Theses of PhD dissertation

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Faculty of Law

Deák Ferenc Doctoral School of Law

Central European Comparative Law Programme

Enabling the Nuclear Renaissance: A Holistic Perspective on Adapting Licensing Frameworks for Conventional and Advanced Nuclear Power Plants

Candidate

Miklós Vilmos Mádl

Supervisor

Prof. Dr. János Ede Szilágyi

Head of the doctoral school

Prof. Dr. Erika Róth

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Table of Content

1. Brief summary of the research task

1.1. Description of the research

1.2. Research questions

2. Brief description of conducted research and experiments, the methods of collecting material the exploration and use of resources

2.1. Methodology

2.2. Selection method for the comparative section

3. Brief summary of the scientific results and their possible practical application

4. The list of publications related to the dissertation's topic

1. Brief summary of the research task

1.1. Description of the research

Europe has been facing and addressing energy crises continuously over the past years, beginning with the Russia-Ukraine war and its implications for the piped supply of fossil fuels to Europe, and continuing with the conflict surrounding Iran and the fossil fuels originating from that region.

As a consequence of these developments' negative effects in Europe – particularly in relation to higher prices and, in some cases, shortages – energy-related issues have come to occupy the spotlight of public and academic discussion. This has also, in turn, affected legal scholarship, prompting both senior and aspiring scholars to devote attention to this area. The author, beginning his doctoral studies in the wake of these energy crises, was intrigued by this specific area of law.

The thesis seeks to contribute to energy law scholarship by discussing the licensing-related implications of the nuclear renaissance.

Briefly described, the term "nuclear renaissance" refers to the prospect of deploying increased nuclear capacity for electricity generation and for other potential applications. This prospect of expanded capacity, and its proposed forms of implementation, is of considerable interest to anyone concerned with the energy sector – not least because, for several decades, the prevailing narrative had been one of decline rather than growth. Following its initial expansion, nuclear energy's momentum was gradually halted: financial factors, safety concerns stemming from nuclear accidents, and environmental issues all contributed to a decline in interest and, in some cases, led to strong opposition towards nuclear energy. These factors, despite the occasional optimism of some scholars

and industry members, together led to a broad consensus that nuclear energy had no real future.

However, in light of the expectations and challenges the energy sector is now facing, this may no longer be the case: many argue that a so-called nuclear renaissance lies ahead, entailing a renewed expansion of nuclear energy. While nuclear energy may positively contribute to fulfilling the expectations placed on the energy sector, with regard to transitioning to less polluting sources and achieving greater energy security, several enabling conditions must be met if this nuclear renaissance is to materialise.

The challenges of the nuclear renaissance are complex and interdisciplinary, ranging from economic questions to educational concerns, as well as technological and, of course, legal issues. The legal challenges are themselves wide-ranging; among them, however, one stands out as fundamentally capable of impeding expansion, while, under certain conditions, equally capable of enabling it: licensing.

Under the permission principle of nuclear law, licensing procedures bear particular relevance for any activity in the sector, given the risks associated with this field. Without authorisation, no activity may be carried out. Licensing processes are complex and lengthy, following the various lifecycle stages of a nuclear power plant.

The thesis essentially examines how licensing procedures may be adapted to better enable the materialisation of the nuclear renaissance, across both conventional and advanced nuclear power plants, without compromising the safety of these installations.

The thesis first discusses the concept of the nuclear renaissance, its past attempts, and the respective reasons for their failure, before turning to how the conditions that would make a nuclear renaissance realistic have

since changed. To avoid basing the reality of the renaissance on theoretical assumptions alone, the work also discusses current projections regarding the future role of nuclear energy, along with the tangible efforts adopted to support the renaissance's materialisation, thereby showing how attitudes towards nuclear energy have evolved.

As the renaissance will materialise through several pathways, the thesis adopts a holistic view of licensing during the nuclear renaissance, covering three pathways, with particular attention given to the first two, as these can genuinely contribute to the renaissance by expanding nuclear capacity.

The first area concerns the licensing of conventional nuclear power plants. Although small modular reactors (SMRs) are often discussed as the renaissance's main driver, expansion is not limited to them: conventional large-scale plants may play an equally important role. Here, the thesis focuses on current national licensing frameworks, aiming to uncover how different national pathways operate, to identify redundancies, and to draw best practices from their comparative analysis, with a view to streamlining these procedures while maintaining nuclear safety. Over the past decades these frameworks have evolved primarily to increase safety rather than efficiency – making this a topical issue, central to creating a climate suited to increased deployment. This part examines the Hungarian, Finnish, and French licensing systems.

The second major topic of the work focuses on advanced nuclear technologies, particularly SMRs. These plants offer several benefits over conventional power plants; however, owing to their divergent characteristics, licensing procedures incapable of reflecting their novelties give rise to significant challenges in their deployment. One of the key questions the thesis intends to address is which features of SMRs

make their licensing difficult, and why current national licensing frameworks are, in some cases, ill-equipped to adequately license these reactors. In addition to examining the challenges SMRs pose to national frameworks, the thesis also explores regulatory approaches that could help mitigate these obstacles, without compromising nuclear safety. While the regulatory solutions proposed in the work could be implemented on a nation-by-nation basis, many experts have argued that certain features of SMRs call for greater harmonisation of regulatory frameworks, in order to fully harness their benefits. Consequently, the work also considers how increased international cooperation could support the efficient deployment of SMRs. However, before turning to the licensing considerations of SMRs, one further question must be addressed: the applicability of the international legal framework governing the nuclear sector to SMRs. Although this topic may seem to fall outside the licensing-focused scope of the thesis, a more holistic perspective on licensing must also account for these international instruments, as they form the foundations of licensing procedures and represent some of the basic considerations appearing within them.

The final aspect of the nuclear renaissance that the thesis seeks to address under its holistic approach to licensing is long-term operation (LTO). Since the deployment of new nuclear power plants in the nuclear renaissance, will still take considerable time before these plants become operational, one option that nuclearised states will need to consider, should their interest in nuclear energy be renewed, is the long-term operation of their existing nuclear fleet. In this part – given that long-term operation serves a different purpose within the nuclear renaissance compared to the thesis's two other topics, as it cannot itself contribute to the expansion of nuclear capacity – the analysis is limited to addressing

some of the most pressing legal considerations arising in the authorisation of long-term operation, namely: what standards these plants must comply with, how these procedures can be efficiently administered, and how they relate to EIA procedures.

1.2. Research questions of the thesis

The thesis raises two overarching research questions that apply equally to each of the topics discussed, helping to clarify both the current state of affairs and the ways forward. In this spirit, the first research question is: in what aspects do licensing frameworks hinder the materialisation of the nuclear renaissance, and where might they pose an obstacle to it? The second question, which builds on the outcomes of the first, is: how can licensing frameworks be transformed to become more enabling of the nuclear renaissance, without compromising the safety of these installations? As noted, whether in relation to the licensing of conventional plants, the licensing of small modular reactors, or the authorisation of long-term operation, the same research questions apply throughout, as the notion of the renaissance – materialising in each case differently – demands an evaluation of current practices and a reconsideration of them to enable its manifestation.

Besides these overarching questions, the thesis also raises more specific research questions within certain sections. Regarding the nuclear renaissance, the thesis first seeks to answer what the nuclear renaissance is, and whether it is realistic today to discuss its enabling conditions. In addition in the case of SMRs the thesis asks how the fundamental instruments of international law governing the nuclear sector may conflict with the advanced nuclear technologies or give rise to open

questions and how the rules of interpretation may contribute to resolving these issues in due course?

2. Brief description of conducted research and experiments, the methods of collecting material, the exploration and use of resources

2.1. Methodology

The thesis employs various methodologies, some of which correspond to specific sections, while others were applied throughout the work more generally.

The first among the general methods is the interdisciplinary approach, which extends beyond a technological background into several other fields. One of the key interdisciplinary aspect of this research is that a significant portion of the scientific literature drawn upon is not strictly legal in focus, but rather concerns various other fields that ultimately shape the relevant legal frameworks. In many cases, this interdisciplinary character involves technological and engineering questions. The subject matter is such that the current legal framework and potential future solutions cannot be properly understood without at least a basic grasp of the technology involved. This interdisciplinary approach is particularly relevant in the case of SMRs, whose licensing challenges, as well as their fit within the current international legal instruments governing the nuclear sector, cannot be properly assessed without first comprehending how they fundamentally differs from conventional plants.

As a second general methodology, the thesis adopts a strong doctrinal approach, within the framework of which it interprets international, community and national legislations, legislative proposals governing the

licensing of nuclear power plants. As part of this doctrinal approach, the thesis employs analytical methods to examine the motivations underlying certain regulatory approaches and to evaluate the extent to which they may impede or support the materialization of a nuclear renaissance.
Among the methods that appear in given sections of the thesis the comparative methodology can be highlighted. This methodology is primarily reflected in the sections discussing how the licensing of conventional nuclear power plants is regulated in the three analysed countries, from the initial political decision to embark on such projects to the commencement of initial operation.

2.2. Selection method for countries in the comparative section

The first criterion on which the selection is based is the Western European Nuclear Regulators Association (WENRA) and EU/Euratom membership. Since the thesis primarily adopts a European perspective, it is crucial to assess countries whose national solutions would be more easily adopted among European states. As the first criterion, this entails being members of WENRA, which seeks to develop common approaches to safety through its standards, and while these approaches are non-binding, states nevertheless adopt them, resulting in a greater degree of convergence in the substantive content of their licensing evaluations, which in turn makes the adoption of best practices among them more feasible. Furthermore, a limitation has to be made to discuss only countries that are members of the EU/Euratom, not only given their shared commitments to nuclear safety and the general organisation of the sector under the Euratom Treaty, but also due to their more general commitments under the EU acquis that shape the course of these projects,

such as those relating to environmental impact assessment procedures or state aid.

The second criterion on which the selection is based relates to nuclear power plant construction experience. Recent construction projects generate recent experience with licensing such installations, thereby highlighting the inefficiencies and redundancies of existing practices and prompting ideas for change, which in many cases are adopted during the deployment of these plants, as in the case of Hungary.

Based on these criteria, apart from Hungary, only a few countries can be considered for comparison, namely Slovakia, Finland, and France. Hungary was included owing to the author's national affiliation, while, of the latter three, Finland and France were selected, since Slovakia's recent construction experience did not involve an entirely new project or technology, but rather the continuation of a previously halted one.

3. Brief summary of the scientific results and their possible practical application.

General answers to the research questions:

What the nuclear renaissance is, and whether it is realistic today to discuss its enabling conditions? Renaissance may not be the best term if understood in its classical sense, in the context of the nuclear sector it refers to the envisaged accelerated expansion of the sector. The new political commitments towards nuclear energy, the positive projections regarding its future role, and the tangible enabling conditions that are being put in place indicate that it is more realistic than ever, but by no means certain.

In what aspects do licensing frameworks hinder the materialisation of the nuclear renaissance, and where might they pose an obstacle to it? For conventional plants and LTO, these procedures do not generally pose an obstacle to expansion, but in both cases, they may hinder it through inefficient and redundant procedures or, particularly in the context of LTO, by setting overly demanding safety expectations. In case of SMRs owing to technology- and application-specific provisions and prescriptive requirements, licensing procedures in cases pose obstacles to the deployment of SMRs. In addition, they generally hinder SMR deployment by providing only for project-specific licences, by involving time-consuming licensing procedures, and by imposing differing design requirements that do not reflect the standardised nature of SMRs.

How can licensing frameworks be transformed to become more enabling of the nuclear renaissance, without compromising safety in the case of SMRs? For all procedures, integrating complementary considerations, namely predictability and efficiency, besides guaranteeing a high level of safety, can help to adapt them to enable the renaissance. For SMRs, what is necessary is more universal in nature: some measures arise in the national context, while others require enhanced international cooperation. Among the national ones, the move towards technology-neutral and goal-setting licensing frameworks, along with the adoption of generic licences, can be highlighted. In the international context, the most critical are the development of harmonised licensing frameworks and enhanced regulatory cooperation in the review of designs. In the case of LTO, the most important task is to set reasonable safety expectations beyond the necessary upgrades and changes, so that the required investment is commensurate with the safety gain.

How the fundamental instruments of international law governing the nuclear sector may conflict with the advanced nuclear technologies or give rise to open questions and how the rules of interpretation may contribute to resolving these issues in due course? The thesis concluded that these international instruments are mostly technology-neutral and thus, in principle, cover SMRs, but that in some cases certain applications raise interpretative challenges that may be resolved through the evolutive interpretation of these instruments. Additionally, several practical questions need attention from States Parties, who should develop answers on the cases in which SMRs may receive different treatment under these instruments.

More specific conclusions and suggestions:

- *Holistic perspective*: A holistic perspective is needed to resolve the licensing challenges of the nuclear renaissance. First, a holistic perspective is necessary to develop new aims for licensing frameworks – complementary to guaranteeing safety – that can guide the adaptation of these frameworks to enable the renaissance. These should include the principles of predictability and efficiency – efficiency not only in terms of the length of these procedures, but also in the sense that they adequately reflect the different deployment strategies and needs of different plants. Second, a holistic perspective is also needed to encompass the different pathways of the nuclear renaissance – be it new construction, LTO, or recommissioning – and to develop adequate solutions to the challenges of these pathways without singling out one and neglecting the others. Third, a holistic perspective is needed to encompass the potential technological diversity of the renaissance and to

develop future-proof solutions. Fourth, a holistic perspective is needed with regard to the licensing procedures themselves, not just addressing the nuclear safety licensing. Finally, a holistic perspective means looking beyond national borders when adapting these frameworks, in order to find best practices or develop common solutions to problems that are similar across countries.

- *Reforming licensing is a tool*: Adapting licensing procedures to enable the renaissance is not going to resolve the delays and hindrances associated with the deployment of nuclear power plants. Adapting licensing procedures to enable the renaissance provides an adequate and efficient setting within which deployment can take place, however other elements particularly in relation to the human resources are needed to successfully make use of this on-paper adequate framework.
- *International cooperation is necessary*: The role of international cooperation in a broad sense – from sharing best practices regarding the efficient licensing of conventional nuclear power plants to the development of harmonised frameworks for standardised SMRs, to the development of shared review frameworks to leverage on foreign regulatory efforts or to answer the interpretative challenges of international instruments – should not be disregarded; for the successful materialisation of the renaissance, intensifying international cooperation is needed.
- *Regulators are crucial*: The role of regulators, as one of the crucial actors in licensing procedures, should not be forgotten, and regulators must be adequately equipped to facilitate the renaissance. In this regard, they need to possess the necessary competencies to carry out their tasks efficiently; regulators who serve merely as contact points while delegating the analysis of all substantive matters to other actors are

inefficient and overly dependent. The powers of regulatory authorities may extend beyond nuclear safety licensing, to other areas that are auxiliary to nuclear safety but necessary for the deployment of these plants, or to the adoption of implementing legislation reflecting technological innovations. As their competencies and responsibilities grow, their independence will be of even more critical importance, which warrants attention.

- *Decision-in-principle*: The nuclear renaissance needs to be transparent about both its benefits and its potential hazards. The energy transition should not be based on political commitment to a given energy source; enabling conditions can be adopted to facilitate this process across different sources – renewables and other low-carbon options alike – but decisions on concrete projects should be made on their merits and should therefore be transparent. If decisions are merit- and fact-based, there is nothing to conceal. A decision-in-principle, in a sector as contested as nuclear energy, is a valuable tool for conducting this merit-based evaluation while simultaneously ensuring transparency. It is not an unnecessary burden on nuclear projects, but rather a response to the associated opposition and the genuine hazards this technology carries. Nevertheless, in practice this stage should strike a balance between adequately evaluating the benefits and hazards of the project and the imperative of not imposing an excessive burden upon the applicant by requiring overly detailed information too early in the project. In this sense, the current Finnish stage is overly demanding while the vague Hungarian solution does not meet this criterion either.
- *Environmental impact assessments:* The staging of the EIA with respect to the nuclear safety licensing procedure is an important matter. To avoid repeated procedures caused by subsequent deviations, EIAs

should be placed at a stage when there is more certain information on the project, especially regarding the site. While environmental impact considerations should play a central role in identifying a suitable site early in the project, from an efficiency perspective – to avoid repetition of the EIA procedure – it would be desirable first to confirm that a site is suitable from a nuclear safety standpoint, since that is more of a yes-or-no question, and only then to conduct the EIA.

- *Reforms of licensing*: Licensing procedures applied today are fundamentally adequate in that they provide a high level of nuclear safety, therefore during the ongoing reforms these should not be abandoned; instead, certain measures are needed to increase efficiency, and some particular changes may be necessitated by SMRs. The extent of these necessary interventions, and whether they necessitate a complete overhaul of licensing procedures, depends on the national context. New stages dedicated to given technologies will not necessitate a complete overhaul, whereas changes to the general approach to licensing, such as moving away from prescriptive systems, may, as they require more substantive changes, albeit ones that will most likely occur at the level of implementing legislation. In relation to how the licensing of SMRs may be integrated into current licensing frameworks there is equally no clear answer as to: whether general procedures should be adopted, through which SMRs and conventional plants would equally pass, or whether separate procedures should be adopted for SMRs. General procedures open to all technologies seem promising, but where countries retain the prescriptive elements for conventional plants to capitalise on prior experience, SMR-specific procedures will be needed.
- *Comparative perspectives on nuclear power plant licensing*: The hypothesis of the thesis, that looking at foreign licensing frameworks in

a comparative manner can help develop more streamlined licensing frameworks, was proven. The analysis of the three countries revealed potential best practices that can help streamline licensing procedures while not compromising nuclear safety. In fact, certain institutions appear very similarly in different jurisdictions, suggesting that direct or indirect regulatory cooperation is already contributing to the advancement of the deployment of nuclear power plants. Particularly indicative were the reform efforts in Finland, which incorporate several rather unique ideas that can, in principle, greatly help to streamline these procedures.

- *Promising licensing stages*: For both conventional and SMR technologies, early engagement opportunities with regulators, in the form of pre-licensing, to receive feedback on the design are crucial to gaining certainty over its licensability and thus mitigating investment risks. Also crucial for both SMRs and conventional plants is the option of long-lead manufacturing, which allows certain construction or manufacturing activities to be carried out at the licensee's own risk while the construction licence application is being processed. From an SMR perspective, a particularly important element is the inclusion of generic licences for sites and designs, thereby de-risking the project-specific licensing stages.
- *Harmonisation for SMRs*: Harmonisation is necessary to deploy standardised SMRs. While there are notable ongoing efforts, namely the Nuclear Harmonisation and Standardisation Initiative, which beyond harmonisation also seeks to develop generic review procedures that can be leveraged among countries, the role of Euratom in advancing the development of harmonised licensing frameworks among Member States should receive more attention. The Community should pursue this by returning to the original, and again timely, rationale of the Treaty of

supporting the nuclear industry, through its capability to develop standards, thereby possibly contributing to climate change mitigation, energy security, and competitiveness.

4. List of Publications related to the topic of the Dissertation

Published:

Mádl, M.V. (2025) ‘The EU’s Energy Policy from the Perspective of a Central-Eastern European Country: Hungary’ in Szilágyi, J.E., Marinkás, Gy. (eds.) *Maastricht 30: A Central European Perspective*. Miskolc–Budapest: Central European Academic Publishing, pp. 653–677. https://doi.org/10.54237/profnet.2025.jeszgymmcep_26

Mádl, M.V. (2024) ‘The Evolution of Licensing Electricity Generation Capacity in Hungary’, *Central European Academy Law Review*, 2(2), pp. 121–142. https://doi.org/10.62733/2024.2.121-142.

Mádl, M.V. (2025) ‘Hungary’s Nuclear Legislation in Light of a Nuclear Renaissance’, *Journal of Agricultural and Environmental Law*, 20(38), pp. 47–90. https://doi.org/10.21029/JAEL.2025.38.47.

Mádl, M.V. (2025) ‘The Euratom Treaty as the Foundation of a Harmonised Licensing Framework for SMRs in Europe’, *Czech Yearbook of Public and Private International Law,* (16), pp. 295–311.

Under Publication:

Mádl, M.V. (forthcoming in 2026-2027) ‘New Build Nuclear Power Plants and Environmental Considerations in their Licensing: A Complex and Critical Mechanism’ in: B. Rakoczy (ed.) *The Interdisciplinary Nature of Environmental Law*, Nicolaus Copernicus University Press.

Angesti, V., Anggarani, B., Bresolin, E. Chen C-Y, Mádl, M.V. (forthcoming in 2026) ‘From Northen Cape to Europe: Feasibility and

Challenges of a Green Hydrogen Corridor', *Central European Academy Yearbook of Contemporary Legal Discourse,* 1(1).