.pdf

This book aims to introduce the concept of IAEA safeguards to the reader and describe the legal framework for their implementation. The book is published by the IAEA and author Laura Rockwood served as the IAEA Section Head for Non-Proliferation and Policy Making in the Office of Legal Affairs for over thirty years. Her analysis examines topics such as the fundamental documents upon which the safeguards system is based, states' undertakings in safeguards agreements, common decisions and practices, and a comparison of safeguards agreements. The publication aims to be accurate and objective, allowing delegates to examine these integral frameworks from the IAEA perspective.

United Nations, General Assembly. *The Convention on the Physical Protection of Nuclear Material (INFCIRC/274/Rev. 1)*. 1980. Retrieved 26 June 2022 from: https://www.iaea.org/sites/default/files/infcirc274r1.pdf

The Convention on the Physical Protection of Nuclear Material is the foundational document codifying the need for levels of physical protection for nuclear material during international transport. States parties to the Convention are required to make serious offenses involving nuclear material punishable by law and have the responsibility to cooperate in the recovery and return of stolen material as applicable. As a critical international security framework, delegates can refer to the Convention to infer recurring themes and implications specific to facility structure and the lifecycle of nuclear materials and use this context to propose new ideas toward workable solutions.

Bibliography

Arms Control Association. *About the Arms Control Association*. n.d. Retrieved 11 September 2022 from: https://www.armscontrol.org/about

Donovan. International Atomic Energy Agency. *Next Generation Nuclear Reactors: IAEA and GIF Call for Faster Deployment*. 2020. Retrieved 9 September 2022 from: https://iaea.org/newscenter/news/next-generation-nuclear-reactors-iaea-and-gif-call-for-faster-deployment

Global Security Institute. *NGO Links*. 2022. Retrieved 11 September 2022 from: https://gsinstitute.org/dpe/ngo-links/

Guillen. International Atomic Energy Agency. *IAEA Forges New Partnerships in Support of Safeguards*. 2021. Retrieved 9 August 2022 from: https://www.iaea.org/newscenter/news/iaea-forges-new-partnerships-in-support-of-safeguards

International Atomic Energy Agency. *The Structure and Content of Agreements Between the Agency and States Required in Connection with the Treaty on the Non-Proliferation of Nuclear Weapons (INFCIRC/153)*. 1972. Retrieved 26 June 2022 from: https://www.iaea.org/sites/default/files/publications/documents/infcircs/1972/infcirc153.pdf

International Atomic Energy Agency. *IAEA Statue*. 1989. Retrieved 22 July 2022 from: https://www.iaea.org/sites/default/files/statute.pdf

International Atomic Energy Agency. *IAEA Safeguards Glossary 2001 Edition*. 2002. Retrieved 22 June 2022 from: https://www.iaea.org/sites/default/files/iaea_safeguards_glossary.pdf

International Atomic Energy Agency. *Factsheets and FAQs – Nuclear Safety*. 2011. Retrieved 9 August 2022 from: https://www.iaea.org/publications/factsheets/nuclear-facility-safety

International Atomic Energy Agency. *Emerging Technologies Workshop: Trends and Implications for Safeguards*. 2017. Retrieved 26 June 2022 from: https://www.iaea.org/sites/default/files/18/09/emerging-technologies-130217.pdf

International Atomic Energy Agency. *Report: Symposium on International Safeguards, Building Future Safeguards Capabilities*. 2018. Retrieved 26 June 2022 from: https://www.iaea.org/sites/default/files/19/07/cn-267-symposium-report.pdf

International Atomic Energy Agency. *Safeguards Implementation Practices Guide on Establishing and Maintaining State Safeguards Infrastructure*. 2018. Retrieved 8 August 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/SVS_31_web.pdf

International Atomic Energy Agency. *Emerging Technologies Workshop: Insights and Actionable Ideas for Key Safeguards Challenges*. 2020. Retrieved 25 June 2022 from: https://www.iaea.org/sites/default/files/20/06/emerging-tehnologies-workshop-290120.pdf

International Atomic Energy Agency. *IAEA Bulletin: IAEA and the NPT*. 2021. Retrieved 8 August 2022 from: https://www.iaea.org/sites/default/files/iaeaandthenpt.pdf

International Atomic Energy Agency. *IAEA Safeguards and SSAC Advisory Service (ISSAS) Guidelines*. 2021. Retrieved 9 August 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/SVS-13-R1web.pdf

International Atomic Energy Agency. *Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards (GC (65)/16)*. 2021. Retrieved 8 August 2022 from: https://www.iaea.org/sites/default/files/gc/gc65-16.pdf

International Atomic Energy Agency. *Assistance for States*. 2022. Retrieved 22 July 2022 from: https://www.iaea.org/topics/assistance-for-states

International Atomic Energy Agency. *Atoms for Peace Speech*. 2022. Retrieved 22 July 2022 from: https://www.iaea.org/about/history/atoms-for-peace-speech

International Atomic Energy Agency. *Basics of IAEA Safeguards*. 2022. Retrieved 22 July 2022 from: https://www.iaea.org/topics/basics-of-iaea-safeguards

International Atomic Energy Agency. *Board of Governors*. 2022. Retrieved 29 October 2022 from: https://www.iaea.org/about/governance/board-of-governors

International Atomic Energy Agency. *Conference of the Parties to the Amendment to the Convention on the Physical Protection of Nuclear Material*. 2022. Retrieved 26 June 2022 from: https://www.iaea.org/events/acppnm2022

International Atomic Energy Agency. *Convention on the Physical Protection of Nuclear Material (CPPNM) and its Amendment*. 2022. Retrieved 11 September 2022 from:

https://www.iaea.org/publications/documents/conventions/convention-physical-protection-nuclear-material-and-its-amendment

International Atomic Energy Agency. *Department of Safeguards*. 2022. Retrieved 9 August 2022 from: https://www.iaea.org/about/organizational-structure/department-of-safeguards

International Atomic Energy Agency. *Development and Implementation Support Programme for Nuclear Verification 2022-2023*. 2022. Retrieved 29 October 2022 from: https://www.iaea.org/sites/default/files/22/02/development-and-implmentation-support-programme-for-nuclear-verification-2022-2023.pdf

International Atomic Energy Agency. *Enhancing Capabilities for Nuclear Verification: Resource Mobilization Priorities*. 2022. Retrieved 1 August 2022 from: https://www.iaea.org/sites/default/files/22/02/rmp-2022.pdf

International Atomic Energy Agency. *IAEA Mission Sees Commitment to Nuclear Safety in Argentina, Recommends Areas for Improvement*. 2022. Retrieved 12 September 2022 from: https://www.iaea.org/newscenter/pressreleases/iaea-mission-sees-commitment-to-nuclear-safety-in-argentina-recommends-areas-for-improvement

International Atomic Energy Agency. *IAEA Safeguards in 2021*. 2022. Retrieved 22 July 2022 from: https://www.iaea.org/sites/default/files/22/06/sg-implementation-2021.pdf

International Atomic Energy Agency. *Information Collection and Evaluation*. 2022. Retrieved 1 August 2022 from: https://www.iaea.org/topics/information-collection-and-evaluation

International Atomic Energy Agency. *Nuclear law institute: A Collective View on a Decade of Capacity Building and Development in Nuclear Law*. 2022. Retrieved 22 July 2022 from: https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1962_web.pdf

International Atomic Energy Agency. *Peaceful Uses Initiative*. 2022. Retrieved 11 September 2022 from: https://www.iaea.org/services/key-programmes/peaceful-uses-initiative

International Atomic Energy Agency. *Safeguards agreements*. 2022. Retrieved 22 July 2022 from: https://www.iaea.org/topics/safeguards-agreements

International Atomic Energy Agency. *Safeguards explained*. 2022. Retrieved 29 October 2022 from: https://www.iaea.org/topics/safeguards-explained

International Atomic Energy Agency. *Safeguards legal framework*. 2022. Retrieved 22 July 2022 from: https://www.iaea.org/topics/safeguards-legal-framework

International Atomic Energy Agency. *Safeguards in Practice*. 2022. Retrieved 1 August 2022 from: https://www.iaea.org/topics/safeguards-in-practice

Mutluer. International Atomic Energy Agency. *Robotics Challenge Winning Design Helps Speed up Spent Fuel Verification*. 2019. Retrieved 28 July 2022 from: https://www.iaea.org/newscenter/news/robotics-challenge-winning-design-helps-speed-up-spent-fuel-verification

Mutluer. International Atomic Energy Agency. *In-field Nuclear Verification Effort Continues to Grow: IAEA Safeguards Statement 2021*. 2022. Retrieved 22 July 2022 from: https://www.iaea.org/newscenter/news/in-field-nuclear-verification-effort-continues-to-grow-iaea-safeguards-statement-2021

Rockwood. International Atomic Energy Agency. *Legal Frameworks for IAEA Safeguards*. 2013. Retrieved 22 July 2022 from: https://www.iaea.org/sites/default/files/16/12/legalframeworkforsafeguards.pdf

Sequeira et al. Institute of Nuclear Materials Management. *Laser Curtain for Containment and Tracking*. 2021. Retrieved 8 August 2022 from: https://resources.inmm.org/annual-meeting-proceedings/laser-curtain-containment-and-tracking

United Nations Conference on International Organization. *Charter of the United Nations*. 1945. Retrieved 29 October 2022 from: https://www.un.org/en/about-us/un-charter/full-text

United Nations, General Assembly. *Disarmament and International Security (First Committee)*. n.d. Retrieved 9 August 2022 from: https://www.un.org/en/ga/first/

United Nations, General Assembly. *Treaty on the Non-Proliferation of Nuclear Weapons (A/RES/2373 (XXII))*. 1968. Retrieved 9 September 2022 from: http://www.undocs.org/en/A/RES/2373(XXII)

United Nations, General Assembly. *The Convention on the Physical Protection of Nuclear Material (INFCIRC/274/Rev. 1)*. 1980. Retrieved 26 June 2022 from: https://www.iaea.org/sites/default/files/infcirc274r1.pdf

United Nations, Office for Disarmament Affairs. *United Nations Disarmament Yearbook 2017: Part II*. 2018. Retrieved 9 August 2022 from: https://www.un-ilibrary.org/content/books/9789210473552c009

United Nations, Security Council. *United Nations Security Council*. n.d. Retrieved 29 October 2022 from: https://www.un.org/securitycouncil/

United States Department of State, Bureau of International Security and Nonproliferation. *The IAEA Peaceful Uses Initiative and the NPT*. 2019. Retrieved 11 September 2022 from: https://www.state.gov/wp-content/uploads/2019/06/PUI-Fact-Sheet.pdf

Wagman. International Atomic Energy Agency. *50 years of NPT Comprehensive Safeguards Agreements – The Legal Bedrock of Nuclear Verification*. 2022. Retrieved 22 July 2022 from: https://www.iaea.org/newscenter/news/50-years-of-npt-comprehensive-safeguards-agreements-the-legal-bedrock-of-nuclear-verification

Watson et al. International Atomic Energy Agency. *Nuclear Power Supply Chain Eyes New Avenues of Success as Global Markets Shift*. 2021. Retrieved 9 September 2022 from: https://iaea.org/newscenter/news/nuclear-power-supply-chain-eyes-new-avenues-of-success-as-global-markets-shift

World Nuclear Association. *Outline History of Nuclear Energy*. 2020. Retrieved 8 August 2022 from: https://world-nuclear.org/information-library/current-and-future-generation/outline-history-of-nuclear-energy.aspx

World Nuclear Association. *Nuclear Desalination*. 2021. Retrieved 8 August 2022 from: https://www.world-nuclear.org/information-library/non-power-nuclear-applications/industry/nuclear-desalination.aspx

World Nuclear Association. *The Many Uses of Nuclear Technology*. 2021. Retrieved 8 August 2022 from: https://www.world-nuclear.org/information-library/non-power-nuclear-applications/overview/the-many-uses-of-nuclear-technology.aspx

World Nuclear Association. *Nuclear Power in the World Today*. 2022. Retrieved 8 August 2022 from: https://world-nuclear.org/information-library/current-and-future-generation/nuclear-power-in-the-world-today.aspx

World Nuclear Association. *Radioisotopes in Industry*. 2022. Retrieved 29 October 2022 from: https://world-nuclear.org/information-library/non-power-nuclear-applications/radioisotopes-research/radioisotopes-in-industry.aspx