NEA framing nuclear megaproject 'pathologies': vices of the modern Western society?[a]

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Abstract

The nuclear sector finds itself at a critical juncture, partly because recent large nuclear power plant projects in Europe and the US have suffered from what some scholars have called megaproject "pathologies", that is, the chronic failure of large, complex infrastructure projects to fulfil the "iron triangle" criteria of project performance: cost, timetable, and predefined project prescriptions. To explore the framings of such problems within the nuclear community, this article analyzes the ways in which 19 experts at the OECD Nuclear Energy Agency (NEA) diagnose such problems and their underlying causes. The analysis draws on framing theory and on the scholarship on megaprojects, with semi-structured interviews providing the empirical material.

The identified four frames highlight as key explanations for pathologies the "vicious circle" of lacking investment, erosion of skills and construction problems; "bureaucratization and contractualization", "broken markets", as well as "complexity and nuclear-sector exceptionality". Two overarching metaframes attribute the ultimate reasons to factors outside the projects and the nuclear community, notably to the lack of political leadership and the inability of the modern Western society to identify and pursue its own interest. The NEA frames bear significant resemblance to the "alternative" megaproject literature, which calls into question the very notion of pathology, stresses the complex, open systems character of megaprojects, and calls for flexibility and adaptability to better align megaprojects with their evolving context. However, the vital need to ensure and maintain an appropriate fit between nuclear-sector megaprojects and their ever-evolving environment deserves greater attention. Towards this end, introduction of OECD-style country peer reviews could constitute an opportunity towards collective "frame reflection", in interaction with communities offering competing framings of the pathologies. Further research would be welcome on the role of the NEA in framing processes within the nuclear community, and on the relationships between megaprojects and modernity in this high-risk industry.

Keywords: megaprojects; framing; OECD Nuclear Energy Agency; European Pressurized Reactor

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I. INTRODUCTION

Nuclear energy projects,[b] including nuclear power plants, represent a specific category of megaprojects,[1,2,3,4,5] i.e. "large-scale, complex infrastructure projects usually commissioned by governments and delivered through partnerships between public and private organizations, with multiple partners, high uncertainties, and considerable political stakes".[6] These projects have particularly long planning and implementation horizons, generate multiple controversies, attract considerable public, political, and media attention, and need to adjust to the constantly changing societal demands and objectives.[7] Moreover, they are typically unique, one-off endeavors lacking precedents upon which to build their planning and assessment. Nuclear power plant (NPP) projects display high technical and organizational complexity, especially in the increasingly complex supply chains and financing arrangements. Complexity is accentuated by market competition with alternative energy sources, safety requirements possibly more stringent than in any other industrial projects,[8] significant legal, social, and environmental implications, the particular strategic importance of these projects for the countries and regions in question, and the value conflicts involved.[9] A typical NPP project involves a range of key participants, most notably the government, responsible for energy policy and sometimes financing; the electricity market, with its multiple players; the utility, responsible for the project as a whole; the engineering, procurement and construction (EPC) companies responsible for delivery to the owner; the vendors, supplying equipment and technology to the owner, the EPC contractor or as part of a joint venture or consortium; and the safety authority, responsible for protecting public safety and the environment throughout the entire lifecycle of the project, until decommissioning and waste management.[10]

Megaprojects often suffer from what some scholars have labelled as "pathologies"[11] or "pitfalls",[12] defined as their failure to meet the "iron triangle" criteria of project performance: cost, timetable, and predefined project prescriptions.[13] Such problems – often attributed to the inherent characteristics of megaprojects – have plagued the recent nuclear power plant projects in the West, notably the European Pressurized Reactor (in the US, the Evolutionary Pressurized Reactor) projects in Finland, France, and the UK. The extent of these problems has led some to call into question the very future of light-water reactor technology,[14] at a moment when few countries in the West are planning significant nuclear new-build programs and several countries, especially in Europe, are phasing out nuclear energy.[15] To explore the views of the nuclear community on such problems, this article *1) draws on framing theories to identify the ways in which officials at the OECD Nuclear Energy Agency (NEA) describe and explain the reasons behind the problems faced by current large-scale nuclear projects, and 2) examines these framings against those found in existing megaproject literature*. In its recent publications, the NEA has indeed underlined the vital role of cost and timetable considerations for the very survival of the global nuclear industry.[8,16] As a leading intergovernmental expert organization with the mission to "keep the nuclear option open" for the willing member countries, the NEA constitutes a fruitful terrain for analyzing views

[b] In this article, the term "nuclear" is henceforth used to denote only civilian uses of nuclear technology.

within the nuclear community. The ways in which the Agency frames these topics can be assumed to reflect the perceptions prevailing amongst its wide industrialized-country membership, while at the same time shaping these very perceptions. Devoid of coercive power, just like its sister organizations in the OECD 'family', the NEA relies on indirect means of influence of "soft governance", entailing processes of socialization, formation of identities, constitution of shared norms, and gradual shaping of the ways in which problems and solutions are framed in policy and public debates.[17,18]

The article draws on theories of framing – which address the ways in which actors make sense of "raw" information and give it meaning and coherence[19] – and on insights from literature on megaproject governance and appraisal. The analysis focuses on one element of framing in particular, namely the "problem diagnosis", that is, the causal explanations offered by the interviewees. Two partly competing accounts suggested in the literature on megaproject governance and appraisal provides the basis for the exploration of framings. The "mainstream megaproject scholarship" has focused its search for explanations and solutions on the "iron triangle" criteria. It identifies overoptimism and strategic misrepresentation of facts as the key culprits, and proposes greater control, accountability and involvement of private risk capital as solutions to bring more realism to project planning, assessment and management. The mainstream has been challenged by alternative accounts that advocate "making the best out of" the irreducible uncertainties in order to introduce flexible and adaptive governance, contest the possibility and desirability of control, and call for the application of project performance criteria that go beyond the "iron triangle".[20]

By exploring the ways in which NEA experts frame the problems faced by current NPP projects, and by mirroring these framings against lessons from megaproject literature, this article seeks to inform both nuclear community's internal debate and its interaction with society at large, at a moment when especially the Western nuclear sector finds itself at a critical juncture. In particular, by identifying the causal reasoning in the argumentation of NEA experts, the article provides an input towards 'frame reflection'[21] – collective exploration and reconsideration of prevailing framings and their alternatives – as a means of greater opening of the nuclear community towards society. This kind of opening appears as a necessary precondition for ensuring an appropriate fit between nuclear-sector projects and their environment, and thereby the resolution or clarification of what often appear as intractable public controversies surrounding nuclear projects. OECD-style peer reviews of NEA member countries' nuclear policies could constitute a possible step towards frame reflection. For megaproject scholarship, the analysis of NEA expert views paves the way for research on the relationships between megaprojects and modernity, in an industry sector with risk and safety as pervasive concerns.

The following section describes the concepts of framing and megaproject pathologies. Section 3 briefly describes the European EPR projects as an example of the problems faced by current Generation III reactor projects, introduces the NEA as a research object, and presents the research methods. Section 4 presents the findings, while section 5 discusses the

implications of the results, and places these in the context of the NEA's role in the nuclear community and as a member of the "OECD family". Section 5 concludes.

II. CONCEPTUAL FRAMEWORK

II.A. What are Frames?

In essence, a frame is a schema of interpreting reality.[19] Entman defined framing as "select[ing] some aspects of a reality", thereby making "them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation."[22] Through framing processes, societal actor groups not only draw attention to specific topics, but also influence which problem definitions, interpretations, moral judgements and/or policy recommendations come to prevail.[23] Frames are more than mere representations: policy actors frame in order to know how to act in a situation at hand, and to influence the framings and behavior of other actors. Frames emerge and evolve through dialogue – mutual interaction of policy actors grappling with real-world problems. Frames are akin to stories or roadmaps, which describe what is wrong with the present situation and tell what to do in order to transform that reality.[24]

Frames interact, typically including overlapping and shared elements. Frames are not always internally coherent and unambiguous: a frame organizes and signposts a discourse, yet the shared concepts and causal beliefs within a frame may lead to diverse normative judgements. Individual frames can be regrouped into overarching "metaframes" that hold a stronger normative content than the individual frames.[25,26] The interaction of competing frames within an organization contributes to the establishment of a dominant "organizational discourse",[27] or on a yet more general level the "culture" of the given community. In this broad sense as "the stock of commonly invoked frames",[25] the NEA frames can be seen as indicative of the prevailing culture within the international "nuclear community".

Frames gain their power in becoming taken-for-granted descriptions of reality. Framing processes entail both conscious attempts by policy actors to advocate frames that they see beneficials for their own interests and values, but also and above all subconscious processes whereby policy actors unintentionally reinforce specific frames by applying these in their discourse and as guide for action. Modifying the frames that guide policy action, and thereby stepping out of the certain inherent determinism implied in the frames, requires explicit attention to the contents and structure of the frames themselves, but also ability to "step back and gain distance from our disposition to act".[24] Analyzing the causal reasoning implied in specific framings does not as such liberate actors from the institutional routines that constrain their ability to take such distance.[24] However, it can provide an elementary basis for dialogical processes of frame reflection, by exposing the often hidden framings to internal and collective scrutiny.

II.B. Two Rival Accounts of Megaproject Pathologies

The emergence and proliferation of scholarly literature on megaproject governance and appraisal can be traced back to what Flyvbjerg et al. describe as the "megaproject paradox": all the while ever more and larger infrastructure projects are being proposed and built, the performance of such projects remains notoriously mediocre, in terms of economy, environment and public support.[2] This literature, mostly in the disciplines of project and innovation management, can in broad terms be divided into what I will in the following call the mainstream and the alternative approaches.

II.B.1. The Mainstream Rationalists

Bent Flyvbjerg and his research group on Major Program Management at the Oxford Saïd Business School constitute the leading and high-profile representative of the "mainstream" vision. Three key elements can be highlighted as constitutive of the mainstream approach.[28,29] First, this literature focuses on the "iron law" of megaprojects,[30] that is, the repeated failure of the vast majority of these projects to meet the "iron triangle" criteria of cost, timetable, and predefined project specifications.[31,32] Second, it argues that megaprojects fail because of project selection dynamics that favor the least viable projects,[33] following from strategic, rent-seeking, and opportunistic behavior by planners and other key actors. Key explanations underline cognitive biases – the inherent optimism of human beings ("optimism bias", or "planning fallacy") – and, above all, "strategic misrepresentation",[34] which postulates that project advocates have an interest to lie and misrepresent costs and benefits in order to maximize the project's chances of winning public funding.[2,35,36] The outcome would be the "survival of the unfittest": the selected projects are those that look best on paper, i.e. projects promising the most – presenting the largest cost underestimates and benefit overestimates.[37] The very long timeframes are seen to further accentuate the problems, since project advocates, including politicians, would often no longer be in office when the actual viability of the project could be assessed reliably.[38,c] Third, in order to remedy the problems, the mainstream focuses on means of strengthening control and accountability, via the involvement of private risk capital, and appraisal methods inspired by behavioral economics, such as "reference class forecasting".[37]

II.B.2. The Alternative Megaproject Literature

While not rejecting the observation concerning the multiple problems facing megaprojects, the alternative strand of scholarship has criticized the mainstream for adhering to an excessively limited range of project performance criteria, and for underestimating the vital role of the context and the numerous alternative rationalities underpinning megaprojects.[6,39,40]

The alternative megaproject literature criticizes the mainstream for assuming that individuals

[c] Locatelli has pinpointed optimism bias and strategic misrepresentation the Olkiluoto and Flamanville EPR projects, especially in the budget and timetable estimates. [9]

are practically always mischievous, ruthless, opportunistic and rational maximisers of their individual utility, able to accurately calculate probabilities and optimize their own position accordingly.[6,38] Megaproject problems would instead result from clashes between different rationalities and "project cultures". This literature underlines the multiple types of complexity involved in megaprojects. These concern the policy area of megaprojects (e.g. sustainable development, regional development, nuclear power, radioactive waste management, etc.) and their governance, which implies facing complex "wicked problems" that entail significant ambiguity and defy optimization or simple true-or-false solutions.[41] Complexities are structural – involving multiple interacting components (including stakeholders) in the overall system architecture – and dynamic, with pervasive unpredictability and continuous flow of emergent events.[42] Failures in light of the iron triangle criteria would often result from "normal practice of professionals operating with limited knowledge, but influenced dramatically by a range of ambiguous and uncertain external and internal forces",[6] and from governance arrangements unable to cope with deep uncertainty.[43]

For megaproject management, this view advocates experimentation, flexibility, strong project leadership, and approaches that embrace the irreducible uncertainties.[40,42,43,44] The "Hiding Hand" principle, coined by Albert Hirschman,[45] asserts that overoptimism is a necessary precondition for projects beneficial for society – not the pernicious root cause of "pathologies". Project planners and managers must underestimate the challenges that a project is likely to present, in order to summon up the necessary courage as well as the vital support from decision-makers and funders. The unexpected challenges encountered during project implementation would prompt the creativity, innovativeness, and learning essential for societal progress. Unsurprisingly, Flyvbjerg, as the leading scholar in the mainstream literature, has rejected the notion, arguing that a "Malevolent Hiding Hand" leads some 80% of projects to fail, because of strategic and opportunistic behavior.[46]

According to the 'alternative' literature, megaprojects would be best understood as loosely defined and evolving networks, i.e. open systems, "programs of projects" [13,42] or "networks of people and organizations that work more or less coherently and purposefully to address complex public problems".[47] The view follows closely Latour's notion of "contextualization", whereby a project itself is transformative, in constantly shaping and recreating its own context, instead of merely adapting to a pre-existing context. To do so, projects "need allies, friends, long chains of translators".[48] Consequently, methods such as cost-benefit analysis would be of little use in assessing megaprojects,[13] which should be judged in terms of their ability to generate "wider benefits" [49] and positive transformational changes over time – in the case of nuclear power projects notably in the broader energy policies. Appraisal criteria should evolve along with changing societal values: a 'failed' project may turn out to be a success over time, when viewed in light of the evolving societal values and project objectives.[13]

Ultimately, this strand of scholarship questions the very notion of "pathology", based on a narrow "iron triangle" view of project performance. In the following, the term is however maintained, as a shorthand for the failure of megaprojects to meet the "iron triangle" criteria.

Table 1 summarizes the key characteristics of the two strands of megaproject literature.

	Mainstream megaproject scholarship	**Alternative megaproject scholarship**
Key philosophical and theoretical focus and commitments	Power, economic rationality, risk, behavioral economics and cognitive biases	Complexity, collaboration, multiple rationalities, learning, deep uncertainty
Political theory	Machiavellian, rationalist	Deliberative democracy, network governance
Reasons for megaproject pathologies	Strategic misrepresentation Optimism bias	Complexity Clashes of cultures
Consequences	Survival of the unfittest	Shifting project goals; ambiguity on what is "success" or "failure"
Remedies	Control, accountability, private risk capital, better governance, reference class forecasting	Adaptive/network governance, embracing and making the best of uncertainties; "governing instead of governance"
View on megaproject success and viability	Skeptical; dominance of a Malevolent Hiding Hand	No a priori position; possibility of a (benevolent) Hiding Hand

Table 1. Key features of the mainstream and alternative strands of megaproject scholarship.

III. METHODS AND THE RESEARCH OBJECT

III.A. Current problems with Generation III reactors as a starting point for reflection on nuclear megaproject pathologies

The problems faced by NPP projects in the West in general, and those with the EPR in particular provided the basis for the inquiry of NEA framings presented in this article. The development of the EPR began at the end of the 1980s as a French-German joint endeavor, promising to relaunch nuclear new-build after the long period without reactor orders following the Chernobyl catastrophe, and to become a major export product of the French nuclear industry – the showcase of the "nuclear renaissance" in Europe.[50] As an incremental improvement to the present reactors, this so-called Generation III reactor would be significantly safer, consume less uranium, produce less radioactive waste, and generate electricity at a cost up to 20% lower than the current Generation II reactors.[50,51]

The European EPR projects have faced drastic budget overruns and delays, following significant technical and organizational problems on the worksites.[52] The extent of these problems has led some critics to question the very future of light-water technology.[53] The Finnish TVO signed in December 2003 a turnkey contract with Areva NP – a joint venture of Areva and Siemens – to build an EPR as the third NPP unit in Olkiluoto. Japan Steel Works and Mitsubishi Heavy Industries supplied the reactor pressure vessel. The construction started in 2005. In 2009, Siemens sold its shares in the joint venture to Areva, but remained

the supplier of the turbine hall. Widespread subcontracting added further complexity: during the peak construction period, the site hosted more than 4000 workers from nearly 60 countries, a wide range of disciplines and backgrounds, and speaking dozens of languages. Areva operated for the first time as the architect-engineer, whereas many of its subcontractors were unfamiliar with the Finnish conditions and regulatory practices.[54] The plant is approximately three times over the initial budget of EUR 3 bn and twelve years behind the original schedule (in August 2020, TVO foresaw the start of commercial operation in February 2022).[55] The repeated delays led to a long-drawn arbitration between Areva and TVO over the apportioning of the cost-overrun. In a dispute settlement, in March 2018, Areva agreed to pay TVO EUR 450 million for cost overruns and delays.[56]

The EPR project in Flamanville, Normandy, has experienced similar delays, cost overruns and serious technical problems. Construction started in 2007, with EDF as the architect-engineer and supplier of the nuclear island, Areva NP as the reactor supplier, Bouygues responsible for the main civil engineering, and Alstom providing the turbine-generator. To avoid problems encountered earlier, stemming from a high number of project partners (as many as 500 in the French N4 projects in the 1980s and 1990s), EDF limited the number of contracts to about 150, with the eight largest partners representing some 70% of the total. This, in turn, led to increasing subcontracting.[52] The original budget of EUR 3.5 billion has grown to EUR 12.4 bn, and the initially expected start date of 2012 delayed until 2023, according to estimates from February 2020.[57] Technical problems have concerned notably the qualification of the pressure-vessel head, and welds in the main secondary system. EDF had solid experience of constructing and commissioning NPPs for the extensive French nuclear program, yet the experience was somewhat outdated, the latest unit having been completed already in 1999. Furthermore, EDF depended on a new and untested supplier network.[52]

The EDF project of constructing two EPR reactors at Hinkley Point, UK, is likewise significantly over budget (initially £16 bn, in September 2019 estimated at £21.5-22.5 bn), with the expected delivery now eight years behind the originally planned 2017.[58] Similar ills have plagued the construction of the American Gen III reactor, AP1000, although its design principles greatly differ from those of the EPR. While the EPR applies active safety features and redundancy – which add costs and complexity – the AP1000 relies on passive safety and reduction of the number of costly components, including piping, and cabling.[59] By contrast – and despite some uncertainty concerning especially budget comparisons – the EPR and AP1000 projects in China have advanced without extreme delays and cost overruns, being delivered about 5 years late of the initially announced schedule,[60,61] and in the case of the EPRs in Taishan, “only” about 60% over budget.[52]

III.B. The OECD Nuclear Energy Agency as a Research Object

Founded in 1958, under the name European Nuclear Energy Agency, at a time when nuclear power was seen as a major solution to Europe’s energy problems, the NEA became in 1972 one of the Special Bodies of the OECD, and includes (in January 2021) 34 nuclear and non-

nuclear countries from Europe, North America, and the Asia-Pacific region.[62] Its membership largely but not fully overlaps with that of the OECD,[d] one of the key organizations of post-War Western reconstruction and champion of economic liberalism.[63,64,65,66,67] The Agency has considerable autonomy in relation to the OECD, notably in deciding on its work program, within the bounds of the OECD code of conduct and rules of recruitment. The NEA describes its core mission as assisting

> its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally sound and economical use of nuclear energy for peaceful purposes. It strives to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD analyses in areas such as energy and the sustainable development of low-carbon economies.[68]

In principle, the NEA does not promote nuclear, but only helps to keep the nuclear option open for the willing member countries. Its work is organized under eight specialized standing technical committees that supervise numerous permanent and ad hoc expert groups consisting of expert delegates nominated by the member country governments. Representatives from industry and academia often participate as observers, but sometimes also as government nominees. Within these groups, experts exchange information, develop joint opinions on technical and policy issues, identify areas for work, and organize joint research projects.[69] As in OECD work in general, these NEA experts from a set of like-minded countries, sharing a number of common values and principles, have considerable freedom to exchange knowledge, experience, best practice, and informal social norms of "good behavior", in the absence of constraints posed by the kinds of bargaining and negotiation typical for organizations with regulatory power.[70]

The NEA can be seen as a creator of shared discourses, joint problem definitions and solutions within the international "nuclear community". While research on framing has largely focused on the role of the media in shaping the understanding and interpretation of policy issues by various audiences,[71] also intergovernmental organizations exercise framing power.[72] As an essentially knowledge-based organization operating at the interface between policy and expertise, covering over 80% of current nuclear capacity in the world, and devoid of direct regulatory power, the NEA's influence indeed relies on such processes involving framing – "soft persuasion", i.e. creation of shared norms, ideas and identities,[17,67] or "epistemic governance".[73] Given the NEA's broad membership, its framings are likely to reflect those present within the global nuclear community.

[d] NEA members include countries that have never operated nuclear power stations (Australia, Austria, Denmark, Greece, Iceland, Ireland, Luxembourg, Norway, Portugal, and Turkey). OECD members not belonging to NEA are Chile, Estonia, Israel, Latvia, and New Zealand – none of which has operating nuclear power stations – while Argentina, Romania, and Russia are the current non-OECD members of the NEA.

The true 'trademark' of OECD is the "peer pressure logic", best understood as a "soft" accountability mechanism, whereby member countries engage in mutual surveillance of the degree of respect for shared norms and principles. Comprehensive international country peer reviews in a given policy area (e.g. economy, environment, energy, territorial policy) constitute the most concrete manifestation of such a logic.[74] The OECD describes these reviews as *"the systematic examination and assessment of the performance of a State by other States, with the ultimate goal of helping the reviewed State improve its policy making, adopt best practices, and comply with established standards and principles",* and being characterised by *dialogue* and interactive investigation, a *non-adversarial* setting, mutual *trust*, shared *confidence* in the process, and mutual *accountability.*[74] The NEA does not carry out comprehensive peer reviews of its member countries' nuclear policy, but only on specific technical topics, at the demand by a specific nuclear-sector organization in the member country, with little peer country scrutiny. The NEA secretariat experts also participate in drafting the nuclear-specific section of IEA energy policy reviews of countries with NPPs.

The NEA secretariat coordinates the work and explicates the joint views amongst the member countries. Its six divisions reflect the Agency's main areas of work: nuclear energy development, nuclear safety and regulation, radioactive waste management and decommissioning, radiological protection and public health, nuclear law and liability, nuclear science, and information and communication. Located at the outskirts of Paris, it has currently a staff of just over 100 highly trained nuclear-sector professionals, representing a wide range of countries and fields of expertise. Nuclear science and engineering dominate, but law, economics, and other social sciences are represented as well. Most work on temporary contracts – including member country secondments and student trainees – and seldom remain at the NEA longer than five years before returning to their home institutions. Because of this relatively quick turnover of officials at the NEA secretariat, the views held and expressed by these experts are probably more representative of those of the wider nuclear community than would be the case if the contracts were longer-lasting, and more conducive to the emergence of an independent NEA-specific culture.

III.C. Material and methods

Semi-structured interviews (in which the interviewer asks open-ended questions) were conducted between July and September 2019 with 19 officials from all six divisions of the NEA secretariat, representing a range of different roles and expertise in the Agency's hierarchy, including both permanent and temporary, senior and junior staff. The largest single division represented was that of Nuclear Technology Development and Economics, with six interviewees. Amongst the diplomas held, engineering (8) and physics (7) diplomas were the most represented, followed by economics (3), law (2), business (2), international relations

(1), and humanities (1).[e] Nine interviewees had worked at the Agency for less than four years, eight (8) between five and ten years, and two for over 25 years.

The interviews were carried out during the 4.5-month period that I spent at the NEA, collecting material for my research. The interviewees were selected via a "snowball method", whereby I asked the interviewees and other Agency staff to suggest individuals with knowledge of nuclear-sector megaprojects in their fields of expertise. The interviews lasted between 55 minutes and 3h10. All were tape recorded, except one, following the interviewee's request. The interviewees received in advance a two-page interview guide, which briefly described the research project, explained the notion of "pathology", and listed the tentative key themes for discussion. The list consisted of potential explanations to the nuclear megaproject "pathologies", drawn from earlier literature, and classified under six categories: economic and financial issues, technology, regulation, organization and management, political aspects, and social/societal aspects. On the recommendation from the first interviewee, the "supply chain" was added as the seventh category. The term "pathology" was chosen partly in order to provoke possible counter-reactions and test the extent to which the interviewees embraced this notion. The interviewees were asked specifically to express their views on the EPR reactor projects and technology. NEA publications helped to prepare for the interviews, but were not the subject of the empirical analysis.

The analysis built on an oft-used typology of four "framing functions" to be found in in a text or discourse: 1) defining the problems, 2) diagnosing causes, 3) providing a moral judgement, and 4) suggesting remedies.[22,75] This article concentrates on the second function, that is, identifying and understanding the ways in which the interviewees diagnosed the causes of nuclear megaproject pathologies. The other framing functions, when mentioned by the interviewees, are in the following addressed to the extent that they help to better understand these causal reasonings. Questions relating to the emergence and evolution of frames, through mutual interaction between competing frames in their policy context, lies beyond the scope of this article, but constitutes a fruitful topic for further research.

The views expressed can be seen to reflect both *frames in thought* – i.e. how the interviewees perceive the problems, their causes and solutions, and *frames in communication*, that is, "the words, images, phrases, and presentation styles that a speaker uses when relaying information to another".[76] The interviewee responses certainly consisted of a combination of inner thoughts and perceptions held by the interviewees, strategic considerations concerning the best ways of communicating these messages to me as an "outsider-insider" (an academic researcher spending 4.5 months to work and collect material at the NEA), and the established institutional "frames in communication" within the Agency.[74]

The material was analyzed via a constant moving back and forth between 1) the notes taken during the interviews, 2) relistening to the audio recordings, and 3) earlier academic literature

[e] Including double diplomas.

on megaprojects. The relistening rounds also allowed completing and refining the field notes. For each interview, a summary, outlining the dominant explanations for "pathologies", was drafted. This summary provided the basis for the construction of the framings and causal relations depicted in the next section. Although verbatim transcription would have allowed more precise and quantitative handling of the material, it would also have absorbed time and resources needed for analysis and interpretation. Crucially, the chosen reflexive, iterative method facilitated the primary objective of frame analysis – the interpretation and understanding of the broader thrust of an interviewees' discourse and reasoning.[77] The process of constructing the frames adopted a combination of a data-based and theory-based approach: on the one hand, frames were constructed as they emerged from the material – the explanations given by the interviewees for the problems – and on the other hand by drawing on the explanations and diagnoses suggested in megaproject literature. Metaframes were subsequently constructed by searching in the frames for shared underlying causal and normative elements. Metaframes are foundational in the sense that all of the other frames can ultimately be deduced to the metaframes. Semi-structured interview method suited the combined data- and theory-based approach, with a tentative list of topics providing guidance but allowing the interviewee to elaborate on issues outside of the list. It also enabled me to further pursue specific questions that appeared as particularly salient, in view of the specific expertise and experience of the interviewee, and to obtain views beyond the official NEA positions.

In the following presentation of the results, anonymized quotes from the interviews are used to illustrate the framings (I-1 = interviewee 1; I-2 = interviewee 2, etc.).

IV. NEA OFFICIALS AND MEGAPROJECT PATHOLOGIES: FOUR FRAMES AND TWO METAFRAMES

This section describes the key findings – the four mutually interacting main frames and two overarching metaframes identified in the interviewees' descriptions of the causal relations behind the problems of nuclear-sector projects. The frames were named as the "Vicious circle", "Bureaucratization and Contractualization", "The Broken Markets", and "Complexity and nuclear-sector exceptionality". The two metaframes were named "Political Support and Leadership" and "The Modern Western Society".

IV.A. Vicious circle

The first frame builds on the observation that became clear early on as I advanced with my interviews: my interlocutors considered the lack of investments in new NPP projects and nuclear programs the primary problem, not the "pathologies" as such. What would be needed, they argued, is a virtuous circle whereby successful nuclear projects engender optimism and enhance the attractiveness of the nuclear sector, thus leading to substantial new-build programs, which would in turn provide the stability and certainty needed to attract investments for individual projects. In line with the megaproject scholarship, this framing therefore underlined the transformative capacity of NPP projects, and their embeddedness in

broader strategies: individual projects would be needed to stimulate larger nuclear programs, shape energy markets, and help create low-carbon societies.

The current reality, as described by the interviewees, was exactly the opposite, that is, a vicious circle from the lack of long-standing lack of investments, through the lack of "exercise of the supply chain", erosion of skills, and subsequent problems in project delivery, back to lacking interest amongst investors and policymakers in nuclear-sector projects. Supply chain problems were repeatedly evoked as a major explanatory factor: the long period without NPP projects in the West had led to the dismantling of the vital supply chains and to the erosion of both technical and organizational project implementation skills in most NEA countries. This skills gap was described as a generic phenomenon plaguing large infrastructure development projects also in other sectors. Skills shortages and lack of experience were evoked to explain the difficulties of construction teams in executing even seemingly simple and "non-nuclear" tasks such as welding or pouring the concrete. Because of the long construction gap also the regulators lacked practical experience, and hence tended to be "extremely cautious", unwilling to deviate from pre-established practices, which, in turn, generated uncertainty and delays. In this frame, improving project performance in terms of the "iron triangle" criteria appeared as essential for attracting investors, not least to avoid further reputational damage inflicted upon the sector by the problematic Gen III projects.

The deleterious effects on technological learning from the lack of investments and "exercise" of the supply chain were in this frame described also via the inability to move beyond first-of-a-kind (FOAK) towards a series delivery of "N^{th}-of-a-kind" (NOAK) projects. Even apparently similar designs – notably the EPR – were said to exhibit significant differences across the current project sites in Europe and China, in terms of the contractor (EDF and Areva), equipment suppliers and supply chains (e.g. reactor vessel for Olkiluoto 3 from Japan Steel Works and Mitsubishi, and for Flamanville 3 from Areva's Le Creusot forge), technical details, regulatory environment and culture (differences between the French ASN and the Finnish STUK in terms of the safety requirements, e.g. concerning the filtered containment venting systems, detail of the documentation, timing of requests), as well as physical and climatic conditions (e.g. the Finnish harsh winters in Finland, strong winds and space limitations at the Flamanville site). The interviewees therefore described the Olkiluoto and Flamanville EPRs as two distinct FOAK projects.

A different twist to this frame was provided by an interviewee who suggested that the problems faced by large NPP projects might have a silver lining in helping to reverse the vicious cycle. If series production of large reactors indeed proves unviable, this might stimulate interest in alternatives, notably SMRs, engendering healthy competition between a range of nuclear technologies, thereby attracting interest from investors and politicians.

The Vicious Circle aligned with both strands of megaproject literature in underlining the transformative nature of nuclear projects. In line with the alternative strand, it portrayed the 'pathologies' as a secondary problem. In underlining learning and skills as vital for breaking the circle and moving towards series production of either large reactors or SMRs, this frame

implicitly builds on the assumption inherent in megaproject scholarship that the uniqueness of megaprojects, i.e. their lack of precedents and enduring FOAK nature, is a crucial contributor to the 'pathologies'. In this sense, the solution would be to move beyond megaprojects.

Figure 1 summarizes the key causal relations involved in this frame.

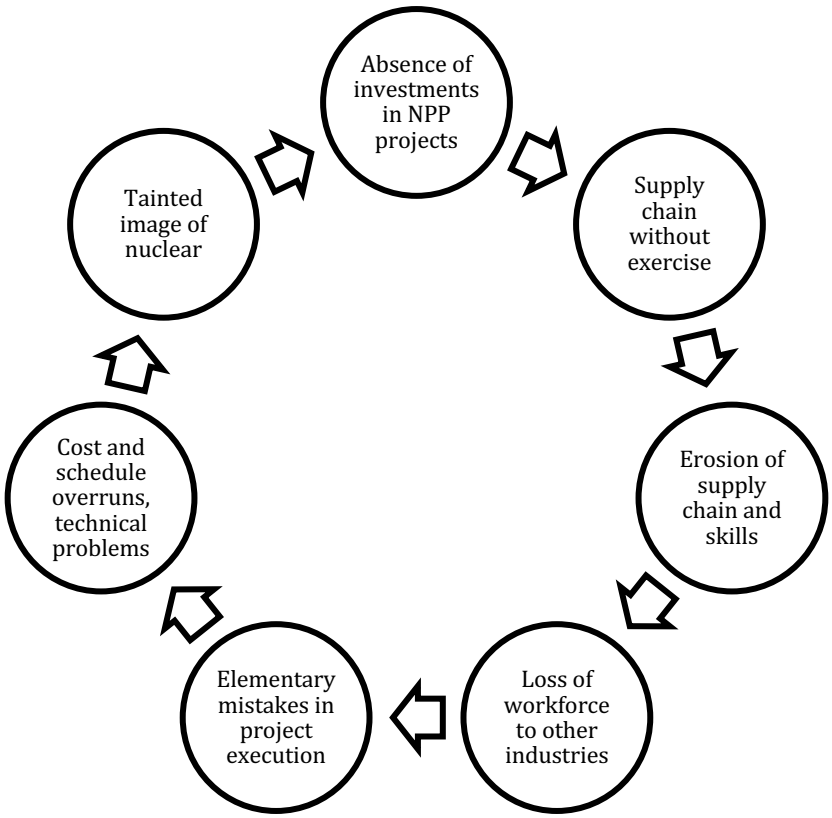

Figure 1. The Vicious Circle

IV.B. Bureaucratization and Contractualization

This frame focuses on the implications that the increasingly bureaucratic and contract-based project management culture across industries has on the innovative and adaptive capacities of nuclear projects. The frame places at the forefront the tensions between the equally necessary needs for stability and flexibility. The interviewees blamed the current project management culture for rigidity, "technocratization" (I-7), and "contractualization", which leave little space for innovation and adaptation. The ever longer and more complex chains of subcontracting lead to the multiplication of increasingly detailed and "punitive" (I-4) contracts. Partly the question was about the time wasted on administrative tasks such as monitoring, reporting, and internal communication: "The number of people to whom you must report is considerable, but the number of people who contribute something is very small" (I-7). Part of the problem was attributed to a "technocratic mode" of management

whereby technical expertise and engagement in managing the project is increasingly replaced by "tick-box" procedures designed to "show that it's not your fault" (I-7), "cover our backs" (I-1), and "pass the blame" (I-4). The project manager having lost a lot of his/her freedom of maneuver, projects would be driven by narrowly specified milestones rather than by what is best for the overall advancement of the project. The EPR problems were in part attributed to a project management culture that does not allow the technology to adapt to the changing context and objectives of society (e.g. economic trends, financing possibilities, demand for safety, nuclear energy policies).

I-13 expressed the problem in the language of risk management: costs are driven up by the fact that "all of the engineering, procurement and construction contractors and equipment suppliers try to hedge against uncertainty, through various contracts between the associated parties".[f] While in the past the project manager would carry the residual risk on behalf of the teams working under his leadership, this option no longer exists, because the huge complexity of projects has transformed the culture of engineering.[g] According to I-10, "captains of industry", dedicated to the long-term development of their company and sector, have been replaced by people "with a much more short-term vision". This substitution of an "industrial vision" by a "purely capitalistic vision" would have eroded the industrial base both in Europe and in the US, coupled with declining university-level student interest in industry careers relative to e.g. consulting. The chain of causality therefore entails successive steps from the nature of contracts, through hedging against risks by the various project stakeholders, the constraints on project managers' freedom, dominance of short-term economic reasoning, unnecessary litigation, lack of adaptation of projects to their context, erosion of skills, finally to technical problems, delays, and cost overruns.

The interviewees elaborated at length on the consequences that the replacement of an "engineering rationality" and individual responsibility by strict administrative rules has had on nuclear safety regulation. The problems were traced to the ever-more detailed, prescriptive, static, and perhaps unreasonably demanding safety regulation, the increasingly problematic and conflict-prone operator-regulator relationships e.g. at the Olkiluoto 3 and Flamanville 3 projects, and the inability of the industry to pass on regulatory information and advice along the extensive supply chain. Several interviewees argued that ever stricter control and verification of compliance with rigid rules would not necessarily enhance safety, which would instead require continuous adaptation and learning from the past.

However, many interviewees pondered upon the complex trade-offs between stability and flexibility, and between prescriptive and objective-based regulation. The constant regulatory

[f] Another interviewee noted: "if you pass on the risk to a subcontractor, what's this going to do? Well, he takes his margin. And when every subcontractor in the chain does the same, this produces a multiplier effect: we arrive at a situation in which the final cost of the project does not represent the tons of concrete and metal, but reflects instead poor risk allocation, in a contractual framework that didn't incentivize virtuous behavior". (I-10)

[g] "Today, you never see anything like this, because the projects are hugely complicated, there are far too many moving parts, so the person who is formally *the* project manager does not make decisions alone, as he would have done in the past." (I-2)

changes during the design and implementation of the projects would cause: i) uncertainty amongst reactor designers and vendors, ii) delays and cost overruns of individual projects, and iii) increasing average construction times and budgets of successive reactor projects over time. The desire of regulators to demonstrate their independence in relation to the operators and the government would add further uncertainty. While this independence was seen as crucial, it would also – together with fundamental differences between regulatory traditions and "philosophies" (e.g. between France and the US) – tend to multiply country-specific standards, and thereby hamper the creation of a true international market for vendors and equipment suppliers. Crucially, it would also discourage cooperation and communication between the industry and the regulators. Many evoked, explicitly or implicitly, the somewhat complicated operator-regulator relations, with the Olkiluoto and Flamanville EPRs as examples.[h]

The suggested remedies help to summarize the underlying reasoning. A "collaborative spirit" in the pursuit of a common objective would be needed (although many struggled to find appropriate words to describe the desired operator-regulator relationships), alongside "reasonable" and context-adapted regulation, which would possibly pay attention to the costs of the safety measures.[i] Flexibility and adaptation would be necessary to ensure that technologies and regulation develop in tandem. I-1 summarized the sentiment in an analogy: "You should not place traffic lights at every 100 meters on a motorway, because if you do, it's no longer a motorway" (I-1).

The overall ethos in this frame echoes the views inherent in the alternative megaproject literature and its emphasis on experimentation, flexibility, and strong project leadership; clashes between professional cultures; the limitations of planning, control, and foresightedness of actors; and the subsequent need to build flexibility and adaptability into the projects.

[h] The Finnish safety authority failed to "take into account the complexity of regulation" and "gave judgements too late, and thereby slowed down everything" (I-8).

[i] Views diverged on whether safety authorities should weigh the benefits against costs (either monetary or non-monetary) when making their decisions.

Figure 2 presents the causal relations involved in this frame.

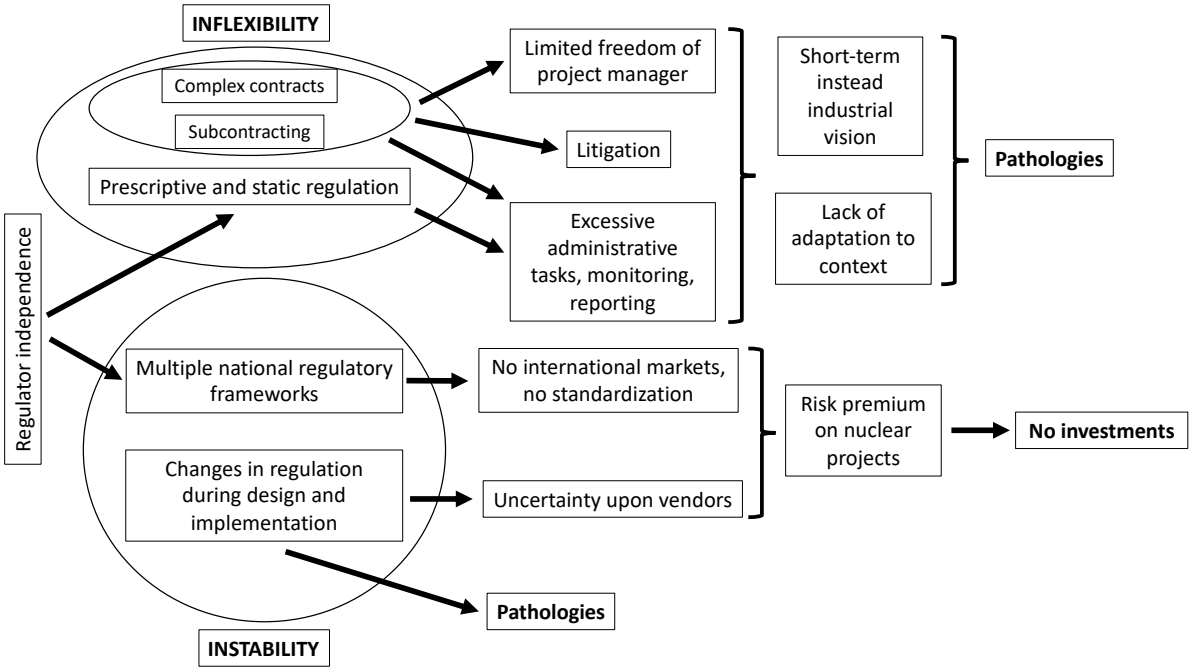

Figure 2. Bureaucratization and contractualization

IV.C. The "Broken Markets"

The third frame concentrated on the alleged failures of the market to provide an environment conducive to nuclear investments. The argument has two variants. The first underlines the deleterious impact of today's liberalized electricity markets on nuclear-sector investments in particular, and on capital-intensive energy-sector projects in general: competitive electricity markets, created to optimize dispatch by existing generation sources, cannot steer long-term investments according to the needs of the society and provide the appropriate price signals for investments in generation assets with up to 60 years' lifetime.

The second part incriminated the direct and indirect subsidies to renewable energy, notably the EU renewables targets. This was illustrated in expressions such as "the markets are broken" and "this is not a market!" As an indirect subsidy, the targets would remove risk from renewables investments, lead to overinvestment and ever more frequent episodes of negative electricity prices, thereby strongly discouraging investments in capital-intensive projects with long lead times. Such capital-intensive projects that suffer from a "risk premium" would include not only NPPs, but also many renewable energy projects.

The liberalization of electricity markets would have left investors at the mercy of "the vagaries of the stock market" (I-1), subjected constructors to "unrealistic financial pressures", and reduced the incentives upon market actors "to do the right thing" (I-2). Vendors would be

incentivized to sell designs that are not ready, as well as to suggest unrealistically low selling prices and optimistic construction schedules (e.g. I-9; I-14). In this frame, poorly operating markets would create perverse incentives that reinforce the over-optimism and strategic misrepresentation highlighted by the mainstream megaproject literature. However, while this literature suggests project-specific solutions such as greater control, improved assessment methods, and involvement of private risk capital, the 'broken markets' frame places the blame and solutions in the external environment, i.e. in the prevailing market conditions. Introduction of appropriate market regulation and state support in one form or another was seen as necessary to enable investments in nuclear power and capital-intensive renewable energy projects.

Figure 3 summarizes the causal relations in the "Broken Markets" frame.

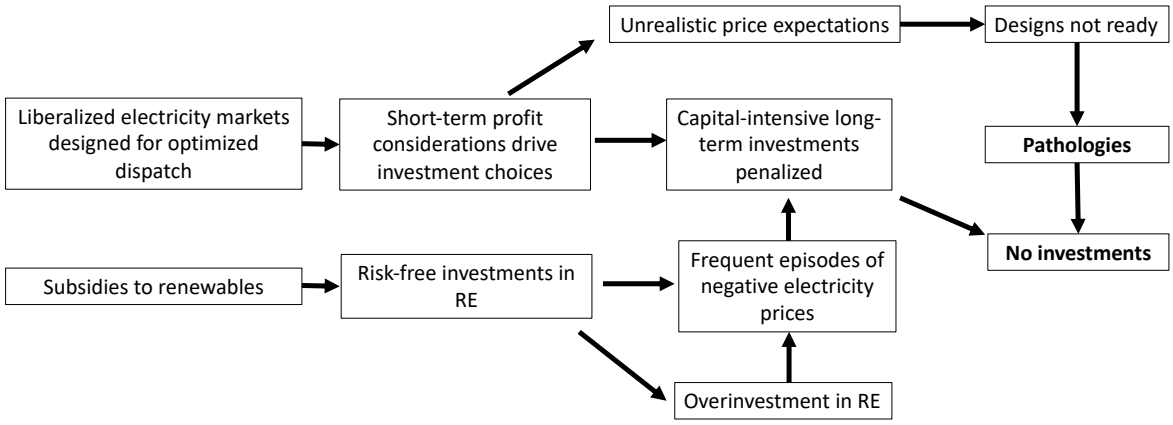

Figure 3. The Broken Markets

IV.D. Complexity and nuclear-sector exceptionality

The fourth frame centered around the questions of complexity of megaprojects, and whether the nuclear sector indeed is exceptional in its complexity. Some ambiguity was present, with simultaneous reference to complexity and the relative "banality" of the reasons behind the "pathologies". Both structural and dynamic types of uncertainty were evoked, i.e. the interaction of multiple components within the overall system, including stakeholders; as well as unpredictability and emergent events over time.

The origins of complexity were traced not only to technology and management structures, but also to long timescales, multiple and fluctuating societal values, as well as the broader energy policies and strategies that underpin decisions concerning megaprojects. The changing values of society over the long course of planning and implementation of projects create a temporal

mismatch between political decision-making and project management. I-7 located complexity in society, which would have "become very complex for projects", notably because of the in and of themselves necessary yet often long-drawn public consultations. Addressing complexity would require a broader and longer-term perspectives to project assessment, going beyond the "iron triangle" criteria of project performance. In contrast with the claims of the mainstream megaproject literature, overoptimism and ability to "sell" the project would be necessary and desirable. The project manager, aware of the multiple risks involved, should conceal these from the decision-maker, and instead "build confidence around the project" and "create a dynamic" (I-7).

Complexity associated with the long timescales and societal values was likewise used to argue for broadening the range of criteria used for appraising nuclear megaprojects. The costs and benefits of any energy-sector project – including significant investments in renewable energy to tackle climate change – should be judged over the entire operating lifetime of a plant (I-13, I-15). Even the Flamanville 3 and Olkiluoto 3 projects may turn out as profitable, just like all NPPs, once operating, have always brought profit to their owners, I-13 argued. The term "pathology" would falsely suggest that megaprojects would be "inherently ill and necessarily harmful or unsuccessful". In line with the emphasis of the alternative megaproject literature concerning the "wider benefits" and the "Hiding Hand", the costs and benefits of megaprojects to society should be appraised against a broader set of criteria than merely those relating to "management success".

Many interviewees explained problems by the particular complexity of the nuclear sector, manifested in contractualization, project management, and in particular the extreme strictness and complexity of the regulatory frameworks, as compared with those in other industries. The technical and organizational complexity was portrayed as a contributor to the nuclear-sector 'skills gap': skills in the nuclear sector are costly and time-consuming to acquire, but highly valuable and transferrable to other industries, many of which are also struggling to find skilled workforce (I-10).

The problems specific to the EPR were attributed to a combination of technical, societal and temporal complexity. Developed in the post-Chernobyl atmosphere, when ensuring the future of the nuclear industry was seen to require demonstration of virtually perfect safety, the EPR design, seeking to combine the best of the German Konvoi and the French N4 designs, is technically highly complex. Crucially, the EPR has failed to adapt to its evolving context, with the technically complex design remaining essentially unchanged over time. Areva's strategic choices in an inherently uncertain business environment illustrated the interdependence between nuclear projects and their societal context. The company's optimistic business strategy seemed fully justified in an atmosphere of "nuclear renaissance" and considerable business profits, but proved fatal once the global economic crisis set in and the Fukushima accident precipitated the downward spiral that brought the company down (I-9). The lack of full commitment by a significant fraction of EDF engineers to a politically driven French-German project was mentioned as an additional weakness (I-3).

A different line of argument contrasted the inherently complex nuclear aspects with the banality and seeming simplicity of the problems encountered. “The problems were almost never related to the nuclear”, but always to simple tasks such as pouring concrete or welding, remarked I-2, while I-4 pointed out, with frustration, that the industry should by now know how to build reactors, given that “it [constructing NPPs] was done over 400 times in the past, reasonably well (…) Frankly, the projects are not all that much different than the light-water reactors we built in the past”. This line of argumentation drew on the complexity frame to argue that the problems encountered are relatively simple, largely common to industries in general, and not inherent to the complex nuclear technologies.

In stressing the multiple forms of complexity, both internal and external to the projects, this frame closely follows the reasoning inherent in the alternative megaproject literature. However, the argument contrasting the complexity of nuclear with the banality of the ‘non-nuclear‘ deviates from this literature by focusing overwhelmingly on technical complexity.

Figure 4 presents the causal relations of the “complexity and exceptionality” frame.

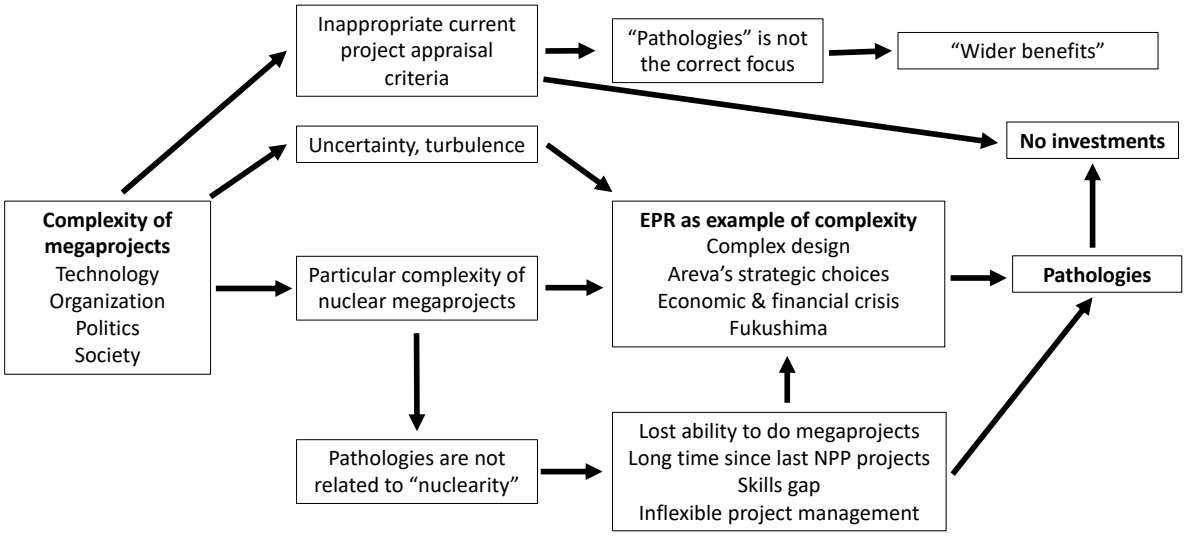

Figure 4. Complexity and nuclear-sector exceptionality.

IV.E. Two Metaframes: Politics and the Modern Western Society

Two metaframes underpin all four frames described above. These relate to political support and leadership on one hand, and the nature of the modern Western society on the other.

IV.E.1. Political Support and Leadership

The first metaframe relates to the need for a strong political “signal”, support and leadership, required to provide the visibility, predictability, and certainty necessary for the

implementation of nuclear projects and programs. I-1 summarized the general sentiment that nuclear energy has been discriminated against, by calling for a "political discourse at the highest level that would be at least neutral and open to nuclear as a clean energy capable of contributing to a low-carbon future, together with renewables". The prevailing lack of political leadership in Europe and the US was often contrasted with the strong political commitment to nuclear energy in China.

Political leadership was seen as a precondition for breaking the vicious circle that hampers technological learning and the transition from FOAK to NOAK projects. Certainty about the government's commitment to nuclear new-build would likewise alleviate the excessive contractualization, help straighten out regulatory complexity, reduce the regulators' excessive desire for independence, and entice the key actors to collaborate towards a clearly defined policy objective.[j] The steps taken by the UK regulator towards a "more constructive", collaborative and cost-aware approach were attributed to political commitment to nuclear (I-10). The German hesitations over their nuclear policy, in turn, served as a counterexample whereby the absence of political commitment had even led to increasing complexity of safety requirements for the EPR (I-8).

Political leadership was seen as crucial for fixing the "broken markets", redressing the market failures, bringing nuclear and renewables onto a level playing field, and thereby relaunching nuclear programs. Finally, political leadership would reduce societal complexity by helping to align different actors, and to incite these – perhaps not to collaborate, given the need for regulator independence – but at least to better take into account the views and objectives of the others.

Political and public support were typically discussed together, although the suggested causal relationships varied. One version was to describe politics-public interaction in Europe as a self-reinforcing spiral, whereby nuclear gets sidelined in decision-making (I-1). A second entailed the notion that strong political leadership would trigger public support (I-10), while a third saw public support as a prerequisite for the needed "political signal": "politicians do what they believe the society wants from them" (I-6). The political power of the dogmatically anti-nuclear "green lobby" (I-1) was frequently mentioned, although not always in such evocative terms. Involvement of the broader (not only anti-nuclear) civil society was seen as necessary to counterbalance this political lobbying power.

This metaframe adheres neither to the somewhat Macchiavellian mainstream view that underlines the deviousness of politicians as a source of overestimation of benefits and underestimation of downsides, nor to the alternative view stressing political "turbulence" as a source of pathologies. However, the metaframe resembles the mainstream in portraying

[j] "When there is no policy, and you send ambivalent messages on nuclear, [the regulator] is free to go ever further in demonstrating its independence. (…) you need visibility for a nuclear program in order to mobilize your supply chain and to launch nuclear projects under good conditions." (I-10)

politics as a factor external to megaprojects, and in adopting a somewhat cynical view of politics.

IV.E.2. The Modern Western Society: Inability to Accept Risk, Loss of Collaborative Spirit

The second metaframe present in the discourses of all interviewees addressed the problematic relationships between the nuclear sector and the modern Western society. A recurring theme was the comparison between the past decades when the nuclear programs were launched, and the many features in today's modern society that prevent the launching of the in and of themselves desirable nuclear projects. Again, all four frames described in the previous section can be traced back to this metaframe. In brief, our society would be unable to adequately identify and pursue the public interest, involving, according to the interviewees, investments in large nuclear new-build projects and programs needed to provide affordable, reliable and low-carbon electricity.[k] The "first-level objectives" like low electricity price would systematically be overridden by "second-level objectives" such as those asking projects to have an "acceptable impact on the environment" (I-13). The vices appeared as typically Western, given the recurrent reference to recent examples of especially the Chinese, Russian and Korean nuclear sector to deliver NPP projects relatively close to budget and schedule. This was contrasted with the almost insurmountable problems in executing megaprojects in Europe, as illustrated by projects such as the Berlin airport and Stuttgart railway station. "In the 1960s-70s it took three years to complete a project, and today, you need 20 years – and that's not specific to nuclear", noted I-7.

Two aspects of this Western modernity were repeatedly evoked: the society's relation to risk, and the alleged loss of a collaborative spirit. As for the first, today's society was described as "very risk-averse", people being unable to put risks into a proper perspective (I-6), or to live with any degree of residual risk (I-13). "Societal aspects" and public fears were described as ultimately driving safety regulation, sometimes to a point of "unreasonableness". Although particularly acute in the nuclear sector, the problems were seen as generic: "technology in general is under question at the moment" (I-5). The inability to deal with risk would have triggered the vicious circle of no NPP investments since Chernobyl (frame 1), spurred the complexification of safety regulation (frames 2 and 4), which in turn, would feed further "technocratization", "bureaucratization" and "contractualization" (frame 2) – paradoxically reinforced by market liberalization (frame 3). Also the market distortions from subsidies to renewable energy sources were described as stemming from an unfounded belief in an electricity grid with 100% renewables and zero risk, while the complexities of stakeholder management, public participation, and political decision-making were traced back to the problematic relation of the modern society with technological risks.

[k] "At the end, the question is who actually commissions nuclear projects (…) it is the society that is the ultimate client." (I-10). "If you are talking about a megaproject, it by definition involves people. That's what success is – it's about making the lives of people better. It's not about project management." (I-18)

The second key element of this metaframe concerns the collaborative spirit that according to the interviewees prevailed in project management and in international cooperation when the currently operating NPPs were built. The collaborative spirit would have been replaced by "bureaucratization" and "broken markets", thereby perpetuating complexity and the vicious circle of lacking investments in nuclear projects and programs. The observation that "the community is in a bad shape" (I-7) resumed the widespread feeling of missing cohesion amongst the various nuclear-sector stakeholders, including the relationships between the project owner, suppliers, and regulators. The Apollo and Airbus experiences were used to illustrate the contrast between the past collective spirit and today's much more fragmented society.[l] Also the remarks about the lack of full commitment within the EDF to a "politically driven" French-German EPR project (I-3) falls within the scope of a 'missing cohesion' within the nuclear sector. At the same time, interviewees struggled to find words for describing appropriate regulator-operator relations. Underlining the importance of regulator independence, they hesitated to talk about "collaboration" or "cooperation". Instead, they underlined the need for joint action towards a shared objective, "taking into consideration the complexity of organizing a nuclear project" (I-8), and a "shared culture", ensured in the past by the similarity of educational and professional background amongst operators and regulatory authorities.

A key question is to what extent the modern society should adapt to the needs of the nuclear sector and its projects, or – as both strands of megaproject scholarship would argue – these projects need to find ways of adapting to society. Many interviewees were careful not to give the impression of advocating a return to the "glorious past", when society was less risk averse, a collaborative spirit prevailed in the nuclear community, and project managers had the freedom to run projects as they thought was best. However, disappointment and disillusionment with today's fragmented and overly risk-averse society colored the discourses. "It was a whole different work environment, which is never going to come back", noted I-2, adding, however, that "we have to go a bit back and become more flexible and more able to adapt". I-12 argued that the NEA is "merely a microcosmos of society and its rampant individualism". Alongside these regrets and implicit hopes that the society might change was the recognition of the historical legacy of opacity and secrecy that undermines the confidence of investors and citizens in the nuclear sector (e.g. I-5; I-16, I-18). "Why would I invest in something, if I don't have the necessary information on the risks and uncertainties, while there are less risky options available?", I-18 rhetorically asked.

[l] "Apollo, it was a joint effort: there were contracts, there were flows of money, but the operators (…) when Apollo got burned on its platform (…) I'm convinced that they didn't embark on a ten-year legal battle against each other!" (I-7); "Wouldn't it be a good idea to have a joint reactor, a bit like Airbus?" (I-1); "When you see an Airbus flying, you see a concentration, in a single element, of technologies coming from different countries. For NPPs, I don't see this vision" (I-4).

Figure 5 compiles the four frames and two metaframes into a single picture.

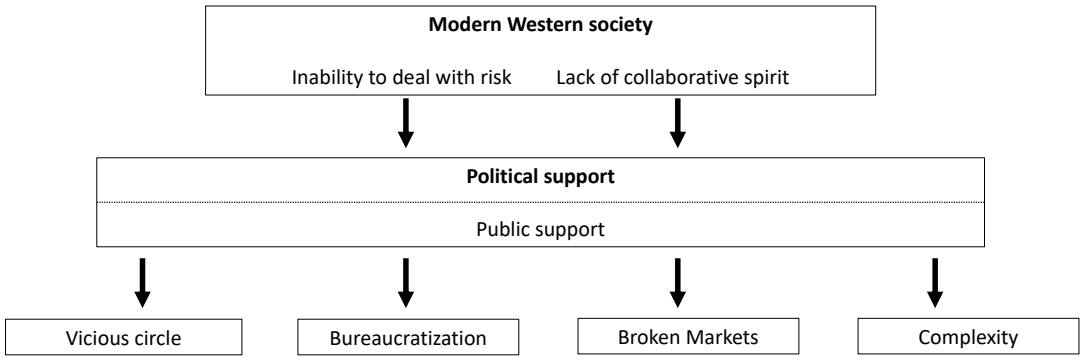

Figure 5. Summary of NEA frames and metaframes.

V. DISCUSSION

V.A. NEA framings and the megaproject literature

The four frames and two metaframes identified in the discourses of 19 NEA officials reveal elements of both the mainstream and alternative megaproject scholarship, with the latter clearly dominating. The frames foreground three typical megaproject characteristics that induce pathologies: transformativity (especially via the profound impact of NPP projects on energy and nuclear policies), multiple types of complexity, and uniqueness – the one-off characteristic of FOAK projects. The frames echo key topics of discussion in megaproject literature, such as the fluidity of the boundaries between "the project" (an individual NPP) and its environment (broader nuclear programs and policies, supply chain, society at large…), the downsides of excessive focus on control and risk minimization, and the relative virtues and vices of overoptimism in project management (the Hiding Hand vs. Malevolent Hand controversy). In advocating flexibility and adaptability to address pervasive uncertainties, appraisal that goes beyond the "iron triangle" criteria addressing instead wider long-term considerations, and in rejecting a control-oriented view of project management, the NEA framings are close to the "alternative" strand of this scholarship. The frames stress the need to remove the technocratic barriers that hold back innovation and creativity and ultimately risk "killing" nuclear projects sorely needed by society. The emphasis on the creativity and the need for leadership by the somewhat heroic figure of the "project manager", resemble the "Hiding Hand" and "wider benefits" arguments. Key elements of the 'mainstream' explanations to pathologies – optimism bias and strategic misrepresentation – have no place in the frames, which hence leave unaddressed the risks highlighted by this strand of literature,

notably the "survival of the unfittest", weakened accountability, and reinforced dominance of vested interests over the public interest in decision-making.

In contrast with alternative strand of megaproject literature, which stresses the open-system character of megaprojects as fluid networks, the NEA frames attribute the ultimate causes for pathologies – and for the lacking investments in nuclear projects – mainly to factors external to nuclear technologies, projects, and largely even to the nuclear community. These include today's prevailing project management culture: excessive rigidity and inflexibility, limited degree of discretion left for the project manager, and the replacement of an "engineering rationality" by short-term economic rationality. These features would be bolstered by the lack of political support and leadership, market distortions, and ultimately, the modern Western society's inability to perceive and pursue its own interest. Even the nuclear community's allegedly "bad shape" was largely attributed to broader external causes, such as the lack of a "collaborative spirit".

V.B. NEA Framings, the OECD Family, and the Nuclear Community

It is certainly not surprising that the NEA officials, as representatives of an international organization, abstain from criticizing its member states, specific technologies, projects or companies. Yet, the tendency to externalize blame raises questions about the role of the NEA as member of the OECD family. In particular, the "Broken Markets" frame may indicate either tensions within the OECD community, or relatively significant changes in the liberal free-market OECD doctrine over the past couple of decades. Replies to my queries – beyond the questions strictly related to the 'pathologies' – as to the compatibility of OECD's market liberalism and NEA's call for state support for nuclear pointed in various directions. Some argued that creating a 'level playing field' for nuclear and other energy sources implied correcting market failures, and was hence fully in line with the OECD doctrine. Others suggested that the NEA had helped to make the OECD and IEA gradually recognize the need to relax the liberal doctrine and acknowledge the need for state intervention in support of sustainable energy transitions. Yet others claimed that the OECD had essentially abandoned the liberal economics doctrine, "free markets" having been replaced by notions such as gender and income equality, innovation, and good life. The OECD doctrine has indeed been flexible and evolving throughout the decades – partly following worldwide trends in policy and academic thinking in economics.[78] Further research could usefully explore the role of the NEA in shaping OECD framings – its culture and organizational discourse. As suggested by some interviewees, in these processes internal to the OECD family, the NEA may suffer from some prejudice, perceived as a historical promoter of nuclear energy, and as such as a somewhat inconvenient partner, in a political environment that in most OECD member countries is rather lukewarm and in some cases outright hostile to new nuclear programs.

To help better understand the possibilities and limitations of the NEA as an actor in international nuclear-sector governance beyond the OECD, the role of the NEA frames in shaping and being shaped by framings within the broader "nuclear community" would deserve further research. The extent to which the NEA acts as a "frame-maker" as opposed to

"frame-adopter" remains uncertain. Further analysis could build on earlier research on the role of the OECD in international "idea games",[17,18,63,64,65,66,78] that is, discursive policy struggles over the definitions, meanings, and policy agendas, and should include analysis of debates in the member countries and amongst industry, as well as the NEA's visibility in national and international media.

V.C. International Nuclear Policy Peer Reviews: a Tool Towards 'Frame Reflection'?

The NEA has adopted the OECD's trademark, the peer pressure logic, to a somewhat limited degree. While the review and joint approval of NEA publications by country delegates is an obvious part of the work of the various NEA expert bodies, its country peer reviews are far from the OECD-style comprehensive policy reviews. The NEA peer reviews focus on specific technical topics, their client is a specific nuclear-sector organization in the member country instead of the government as a whole, they involve little peer country scrutiny, and the review report is only made public if the client organization so wishes. The participation of NEA secretariat experts in drafting the nuclear-specific sections of IEA energy policy reviews, in turn, does not generate the process benefits – such as socialization, building of trust, and creation of identities and shared social norms – stemming from the long-lasting dialogue that characterizes a fully-fledged OECD peer review. Echoing remarks by many other interviewees, I-2 encapsulated the NEA view on peer pressure and peer reviews by noting: "we are not here to critique, we are here to help and assess". The remarks seem somewhat alien to the non-adversarial OECD peer review logic of mutual accountability based on trust between states and shared confidence in the process.[18,79] They may also indicate unwillingness by a still relatively closed nuclear community to expose itself to external scrutiny, even in the form of a relatively mild and "safe" OECD style. Such unwillingness may be reinforced by the NEA's enduring struggle with diminishing resources, in a situation with low demand for new nuclear projects in most of its member countries, evoked by several interviewees.

Introducing OECD-style international peer reviews could serve as a first step towards "frame reflection" – collective exploration and reconsideration of prevailing framings and their alternatives, with a view to assisting in the resolution of seemingly intractable public controversies.[80] Openings towards such reflection could be seen, for instance, in the minor ambiguities in the NEA frames: the possibility of a "virtuous circle" via SMRs and technological competition, the trade-offs between stability and adaptability of regulation, hesitations between the exceptionality and banality of nuclear-sector projects and their problems, and the respective roles of politicians and the broader public in shaping support for nuclear. Lessons from megaproject scholarship could feed such reflection in particular on the question concerning the relationships between society and the nuclear sector: which of the two should adapt to the other? International nuclear policy peer reviews could be conducive to frame reflection given that the very logic of peer pressure operates essentially through subtle and long-term processes of framing and reframing, via dialogue, confrontation of views and constitution of shared identities. Such reviews could provide opportunities for dialogue with a wider range of energy-sector actors, including international organizations

working on other energy sources than nuclear (e.g. IRENA), thus helping to address the pervasive controversies surrounding nuclear power.

V.D. Megaproject scholarship, risk society, nuclear and modernity

The analysis of NEA framings helps to fill a gap in existing megaproject literature concerning nuclear power megaprojects in general, and the framings held by the "nuclear community" in particular. The findings open avenues for enriching the extant scholarship concerning the uneasy relationships between megaprojects, risk, modernity,[2] and post-modernity, in this high-risk industry, arguably distinct from most other megaproject sectors. Perry and Praskievicz's observation of a "resurgence of high-modernist reliance on big infrastructure", driven notably by climate concerns, highlights the close association of megaprojects with modernity.[81] Against this background, the NEA frames appear as critique towards today's society, whether post-modern or a "risk society" described by Ulrich Beck. The frames indicate implicit critique against the mass-media fueled "culture of fear",[82] and towards two key characteristics of a risk society: the overwhelming focus on the avoidance of risk, and growing "individualization". By contrast, Beck's notion of potentially apocalyptic risks from nuclear energy has no place in these frames, which instead locate apocalyptic risks in the modern society's inability to deal with the climate crisis, as a result of biased risk perceptions, and possibly dysfunctional or even excessive safety regulation.

The NEA framings seem to lend support to the alternative strand of scholarship and the "Hiding Hand" principle, yet they also raise questions concerning power, rationality, and the ability of either of the strands to adequately integrate in the analysis various forms of power. In the NEA framings, the impotence of today's society in the face of the climate challenge reflects power relations skewed against the nuclear sector, with especially the renewables lobby wielding excessive clout, distorting rational policymaking, and thereby acting against the public interest. In light of the historically close links of the nuclear sector with state power, the claim is intriguing. It also reflects the mainstream megaproject scholarship's somewhat cynical view of power, albeit not in the explanations for megaproject 'pathologies', but as a general critique of power relations in the energy sector. Further analysis of the discursive framing power in the broader societal debate over nuclear-sector megaprojects could build common ground between the relatively "power-free" approach of the alternative scholarship and the Machiavellian view of power in the mainstream megaproject literature.

VI. CONCLUSIONS

By making explicit the causal reasoning in explanations given by NEA experts to the current problems of nuclear-sector megaprojects, and examining these in light of the existing megaproject scholarship, this article helps to advance reflection over the identified framings, both within the nuclear community and collectively with a broader range of actors in society. The NEA framings concerning current nuclear megaproject problems are founded on the contention that today's (Western) society either does not know what is good for itself, or has

been caught up in a dynamic that prevents it from pursuing its own interest – in particular, combating climate change via nuclear energy. To the extent that "pathologies" exist, they are ultimately to be found in society, rather than in the in and of themselves desirable and necessary nuclear projects, their management, or the nuclear community. The "pathologies" were described as typically Western, as demonstrated by the recurrent reference to the continued ability of the Chinese – and to an extent also other non-Western countries – to deliver complex megaprojects close to budget and schedule, both in nuclear and other sectors. To a degree, the NEA framings indicate a certain nostalgia of a past epoch, when the Western society had not yet lost its ability to accept and deal with risk, a collaborative spirit pervaded the nuclear community, and nuclear power enjoyed wide political support.

While the framings did not adhere exclusively to either of the strands of megaproject literature, they strongly echoed many of considerations of the 'alternative' strand. However, the nuclear community could learn from both literatures. Approaches and methods advocated by the 'mainstream' could help the community and its projects gain credibility: drawing on empirical historical data and experience on NPP projects in their real-world context could introduce greater realism into cost, timetable and performance expectations. Taking seriously the insights from the alternative megaproject scholarship would entail greater attention to the networked nature of NPP projects, going beyond the internal-external dichotomy. In practice, reconceptualizing projects as networks would mean identification of its key actors, constant re-examination of its fluid boundaries (who/what is in and who/what is out), debate and agreement on the shared objectives of the network, and clarification of the multiple accountability relations between actors within and beyond the network. Key explanations and solutions for megaproject problems should be sought in the vital interaction between the nuclear sector and society, rather than in mostly external factors such as "political support" and "the modern Western society". This would also imply keen attention to the means and processes whereby the public interest relating to NPP projects is identified and pursued. In Latourian terminology, recent nuclear-sector megaprojects in Europe and the US have failed in the vital "contextualization", that is, in aligning the various interests of the involved key stakeholders, and in ensuring the compatibility of these projects with the material and institutional environment that characterizes the "modern Western society". For any project to succeed, it must exhibit both an ability to adapt according to its constantly evolving environment, and close attention to the ways in which the project transforms its own context, including energy policy, institutions, territories, discourses, and perceptions. It is here that opportunities for fruitful "frame reflection" may appear – in the slight ambiguities inherent in the NEA framings concerning the causal relationships in the interaction between nuclear projects and society. Resolving what the NEA experts identify as a major problem – a growing gap between the nuclear sector and the modern Western society – would require reflection upon the prevailing framings and their alternatives, jointly between the "nuclear community", and the various "non-nuclear" stakeholders and affected groups in society.

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