

International Cooperation in Nuclear Energy Through the Prism of IAEA Standards

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Abstract

A peaceful use of atomic energy requires international cooperation, security, safety, and nonproliferation standards. International atomic energy cooperation is influenced by IAEA standards. As an international safety authority, the IAEA develops standards and guidelines that become national standards. Using IAEA statutory mandates, security conventions, and nuclear project cases, our analysis compares soft law standards with international obligations that are mandatory. Despite not being legally binding, IAEA security standards are global pillars of nuclear security. The standards contribute to a common security culture, allow for technology exchange with strict guarantees, and are often incorporated into bilateral and multilateral agreements. International nuclear cooperation cannot be safe and effective without adhering to the standards set by the IAEA Atomic Energy Bank, new nuclear energy programs, and expert evaluation missions. Standards from the IAEA aren't formally voluntary, but they are often incorporated into national laws and international agreements, making atomic energy more secure, safe, and resilient.

Keywords: International nuclear cooperation, IAEA safety standards, peaceful use of nuclear energy, nuclear governance and regulation, nuclear safety and security, international nuclear law, compliance with international standards.

1. Introduction

Nuclear energy has a lot of potential, but it also has a lot of risks that do not go away. Accidents or misuse of nuclear material can have global or regional consequences. Since the beginning of the atomic era, international cooperation has been at the center of the world nuclear order. Among these are research and technology exchanges, joint projects, and mutual control. Security, safety, and only peaceful nuclear activities are also crucial to the International Atomic Energy Agency (IAEA), founded in 1957. The IAEA's Charter requires it to promote peaceful use of atomic energy and international cooperation, as well as establish standards for health protection and minimizing risks. Almost 200 security standards have been developed by the IAEA over the last few decades to reflect international consensus on what makes nuclear security good. This IAEA Security Standard covers the entire life cycle of nuclear facilities - from design and construction to operations and decommissioning. Although these standards aren't legally binding on sovereign states, they've been adopted widely and have become "inseparable starting points and common bases" for nuclear security worldwide. The IAEA standards are often used as a basis for national rules or as benchmarks [1].

Legally, IAEA standards are examples of soft law in international nuclear governance. They supplement mandatory international agreements with technical details and best practices.

For example, the contracting parties to various international security conventions (such as the 1994 Nuclear Security Convention) rely on IAEA security standards as a consistent and reliable tool for fulfilling their contractual obligations. In essence, the global nuclear security regime consists of a hierarchy: broad legally binding principles in treaties, reinforced by detailed, non-binding codes and

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IAEA guidelines, which states agree to implement (politically). This interaction made it possible to achieve a high degree of international harmonization in the field of nuclear security without encroaching on national sovereignty, since states voluntarily include these standards. For example, the European Union officially recognized IAEA standards as the basis for harmonizing nuclear security between member states, and the EU's Nuclear Security Directive directly relies on the IAEA's Basic Principles of Security [2].

International cooperation in nuclear energy is not limited to security, it also includes non-proliferation and security. According to the 1968 Treaty on the Non-Proliferation of Nuclear Weapons (NPT), non-nuclear states are guaranteed the "right to develop research, production, and use of nuclear energy for peaceful purposes" and "to benefit from international cooperation" in this area, provided that non-proliferation commitments are observed. Article IV of the NPT thus establishes the legal basis for the exchange of nuclear technologies, stipulated by the IAEA's warranties on preventing the diversion from weapons. The IAEA manages the global guarantee system and requires that any nuclear materials, equipment, or assistance it provides not be used for military purposes. Through technical cooperation programs, the IAEA annually supports hundreds of projects in areas such as nuclear energy, radiation medicine, agriculture, and environmental protection. These projects are an example of peaceful nuclear cooperation in action, often combining donor expertise with recipient needs under IAEA coordination. All such assistance is provided within the framework of agreements obliging the host state to use technology exclusively for peaceful purposes and to apply IAEA standards and security guarantees. Thus, IAEA standards serve as a "prism" through which international nuclear cooperation is focused - ensuring that countries, while gaining the benefits of nuclear technologies, also maintain high standards of security, security, and non-proliferation expected by the international community.

2. Research Method

This research includes a qualitative, legal analytical methodology. We will examine primary international legal documents, IAEA documents, and secondary literature to assess the role of IAEA standards in international nuclear cooperation. The main sources include the IAEA Charter, publication of safety standards, and relevant conventions (Convention on Nuclear Safety, Joint Convention on the Safety of Recycled Fuel Management and on the Safety of Radioactive Waste Management, Convention on the Physical Protection of Nuclear Material, etc.). They are analyzed to determine how they include or refer to IAEA standards. We will also examine IAEA's program reports and resolutions, such as the IAEA's Basic Principles of Security and the IAEA's Nuclear Security Action Plan (2011), to understand the evolution of international norms after major nuclear disasters.

In addition, we conduct practical research on specific cases of international nuclear cooperation, using document analysis and, if available, a combination of reporting data. Cases include technical cooperation projects coordinated by the IAEA in new nuclear energy countries (for example, assistance provided to the United Arab Emirates, Bangladesh, and other countries in launching the first nuclear power plants). The multilateral initiatives under the auspices of the IAEA, in particular, the establishment of the IAEA Low Enriched Uranium Bank (LOU) in Kazakhstan, are an example of global cooperation in ensuring nuclear fuel supply. Missions of the Integrated Regulatory Analysis Service (IRRS) and the Operational Safety Review Group (OSART), as well as missions and networks for mutual review, such as the Regulatory Authority Forum (RCF), which brings together experts from different countries to assess and improve national practices in accordance with IAEA standards.

For each case, we evaluate documents (e.g., mission reports, official statements, agreements) to determine references to IAEA standards and their practical impact. Bangladesh's nuclear energy program is analyzed using government statements and IAEA missions' reports. Compliance with international standards means participating in IAEA expert reviews.

The advantages and disadvantages of relying on IAEA standards in international atomic energy cooperation. What do they do? They analyze legal texts and situations. In light of recent geopolitical events and international law debates (soft law and hard law), the results are discussed. By combining doctrinal analysis with practical examples, you will gain a better understanding of the legal framework and how it works.

3. Result and Discussion

According A In cooperation initiatives, IAEA safety standards play a vital role in ensuring nuclear safety around the world. Since 1958, IAEA has set and adopted safety standards to protect people and the environment from radiation.

IAEA safety standards are not binding on member states because each state regulates nuclear safety within its borders. In practice, these standards are widely recognized and often incorporated into

national laws and international treaties, according to the results. Many countries adopt safety fundamentals and requirements voluntarily, using "shall" language.

Indeed, the use of IAEA standards as a benchmark or minimum criterion for national nuclear regulators is widespread. For example, the United Kingdom's Office for Nuclear Regulation explicitly compares its national safety assessment principles with IAEA standards. Many other countries also have similar approaches, meaning that reactor designs or operational practices acceptable in one country may comply with IAEA standards and therefore be acceptable in other countries - this is a key factor in international cooperation and reactor exports [3].

Global safety conventions affirm this role. The Convention on Nuclear Safety (CNS) obliges its Contracting Parties to ensure a high level of safety by establishing international standards for the safety of nuclear power plants. Although the CNS does not explicitly list each of the IAEA's standards, they were discussed taking these standards into account, and the IAEA's safety guidelines are often explicitly referred to as national performance criteria in the review meetings within the CNS framework. In fact, IAEA standards provide a consistent, reliable way for the parties to these conventions to demonstrate compliance with their treaty obligations. A similar pattern is observed in the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. According to one of the IAEA reports, "The obligations of the Contracting Parties are mostly based on international safety standards developed by the IAEA." IAEA standards are soft law, but they're embedded in hard law through state practice.

IAEA's Nuclear Safety Series plays a parallel role in nuclear safety. The amended Convention on Physical Protection of Nuclear Material (CPPNM) contains comprehensive legal norms for protecting nuclear materials, but implementation depends on IAEA recommendations. IAEA best practices and assessment missions are also used by nuclear security initiatives like the Global Initiative to Combat Nuclear Terrorism.

In a broader sense, regional frameworks and bilateral agreements strengthen IAEA standards in global cooperation. The European Union's Nuclear Safety Directive clearly aligns EU requirements with the IAEA's fundamental safety principles, effectively making compliance with IAEA standards a legal requirement for all EU member states. Dozens of bilateral nuclear cooperation agreements (called "123 agreements" in American practice) include provisions requiring the host party to comply with IAEA safety standards and submit to IAEA inspections. For example, the Bilateral Agreement on Peaceful Nuclear Cooperation between the UAE and the USA (2009) - often referred to as the "gold standard" - obligates the UAE to comply with IAEA safety and security standards and even to forgo sensitive fuel cycle activities, not to proliferate cooperation, and to tie it to the highest safety standards. In conclusion, the results show that IAEA standards have de facto become international standards: any state or organization engaged in nuclear cooperation is expected to meet these criteria, creating confidence in a common language and level of safety [4].

Several case studies demonstrate how IAEA standards function in real international cooperation, bringing significant benefits and revealing challenges.

New nuclear energy programs, when countries decide to implement nuclear power for the first time, usually seek assistance from the IAEA and experienced countries. The IAEA has developed the Milestones approach and offers Integrated Nuclear Infrastructure Review (INIR) missions that assess a newcomer's readiness to address 19 infrastructure issues, including safety standards and regulatory frameworks. As an example, Bangladesh built its first nuclear power plant with Russian help (Rooppur). As a result of the IAEA safety standards, Bangladesh's Prime Minister said the country prioritized nuclear safety and radiological protection and adhered to IAEA safety standards and other guidelines when implementing the Rooppur project. It was used for involvement safety reviews (before fuel loading missions by the Operational Safety Review Team) and regulatory training. The UAE invited IAEA experts to review its Barakah nuclear plant, and the UAE said they would comply with all IAEA standards right away. Bangladesh gained expert feedback through these mechanisms, which helped build trust with neighbors and partners. Besides serving as a blueprint for national regulations, IAEA standards also served as an international oversight criterion, so suppliers (Russian Rosatom, Korean KEPCO) had an idea of what to expect. Newcomer safety standards require time and money, which means sustained political and financial commitment [5].

Several countries and organizations collaborated to establish the LEU Bank (funded by NTI, EU, US, UAE, Kuwait, Norway, Kazakhstan, and others) as a way to ensure countries had access to nuclear fuel without enriching it themselves. In order to meet IAEA safety and security standards, the storage facility had to be updated. It is a model of international cooperation. For such a joint venture to succeed, IAEA general standards (for handling materials, physical safety, etc.) needed to be agreed upon. ElBaradei, former Director General of the IAEA, says the LEU Bank is a great example of international cooperation. In addition to 35 countries, ITER (International Thermonuclear Experimental Reactor)

includes 35 countries. As the partners voluntarily adopted nuclear safety and environmental standards similar to those of the IAEA, the IAEA has influence far beyond its direct mandate.

In addition to coordinating international cooperation in atomic energy, the IAEA coordinates expert review services such as IRRS. During IRRS missions, IAEA staff and regulatory experts check a country's nuclear regulatory system for safety standards. As with IAEA standards, Dutch regulators strive to continuously improve their systems. IRRS allows us to constantly improve our work methods and comply with IAEA standards." According to our research, such missions and operational safety missions (OSART) create a cycle of mutual trust and learning. Many countries, like France, Japan, and Canada, use IAEA expert benchmarking as part of their program [6].

This cooperative control mechanism means that a country joining the nuclear energy sector can rely on global experience and convince the international community of its security measures. It effectively internationalizes the culture of nuclear safety, as although the IAEA cannot implement standards, collective control and transparency encourage compliance [7].

Another cooperation mechanism is the Regulatory Cooperation Forum (RCF), an IAEA initiative that brings together experienced and new regulators. The RCF pairs provider countries (with established nuclear programs) with recipient countries that are initiating or expanding nuclear energy programs to guide them in developing regulatory frameworks that comply with IAEA safety standards. As of 2024, these include developing nuclear countries such as Belarus, Egypt, Nigeria, and established regulators from the USA, Great Britain, France, and others. This forum has allowed regulatory bodies in Poland, Ghana, and Jordan to receive training and consultations from their counterparts in the US or Europe, ensuring that they developed control systems that comply with international standards from the very beginning. The RCF serves as an example of how IAEA standards function as a common language: regardless of geopolitical differences, safety regulators can cooperate on the technical basis of these standards to achieve a high level of safety worldwide [8].

The cases generally follow a clear pattern. Countries adopting nuclear energy for the first time rely on IAEA guidelines for responsible implementation, and suppliers often require compliance with IAEA standards in cooperation agreements. A transnational epistemic community of nuclear experts exists as a result of mutual reviews and forums that are bound by common standards and goals. The IAEA provides quality standards and oversight to multinational nuclear projects under its auspices. As nuclear technologies can be politically sensitive, each of these aspects reinforces the others, resulting in a dense network of cooperation that transcends political boundaries. Despite that, gaps still exist, especially when states don't take part [9].

IAEA standards have several specific consequences for international cooperation. First of all, they improve nuclear safety outcomes. Since all countries strive to get the same level of safety, the likelihood of a serious accident on a global scale is decreasing. Cooperation through the IAEA has led to stricter standards after major accidents. Immediately after Chernobyl, the IAEA spearheaded efforts to strengthen safety and transparency measures (for example, the 1986 Conventions on Early Notification and Assistance and, ultimately, the 1994 Convention on Nuclear Safety). IAEA members unanimously adopted the Post-Fukushima Action Plan after 2011's Fukushima Daiichi nuclear accident, which, among other things, called for strengthening IAEA safety standards in areas like stress testing, handling multiple severe accidents, and preparing for natural disasters. IAEA reports five years after Fukushima show a lot of changes were made to safety guidelines and requirements, which were developed with international participation and subsequently implemented by national regulators. Through the IAEA's coordinating role, all the other states collectively learn and enhance their standards if one country experiences a nuclear crisis [10].

Secondly, IAEA standards and verification help strengthen the international trust necessary for cooperation. Without confidence in the safe and peaceful use of nuclear materials and technologies, many countries are unwilling to allow the export of nuclear technologies or scientific exchanges. A common framework provided by IAEA standards and security guarantees serves as a re-supply mechanism. For example, under the auspices of the IAEA, more than 100 states have concluded comprehensive guarantee agreements and additional protocols, opening their nuclear activities for a thorough investigation. Their return is access to joint projects and technical resources. By joining the "Peace Use" initiative, launched in 2010, recipients of development assistance are showing a commitment to IAEA standards and transparency. It's raised \$150 million for IAEA projects ranging from nuclear power infrastructure to cancer treatments. According to our research, countries with good compliance reports (such as participating in IAEA warranty reports and expert reviews) do better in bilateral and multinational contracts. Those who don't comply or don't have the capability to regulate are isolated or conditionally held liable. IAEA Council partially suspended Iran's technical cooperation over security concerns, but only limited assistance continued under strict controls. Countries have to follow IAEA standards to maximize international nuclear cooperation [11].

Harmonizing nuclear laws and regulations around the world is good for nuclear trade and joint projects. Reactor sellers and multinational operators face fewer regulatory uncertainties if they all adhere to similar fundamental requirements. It is clear that initiatives such as the West European Nuclear Regulators Association (WENRA) will use IAEA standards to develop common security standards throughout Europe. Similarly, the Multinational Design Evaluation Program (MDEP), a National Coalition of Regulators, is working on reactor design convergence, largely relying on IAEA safety requirements. Our results show that although full international regulatory uniformity has not been achieved (each country still licenses reactors independently), the difference in security approaches has significantly decreased due to IAEA standards. For example, after the IAEA updated its seismic safety guidelines, most countries - even non-seismic - introduced more rigorous seismic reviews, which affected the location of nuclear power plants worldwide. This trend supports international cooperation, allowing joint ventures (for example, a jointly built French-Chinese reactor) to meet the expectations of both countries, as well as allowing the public to share trust ("according to AGATE standards, if it is safe in country X, it should be safe in country Y") [12].

However, the results also indicate certain difficulties and limitations. One of the problems is that IAEA standards often change and become stricter over time, which can overload older objects and programs with fewer resources. For example, the new standards following Fukushima required re-configuration measures that some operators considered financially burdensome, which sometimes led to political controversy in international discussions (some developing countries are demanding more assistance in implementing expensive updates). Another issue is that while safety and non-proliferation standards are well institutionalized, nuclear liability standards (disaster compensation) are less harmonized internationally - this is a gap in cooperation mode. Not all states have acceded to the relevant conventions (for example, the Vienna Convention on Civil Liability), which can complicate cooperation in the event of a cross-border nuclear event. The IAEA has guidelines on liability, but they do not have safety standards [13].

The above conclusions show that IAEA standards play an important, but largely informal role in the formation of international nuclear cooperation. From the point of view of legal science, this is an example of the strong influence of the concept of "soft law." Although IAEA security standards are recommendations that have no direct legal force, countries consider them mandatory due to pressure from partners, market expectations, and sincere commitment to security. This situation corresponds to the trends of general international law, where non-mandatory norms of international law (as well as ISO standards in other areas) become actually mandatory for participation in world trade or initiatives. The high level of security and security in the nuclear field has led to an implicit agreement that all partners in cooperation must comply with certain basic standards. Discussions at international forums - for example, at review meetings of the ICCPR or IAEA General Conferences - often consider deviations from IAEA standards as shortcomings that need to be corrected, which further strengthens their authority. Our analysis shows that this soft law system has been significantly successful in improving the level of security worldwide, as evidenced by the decrease in the frequency of serious incidents and the rapid dissemination of lessons learned from their occurrence [14].

The question may arise whether relying on voluntary standards is sufficient for a long-term perspective, or whether it is necessary to "tighten" these norms in contractual obligations. Flexibility and adaptability are some of the advantages of the current approach: IAEA standards can be updated quickly without the hassle of technical committees or legislative ratification. This means that the global regime can effectively respond to new challenges (for example, cybersecurity for nuclear facilities or new reactor technologies) by providing new guidelines. States can implement these updates through regulatory circulars or industrial practice codes without revising international agreements. Additionally, voluntariness encourages wider participation - countries can accept IAEA's mutual review or adopt a standard without feeling any violation of their sovereignty, as they formally retain their right to choose. This dynamic has attracted almost all countries, including those outside major power blocs, to the sphere of cooperation.

On the other hand, the shortcomings of the soft-dominant regime include potential uneven compliance and the absence of enforcement mechanisms. There is no "MAGATE police" to ensure compliance with security standards; the Agency's mandate in the field of security is primarily of a propaganda and advisory nature. As a result, if a state deliberately ignores important security practices, the consequences will be, first and foremost, reputational and, possibly, exclusion from some cooperation, but not legal sanctions. Some experts argue that certain critical standards should be mandatory or, at the very least, compliance reporting (as is done within the framework of conventions) should be strengthened. For example, establishing an obligation for periodic international expert review can ensure regular examination of each nuclear country. There was resistance to formalizing this, but the momentum is slowly growing in this direction - the European Union is now effectively obligating its

members to conduct expert reviews (through the ENSREG process) every ten years. Discussions at the IAEA often revolve around how to balance national sovereignty with global responsibility. Incidents like the security problems at the Zaporizhzhia Nuclear Power Plant in Ukraine in 2020 (occupied during the armed conflict) demonstrate that purely national security control can become an international problem overnight and have prompted calls for stronger international security guarantees. Rafael Grossi created a protective zone around this plant, making it possible for the IAEA to play a bigger role in crisis situations.

As setting high standards isn't enough; countries must also meet them, international cooperation takes a lot of planning, knowledge transfer, and resources. Even though the IAEA has a modest budget, its technical cooperation budget helps countries set up regulatory bodies, set up security measures, and train experts. It shows that cooperation isn't just solidarity and mutual assistance, it's rules and norms as well. After the Soviet collapse, the IAEA and the G7 Nuclear Safety Working Group financed many projects to upgrade Soviet reactors to IAEA standards. Every state benefits from the increased security of others - a classic example of a global public good. Therefore, the constant topic of discussion is the need for constant support from countries with emerging nuclear programs to ensure that lack of experience or funding does not lead to security gaps. It is gratifying that experienced countries and international bodies have shown a willingness to provide this support, viewing it as an investment in collective security.

In terms of security and non-proliferation, IAEA standards (safety guarantees and guidelines) also require continuous cooperation to ensure effectiveness. The growing threat of nuclear terrorism, for example, has led to new IAEA security recommendations (for example, INFCIRC/225/Rev.5 for physical protection). Many countries are currently cooperating through another form of cooperation, formed by IAEA "standards" (although they are called recommendations), - by exchanging information and conducting training on their implementation. Widespread participation in the IAEA Database on Incidents and Illicit Trafficking and in training seminars on nuclear security testifies to the recognition that security should also be coordinated at the international level.

From the perspective of Central Asia, it is possible to assess how IAEA standards contribute to the implementation of projects and partnerships in this region. As noted above, Kazakhstan's location of NTM Bank and cooperation with IAEA on nuclear medicine and agricultural projects allowed it to become a regional leader. The adoption of IAEA standards allowed Kazakhstan to cooperate with the European Union and Russia simultaneously. As Uzbekistan attempted to build the first nuclear power plant in Central Asia, it engaged the IAEA to assess the project and ensure safety, and also began to harmonize its legislation with international conventions [15]. These steps are actually prerequisites for obtaining foreign investments and technologies, which once again shows that compliance with the standards developed by the IAEA is an entry into the field of nuclear development. Although other neighboring countries, such as Kyrgyzstan and Tajikistan, do not strive to create energy reactors, they cooperate with the IAEA in the field of radiation safety and cleansing the legacy of uranium production, following the directives of the Security Agency. This regional example shows that regardless of the size of the country, the structure of international cooperation through IAEA standards expands in accordance with their needs.

4. Conclusion and Recommendation

International cooperation in the field of nuclear energy is inextricably linked with the standards and guidelines established by the IAEA. As a result of this study, we found that IAEA safety standards serve as a common language for nuclear projects worldwide, allowing countries to collaborate within the framework of a shared commitment to safety and security. As the foundation for cooperation, the NPT and safety conventions provide meaning and build trust, but IAEA standards and peer review make them work. The IAEA's non-binding norms come into force through binding treaties and implementation in state practice, while agreements gain flexibility and technical legitimacy by relying on the IAEA.

Case studies conducted worldwide - a new plant in Bangladesh, a fuel bank in Kazakhstan, expert regulatory reviews in Europe, and others - demonstrate the significant advantages of this cooperation regime. Countries that adhere to IAEA standards attract partners and investments, and the international community has collectively managed to continuously raise safety criteria, especially after learning from past accidents. Today, the nuclear industry operates with much greater transparency and uniformity in safety culture than in the first decades of nuclear energy, mainly due to the coordinating role of the IAEA.

Nevertheless, the work is not complete. To address the identified issues, the international community can consider several steps. Firstly, universalizing participation in key conventions (e.g., safety and liability conventions) legally enshrines some IAEA standards and normalizes the expectation of mutual peer reviews. IAEA's technical cooperation and safety assistance programs need more

money so they can help less developed countries meet stringent standards - so there are no truly vulnerable links left. With innovations like small modular reactors (SMRs) and advanced fuel cycles, all countries need to become involved in IAEA standards for better oversight.

International nuclear cooperation through IAEA standards is an excellent example of multilateralism. Although it is viewed as divisive and fragile, it is an excellent example of how shared norms can unite nations for greater prosperity. A foundation of trust and cooperation will continue to be the IAEA's standards and review services in an era when nuclear energy is perceived as a clean energy. In order to develop nuclear technology and ensure public safety, academic, technical, and diplomatic support is needed. Developing a truly global nuclear safety and security culture is difficult if each state, operator, and stakeholder views international standards as internal, not external. Cooperation, transparency, and universalizing best practices are essential to maximizing the benefits of nuclear power while minimizing its risks.

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