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Łukasz Młynarkiewicz
Pomeranian University in Słupsk, Poland
ORCID: 0000-0001-9876-9931
lukasz.mlynarkiewicz@upsl.edu.pl

The Use of Proven Technologies in Nuclear Facilities: An Analysis of Article 36b of the Atomic Law

Stosowanie sprawdzonych technologii w obiektach jądrowych. Analiza art. 36b Prawa atomowego

ABSTRACT

This article analyses Article 36b of the Polish Atomic Law, which imposes an obligation to use of either practically proven solutions and technologies or those confirmed safe through tests, research, and analyses in nuclear facility design and construction. The scientific problem addressed is the lack of precise guidelines for verifying proven technologies and the dilemma of balancing nuclear safety with technological progress, a critical issue for Poland's burgeoning nuclear energy sector. The aim of the research is twofold: to reconstruct the legal norm within this provision, clarifying the concepts of "proven in practice" and "through tests, research, and analyses", and to formulate *de lege ferenda* postulates for amendments. The main theses highlight the crucial role of the President of the Polish National Atomic Energy Agency, potential interpretative problems from the current wording, and the need for clearer verification methods for novel technologies, drawing comparisons with international frameworks. The originality of the research lies in providing the first comprehensive analysis of this specific Polish requirement, uniquely contrasted with the Convention on Nuclear Safety and International Atomic Energy Agency standards. The scope of research is national, EU-wide, and international, focusing on Polish law while gaining insights from broader nuclear safety frameworks. This article offers significant cognitive value for both legal science and practice, illuminating regulatory gaps and proposing solutions to enhance nuclear safety and technological advancement in Poland and internationally.

Keywords: Atomic Law; proven technology; nuclear safety; nuclear power plant; nuclear energy

CORRESPONDENCE ADDRESS: Łukasz Młynarkiewicz, PhD, Assistant Professor, Pomeranian University in Słupsk, Institute of Law and Administration, Krzysztofa Arciszewskiego 22A, 76-200 Słupsk, Poland.

INTRODUCTION

Nuclear safety is a paramount concern for the peaceful use of atomic energy, whether in power generation, medicine, or industry.[1] The significant risks of nuclear accidents necessitate robust regulatory frameworks for designing and constructing nuclear facilities. In Poland, the Act of 29 November 2000 – Atomic Law[2] establishes critical obligations for investors, contractors, and regulatory bodies. These aspects can encompass purely design-related and technical issues, specific internal procedures, work instructions, and organizational culture, including the attitudes and behaviours of personnel.[3]

The subject of this article is a detailed legal analysis of Article 36b of the Atomic Law. This provision prohibits using solutions and technologies in nuclear facility design and construction that have not been "proven in practice in nuclear facilities or by means of tests, research, and analyses". Such a requirement raises a series of crucial legal questions, including its legislative purpose, the interpretation of its constituent elements, the entities obligated to comply, the timing of compliance assessment during the licensing process for nuclear facilities, and the legal consequences of non-compliance. In the context of planned nuclear investments in Poland, Article 36b is pivotal for technology selection and ensuring the highest level of safety. The essence of the problem (and the core research question) lies in the absence of precise legal guidelines for interpreting this crucial requirement, particularly concerning the verification methods for new technologies, and the inherent dilemma of balancing rigorous nuclear safety with technological progress. This challenge extends beyond Poland, as evidenced by analogous requirements in the Convention on Nuclear Safety[4] and relevant International Atomic Energy Agency (IAEA) standards.[5]

The purpose of this article is twofold: first, to reconstruct the legal norm embodied in Article 36b of the Atomic Law, clarifying its core concepts and implications; second, to formulate concrete recommendations and *de lege ferenda* postulates for legislative amendments. The main hypotheses proposed are that Article 36b's current wording creates substantial interpretative difficulties, the President of the Polish

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[1] See more in Ł. Młynarkiewicz, *Podstawowe zasady systemu ochrony przed promieniowaniem jonizującym Międzynarodowej Agencji Energii Atomowej w polskim prawie atomowym*, "Prawo i Więź" 2023, no. 4, p. 709; idem, *Implementacja wybranych zasad bezpieczeństwa jądrowego i ochrony radiologicznej Międzynarodowej Agencji Energii Atomowej w polskim prawie atomowym*, "Studia Iuridica" 2021, vol. 87, pp. 332–333.

[2] Consolidated text, Journal of Laws 2024, item 1277, as amended.

[3] See Article 3 (8c) and Article 36k (2) (10) of the Atomic Law.

[4] See Article 18 of the Convention on Nuclear Safety, done at Vienna on 20 September 1994 (Journal of Laws 1997, no. 42, item 262), hereinafter: CNS.

[5] IAEA, *Safety of Nuclear Power Plants: Design*, Specific Safety Requirements, No. SSR-2/1 (Rev. 1), Vienna 2016, p. 16; IAEA, *Safety Assessment for Facilities and Activities*, General Safety Requirements, Part 4 (Rev. 1), Vienna 2016, p. 17.

National Atomic Energy Agency (PAA) holds a crucial yet potentially ambiguous role in compliance evaluation, and clear, internationally harmonized verification methods are vital for fostering innovation without compromising safety.

Regarding the state of research, despite its profound practical importance for Poland's ambitious nuclear energy program, Article 36b of the Atomic Law has not been the subject of dedicated research or comprehensive publications in Polish legal literature until now. This study, therefore, constitutes the novelty of the discussion, offering the first in-depth legal analysis of this critical provision.

The research methodology primarily involves dogmatic-legal analysis, focusing on interpreting national legal texts and comparing them with international standards. A systemic approach is employed to understand Article 36b of the Atomic Law within the broader nuclear safety legal framework, complemented by comparative legal analysis to draw insights from CNS and IAEA guidelines.

RESEARCH AND RESULTS

1. Genesis and *ratio legis* of Article 36b of the Atomic Law in light of the Convention on Nuclear Safety

Article 36b of the Polish Atomic Law was introduced into the legal system on 1 July 2011.[6] Its inclusion was directly inspired by Article 18 (ii) CNS,[7] which emphasizes the global commitment to high nuclear safety standards through robust national controls and international cooperation.[8] The CNS aims to ensure effective instruments against radiological hazards, obligating member states to implement legal, supervisory, and administrative measures to protect humans, society, and the environment from the harmful effects of ionizing radiation from nuclear facilities.[9] It specifically regulates the design, construction, operation, and accident mitigation of nuclear power plants.

Article 18 (ii) CNS stipulates that each Contracting Party shall take appropriate steps to ensure that "technologies incorporated in the design and construction of a nuclear installation are proven by experience or qualified by testing or analysis". This provision served as the direct basis for formulating Article 36b of the Atomic Law.[10] The legislative intent behind Article 36b, and the broader integration of the

[6] Article 1 (14) of the Act of 13 May 2011 on amending the Atomic Law and certain other acts (Journal of Laws 2011, no. 132, item 766).

[7] Sejm of the Republic of Poland, 6th term, *Justification for the Draft Act Amending the Atomic Law and Certain Other Acts*, Sejm Print 3939, pp. 40–41.

[8] Article 1 (i) CNS.

[9] Article 1 (ii) in conjunction with Article 4 CNS.

[10] Sejm of the Republic of Poland, *op. cit.*, pp. 40–41.

Office of Technical Inspection (UDT – Urząd Dozoru Technicznego) into nuclear projects, was to ensure safety "during the construction and future operation of nuclear facilities by applying proven methods and control procedures" related to their design and construction.[11] This underscores the intrinsic link between applying proven technologies and achieving safety throughout a nuclear facility's lifecycle.

The requirement for proven technologies, outlined in Article 18 (ii) CNS, must be analyzed alongside Article 18 (i) and (iii) CNS, which emphasize defence-in-depth and human factors in design, respectively. Article 18 CNS, titled "Design and Construction", forms a coherent whole; its provisions are interconnected and should be interpreted systemically to fully grasp their role in the overall nuclear safety system. The overarching goal of the CNS is sustained high-level global nuclear safety, where rigorous technology verification is a key instrument, not an end in itself.

Defence-in-depth, enshrined in Article 18 (i) CNS and implemented in Polish law (e.g. Article 36c (1) (2) of the Atomic Law), mandates multiple, complementary layers of protection and barriers to prevent accidents and mitigate their consequences. The application of proven technologies constitutes a crucial element of the initial layers of this concept,[12] focusing on preventing deviations from normal operation and system failures.[13] Furthermore, national regulations, such as the Regulation of the Council of Ministers of 31 August 2012 on nuclear safety and radiological protection requirements to be included in the design of a nuclear facility,[14] detail how this defence-in-depth principle is realized, emphasizing redundancy, physical separation, and functional independence of safety systems.[15]

The use of proven technologies strengthens the foundations of safety, reducing the likelihood of events that would require activating subsequent levels of defence-in--depth.[16] However, should an accident occur despite the application of proven technologies, subsequent defence-in-depth levels (e.g. emergency reactor cooling systems, containment structures) are designed to mitigate its consequences and prevent the release of radioactive substances.[17] The stable and predictable operation of a facility, resulting from the use of proven technologies, facilitates the functioning

[11] *Ibidem*, p. 41.

[12] IAEA, *Safety of Nuclear Power Plants…*, pp. 15–17.

[13] *Ibidem*, pp. 13–15.

[14] Journal of Laws 2012, item 1048, hereinafter: the Design Regulation. According to § 3 of the Design Regulation, the requirement referred to in Article 36c (1) (2) of the Atomic Law is implemented, in particular, by including in the design of the nuclear facility a sequence of five safety levels, described in that provision, as well as a system of successive protective barriers ensuring the retention of radioactive substances in specified locations within the nuclear facility and preventing their uncontrolled release into the environment, such as nuclear fuel material (fuel matrix), fuel element cladding, reactor coolant pressure boundary, and reactor containment.

[15] See § 34 (1) of the Design Regulation.

[16] IAEA, *Safety of Nuclear Power Plants…*, pp. 13–15.

[17] *Ibidem*, pp. 15–17.

of these safety systems. Thus, Article 36b of the Atomic Law, by promoting proven technologies, aligns with the implementation of the defence-in-depth principle and contributes to the comprehensive assurance of nuclear facility safety at all stages of its lifecycle – from design and construction to operation.

Article 18 (iii) CNS mandates that nuclear facility design should enable "reliable, stable and easily manageable operation, with specific consideration of human factors and man-machine interface". This has been implemented in Article 36c (1) (3) of the Atomic Law. This requirement ensures that facilities are designed not only for technical safety (as per Article 36b) but also for safe and easy operation, minimizing the risk of human error.[18] Using proven technologies from reference facilities allows for leveraging existing operational procedures, training programs, and lessons learned, significantly reducing human error potential. Conversely, unproven technologies introduce higher uncertainty and may necessitate new procedures, increasing risk.

The author argues that the concept of "proven technology" concerning nuclear facility design must be assessed by the nuclear regulatory body in close conjunction with the objectives of Article 18 (iii) CNS and Article 36c (1) (3) of the Atomic Law. This means evaluating "proven" status goes beyond formal confirmation of prior use; it requires considering operational experience from reference facilities to ensure the solution promotes safe, stable, and manageable operation with due regard for human factors. National regulations further specify design requirements for human factors, aiming to minimize human error through optimized spatial layouts, ergonomics, and clear information presentation for operators.[19] Thus, Article 36b of the Atomic Law, by promoting proven technologies, directly contributes to both the defence-in-depth principle and the safe, effective operation with human factors considered.

In conclusion, the *ratio legis* of Article 36b of the Atomic Law extends beyond a simple mandate for proven solutions. Its fundamental aim is to ensure that technologies in nuclear facility design and construction guarantee the highest possible safety, encompassing both accident prevention and mitigation, in line with the defence-in-depth concept. The emphasis on technologies "proven in practice" or "by means of tests, research, and analyses" stems from the imperative to minimize risks associated with untested or inadequately verified solutions. The choice of proven technologies is thus a critical element in realizing the defence-in-depth principle and accounts for the crucial role of human factors by integrating operational experience from reference designs to limit potential human errors and mitigate their consequences. For innovative technologies, detailed verification must similarly analyze human-machine interaction and potential impact on personnel to ensure an equally high level of safety regarding human factors.

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[18] See more on the use of operating experience from nuclear installations in IAEA, *Operating Experience Feedback for Nuclear Installations*, Specific Safety Guide: No. SSG-50, Vienna 2018.

[19] See § 43 (1) and (2), and § 44 (2) of the Design Regulation.

2. Solutions and technologies proven in practice or verified by testing and analysis

The primary objective of introducing Article 36b of the Atomic Law was to ensure the highest level of nuclear facility safety. This is achieved by mandating the use of solutions that have been proven in practice and confirmed reliable, or, for innovative solutions, subjected to rigorous, multi-stage, independent verification.[20] This interpretation aligns fully with the legislative purpose of protecting life, health, and the environment from nuclear energy risks, specifically by minimizing hazards associated with inadequately tested or entirely unproven technological solutions. This requirement aims to increase the probability of correct nuclear facility functioning and effectively prevent potential accidents, directly enhancing public safety. Crucially, this provision implements Article 18 (ii) CNS, underscoring its international context and goal of harmonizing global nuclear safety standards.

Despite its apparent simplicity, Article 36b of the Atomic Law raises significant interpretative doubts that can complicate the implementation of both proven and innovative technologies. A key issue is the lack of precise legal definitions for terms such as "solutions and technologies proven in practice" or the unspecified "tests, research, and analyses" meant for novel solutions. This ambiguity, inherent in highly specialized terminology used without clear legal definitions, can lead to inconsistent interpretations and hinder the evaluation of proposed solutions, particularly innovative ones, against safety requirements.

2.1. Scope of the requirement: addressees and covered facilities

Firstly, the primary addressees of this norm are entities actively involved in the design and construction of nuclear facilities. This includes investors, designers, contractors, and specialized suppliers of reactor technologies and key components. Additionally, relevant public administration bodies, notably the PAA President as the nuclear regulatory body, technical supervision authorities, and architectural-building authorities, are also subject to this stringent requirement. While the comprehensive assessment of this requirement is not solely within the PAA's competence, its specialized expertise makes the safety assessment during the licensing process for nuclear facility construction a crucial verification stage. A nuclear facility can only be legally built and safely operated once it is unequivocally demonstrated that all proposed safety measures adequately address potential hazards and sufficiently protect people and the environment.[21]

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[20] The definition of "nuclear installation" is provided in Article 2 (i) CNS.

[21] IAEA, *Fundamental Safety Principles*, IAEA Safety Standards Series: No. SF-1, Vienna 2006, p. 9.

Secondly, the regulation applies to all nuclear facilities as defined in Article 3 (17) of the Atomic Law, encompassing nuclear power plants, research reactors, enrichment plants, fuel fabrication plants, spent fuel reprocessing plants, spent fuel storage facilities, and on-site radioactive waste storage facilities directly associated with these. The placement of Article 36b within the "Nuclear Facilities" chapter of the Atomic Law confirms this scope. However, based on its literal wording, Article 36b does not directly apply to certain facilities within the broader nuclear fuel cycle[22] not explicitly listed in Article 3 (17), such as uranium and thorium ore mining and preliminary processing facilities, or standalone radioactive waste storage facilities located off-site.[23]

The author argues that, under rules of teleological interpretation, the requirement of Article 36b of the Atomic Law concerning proven technologies or their verification should unequivocally apply to all facilities involved in the nuclear fuel cycle, including mining and preliminary processing of uranium and thorium ores and standalone radioactive waste storage facilities. Despite not being *expressis verbis* listed, these facilities are integral to the fuel cycle and significantly impact nuclear and radiological safety. Extending this requirement would enhance the safety of the entire fuel cycle, minimizing risks from untested solutions. Analogous regulations, like Article 55d (1) of the Atomic Law concerning radioactive waste repositories,[24] support this legislative intent for high safety standards at all stages of nuclear material and waste management. *De lege ferenda*, an expansion of Article 36b's scope to all nuclear fuel cycle facilities is postulated to strengthen the safety system and eliminate potential regulatory gaps.

Thirdly, the content of the obligation under Article 36b of the Atomic Law is the mandatory application of solutions and technologies "proven in practice" or, alternatively, subjecting them to "tests, research, and analyses" confirming their safety. This obligation applies throughout the entire design and construction process, suggesting its absolute nature, albeit with the possibility of using innovative solutions after proper verification.[25]

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[22] C. Stoiber, A. Baer, N. Pelzer, W. Tonhauser, *Handbook on Nuclear Law*, Vienna 2003, p. 63; D. Bodansky, *Nuclear Energy Principles, Practices and Prospects*, New York 2005, p. 193 ff. For more on the nuclear fuel cycle, see H. Cook, *The Law of Nuclear Energy*, London 2013, pp. 347–350; Ł. Młynarkiewicz, *Decyzja zasadnicza w procesie przygotowania i realizacji inwestycji w zakresie obiektów energetyki jądrowej*, Sopot 2020, pp. 57–73.

[23] Ł. Młynarkiewicz, *Decyzja zasadnicza w procesie przygotowania…*, pp. 71, 75–80.

[24] According to Article 55d (1) of the Atomic Law, in the process of construction, operation, and closure of a radioactive waste repository, solutions and technologies that have not been proven in practice in radioactive waste repositories or by means of tests, research, and analyses shall not be used.

[25] Cf. the requirement for "proven" technologies under nuclear energy law applicable in the United Arab Emirates: H. AlKaabi, *Nuclear Newcomer Countries – The Path of the United Arab Emirates*, [in:] *Nuclear Law: The Global Debate*, Vienna 2022, p. 312.

2.2. Understanding "proven in practice" and verification methods

Crucially, the term "solutions and technologies proven in practice" lacks a legal definition in the Polish Atomic Law, necessitating clear regulatory guidance. This article interprets "solutions and technologies" as encompassing all critical technical, structural, organizational, and procedural elements within a nuclear facility. "Proven in practice" implies successful prior application under real operating conditions, thus requiring documented operational experience confirming reliability and safety. The necessary duration of this experience depends on the solution's criticality and potential risks; for key safety systems, years of flawless operation in comparable facilities may be required. Importantly, this operational experience can and should originate from both Polish and international nuclear facilities, provided they are strictly comparable in technology and key design, as well as operational characteristics.

Operational experience from nuclear installations is shared internationally through various channels, including bilateral exchanges and structured multilateral formats under international organizations. This exchange occurs via regular reports discussed during CNS review meetings[26] and through the IAEA's incident reporting systems.[27] These incident reporting systems (e.g. IRS for nuclear power plants, FINAS for fuel cycle facilities, IRSRR for research reactors) are designed for a broad range of nuclear industry stakeholders. Reports detail significant events, analyze root causes, and highlight corrective actions and lessons learned, allowing global users to continuously enhance safety. Analyzing this operational feedback is crucial for identifying potential problems and implementing remedies during the design and construction of new facilities.

In the author's opinion, in the absence of a legal definition, "solutions and technologies proven in practice" should be interpreted based on scientific, technical, and engineering practice in nuclear facility operation. The application of proven engineering practices is an IAEA safety requirement, as stipulated in *Safety of Nuclear Power Plants: Design*.[28] According to Requirement 9 of this document, elements crucial for the safety of a nuclear power plant should be designed in accordance with relevant national and international norms and standards.[29] Moreover, this document recom-

[26] See Article 5 in conjunction with Article 20 CNS.

[27] On the IRS system, see Nuclear Energy Agency, *Nuclear Power Plant Operating Experiences from the IAEA/NEA Incident Reporting System 2015–2017*, No. 7482, OECD 2020; IAEA, *IRS Guidelines: 2022 Edition*, IAEA Services Series 19 (Rev. 1), Vienna 2022.

[28] IAEA, *Safety of Nuclear Power Plants…*, p. 16. Cf. also guidelines from the Canadian Nuclear Safety Commission (CNSC), which implement the requirements and principles resulting from the cited IAEA document: CNSC, *Design of Reactor Facilities*, REGDOC-2.5.2. Version 2.1, Ottawa 2023, in particular pp. 18–19.

[29] IAEA, *Safety of Nuclear Power Plants…*, p. 16.

mends that all safety-critical elements be designed using constructions previously verified in identical applications in operating plants. If not, they must be high-quality components based on previously proven and tested technology. For unverified designs or functions, or deviations from established engineering practices, safety must be demonstrated through supporting studies, performance tests with detailed acceptance criteria, or analysis of operational experience from analogous applications. New designs, functions, or practices should also be tested pre-operation and monitored during operation to verify compliance with design assumptions.

The IAEA emphasizes that "proven technology" encompasses a nuclear power plant's general systems and components, including not only physical elements and structures but also advanced design and safety analysis techniques, maintenance and safe operation features, and established construction methods. The IAEA outlines several ways to demonstrate that solutions or technologies are "proven":

- extensive, safe, and efficient operation in existing nuclear power plants with a strong operational history (e.g. high availability factors);
- results from representative partial or full-scale test facilities that simulate power plant operating conditions;
- documented, long-term operation in other relevant high-safety industries (like conventional power or advanced processing), with due consideration for nuclear specifics.

Furthermore, technology vendors should review global operational experience databases for both positive insights and causes of significant events/outages, proactively integrating solutions into the plant design. Finally, the reactor system should be licensable in its country of origin, with licensing information shared with the technology recipient.[30]

Therefore, a solution can reasonably be considered "proven in practice" if it cumulatively meets these criteria: (1) successfully applied in at least one nuclear facility of similar nature and scale; (2) no serious accidents or safety-impacting incidents have occurred due to its application; (3) operational data confirms its reliability and safety over a period adequate to its safety criticality; (4) it complies with current nuclear safety norms and standards.

While Article 36b of the Atomic Law specifically references "proven in practice in nuclear facilities", considering experience from other industries where a technology has been successfully applied, as suggested by the IAEA, can provide additional evidence of reliability and safety. This is especially relevant for innovative technologies lacking extensive nuclear operational history. However, the adequacy and similarity of operating conditions in other sectors to specific nuclear energy requirements must always be assessed.

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[30] IAEA, *Common User Considerations (CUC) by Developing Countries for Future Nuclear Energy Systems: Report of Stage 1*, IAEA Nuclear Energy Series No. NP-T-2.1, Vienna 2009, p. 43, 58. See there for a detailed description of technical considerations relating to "proven technology".

2.3. First-of-a-Kind (FOAK) vs. Nth-of-a-Kind (NOAK) projects

Where a solution or technology has not been proven in practice, Article 36b of the Atomic Law permits its use if its safety is confirmed through comprehensive tests, research, and analyses. This pathway is particularly relevant for First-of-a--Kind (FOAK) projects – pioneering commercial-scale deployments of new technologies. Unlike Nth-of-a-Kind (NOAK) projects, which are serial deployments of already proven and commercially operated technologies, FOAK projects inherently carry higher technical and financial risks but represent crucial steps from R&D to industrial application. NOAK projects benefit from extensive operational history, leading to reduced risk, optimized costs, and shorter schedules.

Polish Atomic Law does not preclude the use of FOAK solutions or technologies. However, for FOAK technologies, rigorous safety verification through the aforementioned tests, research, and analyses is paramount. This aims to confirm that, despite lacking full-scale historical operational data (characteristic of NOAK projects), the new solution meets the highest safety standards, often surpassing those of established NOAK designs. Only positive results from these comprehensive verifications can pave the way for FOAK technology adoption in Polish nuclear energy. While not disqualifying innovation, Polish law sets exceptionally high safety demonstration requirements for FOAK technologies, essentially demanding a "virtual operational history" that predicts long-term behavior under various operational and accident scenarios with high scientific and engineering certainty.

2.4. Verifying innovative and advanced reactor designs

Allowing solutions whose safety is confirmed by advanced tests, research, and analyses creates a regulatory pathway for groundbreaking, potentially transformative technologies that can significantly enhance nuclear energy's safety, economic efficiency, and sustainability. These solutions may lack extensive commercial operational experience, a challenge particularly relevant for rapidly developing technologies like Small Modular Reactors (SMRs).[31] In such cases, robust safety verification, adapted to the technology's specifics, is crucial.

The IAEA categorizes advanced reactor designs into three types: proven (mostly NOAK), evolutionary (based on proven designs with improvements), or innovative (often FOAK), as reflected in the IAEA ARIS (Advanced Reactor Information Sys-

[31] See the issue of applying the defence-in-depth concept to SMR-type facilities in IAEA, *Application of the Principle of Defence in Depth in Nuclear Safety to Small Modular Reactors: Addendum to INSAG-10*, INSAG-28, Vienna 2024.

tem) database.[32] Many advanced or innovative reactor projects feature key systems or components that are highly developed and even proven in other industries, while other, more novel elements might be less defined or still under development. Notably, some systems or components may be widely proven in non-nuclear industries (e.g. advanced steam turbines) but lack direct implementation in the nuclear environment.[33]

According to the IAEA's *Safety Assessment for Facilities and Activities* a key international standard, a comprehensive safety assessment of any nuclear facility must confirm the maximum possible use of robust, proven designs for structures, systems, and components.[34] However, for innovative improvements beyond current engineering practices, the safety assessment authority must verify compliance through an appropriate program of research, analysis, and tests, supplemented by an operational monitoring program.[35] For NOAK projects, extensive operational history significantly aids safety assessment, providing valuable supplementary information for specific analyses and tests.

The challenge of integrating innovation into nuclear safety assessment is currently being addressed by an upcoming IAEA safety guide – *Safety Demonstration of Innovative Technology in Nuclear Power Plants*.[36] Recognized IAEA standards require any applicant for a nuclear facility construction license to submit a scientifically justified safety demonstration.[37] This guide aims to provide clear recommendations on best practices and methodologies for the complex process of demonstrating the safety of novel solutions for nuclear power plants.[38] It also includes specific recommendations for various innovations, such as novel fuel concepts, coolants, advanced safety systems, optimized operating modes, modern structural materials, and cutting-edge

[32] See the IAEA database containing information on evolutionary and innovative nuclear projects: https://aris.iaea.org

[33] IAEA, *Nuclear Reactor Technology Assessment for Near Term Deployment*, IAEA Nuclear Energy Series No. NR-T-1.10 (Rev. 1), Vienna 2022, p. 77.

[34] IAEA, *Safety Assessment for Facilities…*, p. 17.

[35] *Ibidem*, point 4.29. Cf. Requirement 9 in IAEA, *Safety of Nuclear Power Plants…*, p. 16, point 4.14 ff.

[36] See IAEA, *Safety Demonstration of Innovative Technology in Nuclear Power Plants (DS537*) – *version 4*, Vienna 2022. According to the adopted schedule, this document should be adopted in the second quarter of 2026. See IAEA, *Document Preparation Profile (DPP) for DS537*, NS-SPESS F DPP-V.13, Vienna 2020, p. 7.

[37] See Requirement 24 in IAEA, *Governmental, Legal and Regulatory Framework for Safety*, IAEA Safety Standards Series No. GSR Part 1 (Rev. 1), Vienna 2016, p. 25. On safety demonstration in the area of SMR reactors, see S.G. Burns, K. Sexton Nick, C. Raetzke, L. Thiele, *Regulation, Licensing and Oversight of Nuclear Activities*, [in:] *Principles and Practice of International Nuclear Law*, eds. K. Sexton Nick, S.G. Burns, 2022, https://www.oecd-nea.org/upload/docs/application/pdf/2025-06/7599_principles_and_practice_of_international_nuclear_law_2025-06-13_14-30-7_164.pdf (access: 27.12.2025), pp. 148–159.

[38] See IAEA, *Explanatory Note: Safety Demonstration of Innovative Technology in Nuclear Power Plants (DS537)*, Vienna 2022, p. 1; IAEA, *Safety Demonstration…*, p. 3.

manufacturing techniques for key components.[39] For NOAK projects, these safety demonstration strategies can be streamlined or focused on specific modifications.

Innovative reactor designs often introduce fundamentally new approaches for key components, complex safety systems, or the entire reactor concept, differing significantly from established NOAK engineering practices. While these pioneering projects may incorporate some known engineering practices, they have not yet achieved the same high level of technological maturity, engineering knowledge, and extensive regulatory and operational experience as current, proven reactor designs. Innovative reactor projects encompass both prototype research facilities and first-of-a-kind commercial demonstration plants, and they vary greatly in their maturity regarding accumulated engineering knowledge and practical operational experience. This includes, e.g., advanced reactors in early maturity with innovative safety approaches, novel reactor designs using existing, proven non-nuclear technology in a new nuclear context, and well-known nuclear technologies applied in new, previously unapplied or novel operational contexts.[40]

Within the framework of safety demonstration, an innovation is defined as a new type of system, structure, critical component, or a specific operating mode crucial for safety that has not been previously used in nuclear energy, or is used in a new, untested way. This applies when: (1) proven engineering practices for nuclear power plants are not fully defined and documented; or (2) existing practices or standards require significant interpretation and deep assessment for their application in a new context.[41] In NOAK projects, innovations are typically evolutionary, introduced cautiously, and built upon extensive experience from previous deployments.

Innovation can span from evolutionary modifications with new features to technologies with entirely novel properties not previously applied in nuclear energy. The IAEA document elaborates on specific challenges, approaches, and strategies for safety demonstration based on the type of innovation. This includes utilizing various tests, research, and analyses, such as digital twins, laboratory tests, computer simulations, and probabilistic analyses.

In Polish law, Article 36b of the Atomic Law does not specify acceptable types of tests, research, and analyses for innovations. However, relevant requirements are detailed in the implementing regulations, including the Design Regulation and the Regulation of the Council of Ministers of 31 August 2012 on the scope and manner of conducting safety analyses performed before submitting an application for a permit to construct a nuclear facility, and the scope of the preliminary safety report for a nuclear facility.[42]

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[39] *Ibidem*.
[40] IAEA, *Document Preparation Profile…*, p. 1; IAEA, *Safety Demonstration…*, pp. 4–8.
[41] IAEA, *Safety Demonstration…*, p. 5, point 2.4.
[42] Journal of Laws 2012, item 1043.

These requirements apply to both "proven in practice" solutions used in NOAK projects and innovative solutions implemented in FOAK projects. The use of widely "proven" solutions in multiple NOAK deployments does not automatically lead to reduced regulatory burden or a narrower scope of obligations during the design and construction of subsequent nuclear facilities. The investor remains obligated to conduct appropriate, detailed safety analyses tailored to the specific project and location. For "new" solutions (FOAK), greater organizational effort is required due to the absence of direct reference objects and extensive documented operational experience. While NOAK projects can heavily rely on the rich operational history of reference facilities, this does not exempt them from rigorously accounting for the new project's specific features and potential modifications.

Crucially, Annex 2, point 1.1.19, of the Documentation Regulation[43] requires that applications for nuclear facility construction permits include "information on reference nuclear facilities under construction or in operation, along with a description of significant differences between the reference facilities and the facility to which the application pertains, or, in the absence of such facilities, information on solutions and technologies that have been verified through tests, research, and analyses". Information on reference facilities significantly supports the regulatory assessment process, enabling the PAA President to obtain detailed operational experience, including information exchange and cooperation with nuclear regulatory bodies from other countries operating similar NOAK facilities. For FOAK projects, where direct operational references are unavailable, detailed descriptions of tests, research, and analyses become especially vital, serving to "simulate" future operation and prove the innovative solution's safety.

These provisions grant the investor and designer limited discretion in selecting safety verification methods while assigning responsibility for their proper choice, especially for innovative FOAK technologies lacking established procedures. The adequacy of chosen methods and their approval for use falls to the public administration bodies involved in the design and construction process. A fundamental challenge, however, is the lack of clear, universal criteria for conclusively determining whether specific tests, research, and analyses are sufficient to confirm the safety of new FOAK solutions and technologies. In practice, these can encompass a wide range of methods, including laboratory tests, prototype tests, simulated condition tests, non-destructive examinations, environmental interaction studies, qualification tests, material analyses, reliability analyses, theoretical analyses, computer simulations, and probabilistic or deterministic analyses. It is essential that these are conducted according to recognized methods agreed upon with reg-

[43] Regulation of the Council of Ministers of 30 August 2021 on documents required when submitting an application for a permit to perform activities involving exposure to ionizing radiation or when notifying the performance of such activities (Journal of Laws 2021, item 1667).

ulatory bodies, by competent and independent entities, and that their results are thoroughly documented and subjected to multi-stage, independent verification. For NOAK projects, the choice of verification methods can draw upon experience from previous projects, simplifying the regulatory assessment but not negating the obligation for thorough execution for the new facility.

From a practical perspective, interpreting Article 36b of the Atomic Law must account for the realities of complex, long-term nuclear investment processes. While this provision enhances nuclear facility safety by minimizing accident risks, especially for FOAK technologies that present greater unknown risks than NOAK solutions, its interpretation is delicate. Too liberal an approach could jeopardize safety by allowing untested solutions without proper verification. Conversely, an overly stringent interpretation could stifle technological progress, extend project timelines, increase costs, and impede the adoption of potentially safer and more efficient FOAK technologies, or even innovative solutions not yet proven in nuclear energy but offering superior safety, economic efficiency, or environmental benefits. Public administration bodies must find a balance between safety and technological advancement, enabling the implementation of innovative solutions after thorough and transparent verification, while incorporating experience and best practices from NOAK projects where possible.

The PAA President plays a pivotal role in evaluating and accepting solutions used in nuclear facilities. Under Article 109 (1) and Article 110 of the Atomic Law, the PAA President oversees nuclear safety and radiological protection, including the design, construction, and operation of nuclear facilities. The PAA President can request documentation from investors, designers, and contractors to confirm compliance with Article 36b of the Atomic Law, including test, research, and analysis reports tailored to the technology's nature and novelty. In case of irregularities, the PAA President wields a broad range of supervisory powers, including ordering work suspension or requiring design changes or safer solutions.[44] Lack of PAA President approval for proposed solutions can halt or even terminate the investment process, notably through denial of crucial construction, commissioning, or operating permits,[45] underscoring the PAA's fundamental role in ensuring public safety and environmental protection.

2.5. Postulates for legislative amendment (*de lege ferenda*)

Given the interpretative ambiguities regarding Article 36b's application to various technologies, this article postulates two *de lege ferenda* recommendations for process improvement and transparency: (1) clarifying the definition of "solu-

[44] Article 110 (13) in conjunction with Article 37 (6) of the Atomic Law, and Articles 68–68b of the Atomic Law.

[45] See Article 5 (7a) in conjunction with Article 4 (1) (2) of the Atomic Law.

tions and technologies proven in practice" through legislative amendment or PAA President's interpretative guidelines (e.g. technical-organizational recommendations),[46] and establishing evaluation criteria for innovative FOAK solutions; and (2) developing a catalog of recognized and recommended verification methods for new solutions, differentiating between those suitable for proven and innovative technologies. Additionally, mechanisms supporting the implementation of pioneering nuclear energy solutions should be established, perhaps via public-funded research programs, while maintaining the highest safety standards.

Furthermore, consideration should be given to supplementing the conditions for issuing the decision-in-principle, as outlined in Chapter 1a of the Act of 29 June 2011 on the preparation and implementation of nuclear energy facility investments and accompanying investments,[47] with an explicit requirement for technological maturity (TRL – Technology Readiness Level).[48] Introducing such a requirement, even in a limited form, reflecting the precautionary principle and evidential requirements of Article 36b of the Atomic Law, would ensure nuclear safety considerations are addressed early in the investment planning phase. This is crucial for minimizing financial risk and ensuring public safety long before construction begins. For FOAK projects, assessing TRL at this stage would allow early identification of potential challenges and the need for extensive research and testing.

The IAEA identifies "technological maturity" as one of ten key elements in its comprehensive Reactor Technology Assessment (RTA). For NOAK projects, the level of technology, knowledge, and regulatory/operational experience maturity is significantly higher than for FOAK projects, serving as a critical component in project safety and feasibility assessments. The evaluation of a technology's readiness for implementation and commercialization should occur at various stages of the decision-making process in a nuclear energy-implementing state, including: government program/strategy development, preparation for tender invitations and technical/economic evaluation of suppliers, and technology selection within competitive processes and complex contract negotiations.[49] For "private" projects not directly involving state support, an initial, independent TRL assessment should be

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[46] For example, by issuing technical and organizational recommendations under Article 110 (3) of the Atomic Law.

[47] Consolidated text, Journal of Laws 2024, item 1410, as amended, hereinafter: the Investment Act.

[48] Technology Readiness Level, determined according to the TRL scale, is a commonly used method for assessing the degree of advancement in the development of a given technology. See more in U.S. Department of Energy, *Guide (DOE G 413.3-4A): Technology Readiness Assessment Guide*, Washington 2011.

[49] IAEA, *Nuclear Reactor Technology…*, pp. 2, 4–11, 77–80; N. Anuar, W.S.W.A. Kahar, J.A.N.A. Manan, *Defining the "Proven Technology" Technical Criterion in the Reactor Technology Assessment for Malaysia's Nuclear Power Program*, "AIP Conference Proceedings" 2015, vol. 1659(1), p. 020006-1 ff.

mandatory at the decision-in-principle stage to ensure a minimum level of certainty regarding project feasibility and safety early in the licensing process.[50]

Assessing technological maturity could be initiated by the investor (by virtue of Article 106 of the Administrative Procedure Code[51]) or by the proceeding authority, especially for innovative technologies not yet practically applied in nuclear facilities. Currently, the lack of a mandatory formal opinion from the PAA President during the decision-in-principle procedure is a negative aspect.[52] The PAA President possesses unique and specialized knowledge vital for comprehensively assessing nuclear technologies, including their maturity, potential risks, and impact on nuclear safety and radiological protection. In many developed nuclear sectors, such preliminary opinions from independent nuclear regulatory bodies are common practice, serving as an important part of the approval procedure for nuclear ventures and increasing public trust in the decision-making process.[53]

Additionally, the minister responsible for energy resources could and should request such a formal opinion under Article 7b of the Administrative Procedure Code, which establishes the principle of inter-agency cooperation for accurate factual and legal clarification. Requesting the PAA President's stance on technological maturity, particularly for FOAK technologies, can be necessitated by the need for a comprehensive assessment of proposed technologies, including reactor designs, considering overriding public interest and state security criteria outlined in Article 3a (1) of the Investment Act.

DISCUSSION AND CONCLUSIONS

This article analyzed Article 36b of the Polish Atomic Law, which mandates the use of either practically proven solutions or those rigorously verified through testing and analysis in nuclear facility design and construction. The central problem identified is the lack of precise legal guidelines for interpreting this requirement, especially concerning novel technologies, and the inherent dilemma of balancing stringent nuclear safety with technological progress.

[50] On the issue of RTA in the context of SMR projects, see *ibidem*. Cf. IAEA, *Technology Roadmap for Small Modular Reactor Deployment*, IAEA Nuclear Energy Series No. NR-T-1.18, Vienna 2021, p. 52, 76; Z. Liu, J. Fan, *Technology Readiness Assessment of Small Modular Reactor (SMR) Designs*, "Progress in Nuclear Energy" 2014, vol. 70, pp. 20–28.

[51] Act of 14 June 1960 – Administrative Procedure Code (consolidated text, Journal of Laws 2024, item 572, as amended).

[52] Ł. Młynarkiewicz, *Decyzja zasadnicza w procesie inwestycyjnym w zakresie obiektów energetyki jądrowej. Ocena zmian wprowadzonych w latach 2023–2024*, "Prawo i Więź" 2024, no. 3, pp. 454–455.

[53] *Ibidem*, p. 454.

The main hypotheses of this research are confirmed: Article 36b's current wording indeed creates significant interpretative challenges. While the PAA President plays a crucial role in evaluating compliance, this process lacks clear, internationally harmonized verification methods. The article's reconstruction of the legal norm within Article 36b clarifies the concepts of "proven in practice" and "through tests, research, and analyses" demonstrating that Polish law, by implementing the CNS, permits innovative FOAK solutions, provided their safety is rigorously confirmed. This nuanced approach, balancing safety with innovation, is vital for the strategic development of Poland's nuclear energy sector. In the author's view, interpreting Article 36b requires balancing paramount safety with the integration of potentially beneficial innovations that could enhance future safety and efficiency.

In this context, IAEA standards and guidelines are crucial for assessing innovative technologies, widely recognized as best practices in international nuclear law. IAEA standards are a crucial component of the international nuclear law regime, reflected in the widespread practice of states and international organizations that commonly apply them as best practices, and in nuclear energy law doctrine.[54] The ongoing IAEA safety guide (*Safety Demonstration of Innovative Technology in Nuclear Power Plants*) offers vital insights into challenges, recommended approaches, and strategies for demonstrating safety, considering various innovations and verification techniques. Reference to proven engineering practices is also essential, forming a cornerstone of nuclear energy safety assessment.

Furthermore, to facilitate the investment process and enhance legal certainty, it would be advisable for investors to more actively leverage the option of obtaining a general opinion from the PAA President concerning planned organizational and technical solutions, as provided by Article 39b of the Atomic Law. Securing such a preliminary opinion early in investment planning, particularly for novel solutions and technologies, would enable the identification of potential regulatory challenges and allow for plan adjustments to ensure compliance with safety requirements, even before submitting a formal construction permit application. This proactive stance by the investor and early engagement of the regulatory body could significantly streamline the licensing process and mitigate the risk of costly delays. Concurrently, it is essential to foster closer international cooperation among regulatory bodies from different states and nuclear technology suppliers, to exchange experiences and harmonize approaches to the safety assessment of innovative solutions.[55]

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[54] T.R. Nowacki, *Możliwość uznania standardów bezpieczeństwa Międzynarodowej Agencji Energii Atomowej za źródło prawa w świetle Konstytucji Rzeczypospolitej Polskiej*, [in:] *Aktualne problemy konstytucji. Księga jubileuszowa z okazji 40-lecia pracy naukowej Profesora Bogusława Banaszaka*, ed. P. Kapusta, Legnica 2017, p. 655 ff.

[55] On the necessity of regulatory cooperation in the area of innovation and SMR reactors, see S.G. Burns, K. Sexton Nick, C. Raetzke, L. Thiele, *op. cit.*, pp. 185–186.

The significance of this study, particularly in the area of law, is substantial. It illuminates critical regulatory gaps, such as the absence of clear definitions for "proven technologies" and standardized verification methods for innovative solutions. By proposing concrete *de lege ferenda* postulates – including statutory clarification or detailed PAA guidelines, and integrating a technological maturity (TRL) requirement into the decision-in-principle process – the article offers practical pathways for legal reform. These recommendations aim to enhance legal certainty, streamline the licensing process, and enable the safe integration of cutting-edge nuclear technologies, drawing insights from international best practices identified by the IAEA and other nations.

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ABSTRAKT

Przedmiotem artykułu jest analiza art. 36b ustawy Prawo atomowe, który nakłada obowiązek stosowania w projekcie i procesie budowy obiektu jądrowego rozwiązań oraz technologii sprawdzonych w praktyce w obiektach jądrowych lub, alternatywnie, poddanych próbom, badaniom i analizom potwierdzającym ich bezpieczeństwo. Problemem naukowym rozpatrywanym w opracowaniu jest brak precyzyjnych wytycznych dotyczących rozumienia tego wymogu oraz dylemat równoważenia bezpieczeństwa jądrowego z postępem technologicznym, co stanowi kluczową kwestię dla rozwijającego się polskiego sektora energetyki jądrowej. Cele badań są dwojakie: rekonstrukcja normy prawnej zawartej w tym przepisie, wyjaśnienie pojęć „sprawdzone w praktyce" oraz „sprawdzone za pomocą prób, badań oraz analiz", a także sformułowanie postulatów *de lege ferenda* dotyczących proponowanych zmian legislacyjnych. Główne tezy artykułu podkreślają kluczową rolę Prezesa Państwowej Agencji Atomistyki, potencjalne problemy interpretacyjne wynikające z obecnego brzmienia przepisu oraz potrzebę precyzyjnych metod weryfikacji nowych technologii, dokonując porównań w oparciu o ramy międzynarodowe. Oryginalność badań polega na przedstawieniu pierwszej kompleksowej analizy tego specyficznego polskiego wymogu, skontrastowanego z Konwencją o bezpieczeństwie jądrowym oraz standardami Międzynarodowej Agencji Energii Atomowej. Zakres badań jest krajowy, unijny i międzynarodowy. Skoncentrowano się na prawie polskim, a jednocześnie czerpano wnioski z szerszych prawnych ram w obszarze bezpieczeństwa jądrowego. Artykuł oferuje znaczącą wartość poznawczą zarówno dla nauk prawnych, jak i dla praktyki, wskazując na luki regulacyjne i proponując rozwiązania w celu zwiększenia bezpieczeństwa jądrowego i postępu technologicznego w Polsce i na świecie.

Słowa kluczowe: Prawo atomowe; sprawdzona technologia; bezpieczeństwo jądrowe; elektrownia jądrowa; energia jądrowa