The European Pressurized-Water Reactor Between Narratives and Policies:

Exploring the French Nuclear Reactor Design with a Feasibility Framework to Assess Wider Implications for France and the EU

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Abstract:

With fossil fuel-dependencies affecting energy generation, and renewables being contextually limited by intermittency and dispatchability issues, this work explores European Pressurized-water Reactors (EPRs) as a nuclear-based climate mitigation measure in France and in the EU. Through its conceptual framework, this paper evaluates the technical potential of EPRs through the gate-keeping effect of initiative feasibility and narrative analysis. Policy findings, obtained through a mixed review of literature and supplementary publications, and narrative findings, acquired through content analysis of international news media in English, constitute the qualitative data subjected to examination. Despite unanimous negative narratives surrounding EPRs, especially regarding economic factors, a predominantly favorable French policy environment suggests that EPRs and nuclear can still constitute a viable option in France, while not exempt from risks. The same cannot be said for the rest of the Union where inadequate policies may disfavor such developments. Finally, policy recommendations and broader implications are also discussed.

Keywords: *EPR, nuclear, feasibility, narrative, policy, sustainability science*

Word count: 11950

Abbreviations:

EPR	European Pressurized-water Reactor	**IPCC**	Intergovernmental Panel on Climate Change
EU	European Union	**WNA**	World Nuclear Association
IEA	International Energy Agency	**EGD**	European Green Deal
RQ	Research Question	**EPR**	European Pressurized-water Reactor

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For *Nonna Ida*,
As you left us soon after I moved to Sweden to start this new chapter of my life.

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1 Introduction

1.1 Energy Generation, Climate Change and EU's Mission

The energy sector is the largest contributor to global greenhouse gas emissions with fossils fuels representing the biggest driver of climate change, dominating the global energy supply (IPCC, 2022; Ritchie et al., 2020). The European Union (EU) is aiming at climate neutrality by 2050 with its European Green Deal (EGD) agenda, which implies the decarbonization of EU's energy systems over the next few decades (European Commission, 2022b), together with ending dependency on Russian fossil fuels by diversifying its energy supplies (European Commission, 2022a).

1.2 Why Even Consider Nuclear if we Have Renewables?

Renewable sources, are at the center of EU's decarbonization strategies (European Council, 2022), but their great potential of replacing fossil-fuels could be held back by contextual limitations. Variable renewables in particular, can suffer from issues of dispatchability and intermittency (Cebulla et al., 2017; Hu et al., 2023; Tran & Smith, 2017; Yıldıran, 2023), together with technical and economic challenges of energy storage systems (Koohi-Fayegh & Rosen, 2020). Furthermore, an entirely 100% renewables scenario would lead to increased cost of energy generation, as well as an over reliance on biomass production, which would translate to subsequent needs for carbon capture and storage solutions to offset indirect emissions (Zappa et al., 2019). In this context, nuclear energy compares well with some of the least polluting renewable energy sources in terms of emissions per unit of electricity produced, while at the same time having one of the lowest ratios of deaths per unit of electricity generated (Bruckner T. et al., 2014; Ritchie & Roser, 2020). Nuclear generation also provides capacity factors close to 100% which means that, from a functional point of view, it could effectively substitute baseload electricity generation from traditional fossil fuel plants (Michaelides & Michaelides, 2020).

The International Energy Agency (IEA) emphasizes how, in its *net-zero emissions by 2050* scenario where energy generation from the nuclear industry declines, an expansion of energy storage systems as well as fossil fuel plants with carbon capture and storage would be required (IEA, 2022). Globally, this would drastically increase the investments necessary to achieve the net-zero objective as well as increasing electricity bills for final consumers by 20 billion $ per year to 2050 (IEA, 2022). Finally, according to the scenarios evaluated by the Intergovernmental Panel on Climate Change (IPCC), nuclear power shares are expected to grow in most 1.5°C pathways which consider no or limited overshoot by 2050 (IPCC, 2018).

Still, what chances does nuclear have in contributing to the decarbonization of the energy sector in the foreseeable future? According to the IEA (2022), there are five features of the journey to net-zero emissions that open up opportunities for nuclear energy. The first is the widespread electrification of end uses, with electricity taking progressively higher shares of final consumption. The second is the rapid growth in low emissions electricity generation. The third, is the need to curb emissions from heat production. The fourth is the fast-growing demand for low emissions hydrogen. And last, the continued need to support innovation, which facilitates the development of advanced nuclear technologies.

1.3 Nuclear Generation: A Downward Trend in the EU

If nuclear can play such an important role in decarbonizing the energy sector globally, what is the tendency in the EU? Well, the data shows decreasing trends, suggesting weakening support towards the technology. In fact, nuclear electricity production in the EU reached its peak of 928 TWh in 2004, but has since decreased to 609 TWh in 2022 (EUROSTAT, 2022, 2023), a 34% reduction. Nevertheless, nuclear produced 22% of EU's electricity in 2022 (European Council, 2023b), and as of August 2023, there are still 100 operational nuclear reactors among member countries, 113 if we also consider the UK and Switzerland which are Euratom associate states (European Council, 2014; STATISTA, 2023a; UK Government, 2020). Nonetheless, these decreases in nuclear generation in the EU reflect a general global struggle that the nuclear industry has been facing in delivering its projects in advanced economies. As the IEA (2022) states:

> *Investment in nuclear power in advanced economies has stalled over the last two decades because of high costs of new projects, long construction times, unfavorable electricity market and policy environments, and, in some countries, a lack of public confidence after the accident at the Fukushima Daiichi Nuclear Power Station. Construction of first-of-a-kind Generation III reactors has been subject to delays and significant cost overruns. The competitiveness of new nuclear power plants is further undermined by the fact that most power markets still do not adequately remunerate the low emissions and dispatchable attributes of nuclear power.* (p.16)

Delayed construction times and subsequent rising costs are critical problems. Globally, the median construction time of nuclear reactors was of 93 months between 2016 and 2020 (IAEA, 2021b).

Nonetheless, time and costs of construction, which are key factors in determining relative investment in competing dispatchable generating sources, are far from uniform globally (IEA, 2022). Generally, most reactors that are being built today started construction in the last ten years, while the small number that have taken longer are either first-of-a-kind reactors, or projects where construction was suspended before being restarted (WNA, 2022). However, the two most recent nuclear builds in the EU tell quite a different story. The Olkiluoto-3 reactor in Finland took 199 months for its completion in March 2022, while the Flamanville-3 reactor in France is expected to take 187 months (PRIS, 2023a; STATISTA, 2022), in both cases undeniably concerning numbers.

In this complicated context for the industry, France is one of the few EU countries still supporting new nuclear development even after the Fukushima accident, with widespread public acceptance in French society (Lee & Gloaguen, 2015). The well-established French nuclear industry is behind several projects, not just in France, but also in Finland, UK and China, based on the European Pressurized-water Reactor (EPR) design (Nuttall, 2022). Consequently, civil nuclear plays a central role in France's economy, establishing the country as the second largest nuclear power producer in the world with 56 operational plants nationwide (IAEA, 2022b). In the following paragraph, I'll disclose how this strong development came into being.

1.4 France and its Civil Nuclear Tradition

In France, the nuclear industry has long been part of a public narrative where it reflected a fundamental part of French modernity, representing France's capabilities for technological innovation (Schweitzer & Mix, 2021). As described by Hecht (2009), French nuclear projects, through the French atomic commission and the national electricity provider, now EDF, intended to convey an image of radiance through technopolitical efforts which embodied national pride, splendor and identity. Whereas in other European countries nuclear development has often been challenged, in France, ever since its early deployment, no president has ever questioned nuclear's role (Schweitzer & Mix, 2021).

As Topçu (2011) explains, nuclear energy, through EDF, first entered the public discourse in the 70s as the only way France could secure energy independency in a cost-effective way. There was then a switch of narratives during the 80s after the Chernobyl accident, where the focus was on emphasizing French plants faultless safety due to the reactors having a completely different design from Russian ones. This meant embracing a political strategy dedicated to reassuring the public that the French nuclear industry was also transparent and trustworthy. Finally, it approached the 90s with a more ecologically oriented messaging (Topçu, 2011). The latter strategy was then continued up until recent times where nuclear is presented in French dominant narratives as a clean energy source, playing a central role in supporting climate change mitigation efforts (Szarka, 2013). Indeed, almost 63% of electricity in France was produced via nuclear in 2022 (STATISTA, 2023b).

It is therefore apparent how nuclear's public acceptance, as described by Bess (1995), was always nurtured through a top-down strategy, with state experts asserting authority over public understanding of nuclear and its implications. Through this approach, experts discredited opponents argumentations by presenting the opposition as less knowledgeable on the matter and thus less legitimate (Szarka, 2013). That is not to say that French normative stakeholders did not recognize nuclear energy's inherent risks or acknowledge the impossibility of a zero-danger scenario, but the risk is referred to as tolerable, stressing the regulatory and control measures that civil nuclear undergoes (Schweitzer & Mix, 2021). French authorities have always pushed for a regular communicative approach with the population, with information campaigns about nuclear safety proving to lower the perception of risk, as well as increasing public acceptance, especially when emphasizing the dangers of climate change and hydrocarbons dependency (Perez et al., 2020).

The French case demonstrates how institutional and sociocultural factors play an important role in the development of nuclear energy. The IPCC (2018, p. 382) also refers to these two factors as being the biggest influences in affecting nuclear energy's feasibility. Therefore, it is safe to assume how governmental support through policies and public perception through narratives play major roles in nuclear power's development in a country. The reader shall keep these last two factors in mind, as I addressed both, each with a dedicated research question (RQ), and my framework of choice. These will be presented in the coming sections. A background on the EPR and a broad assessment of its *technical potential* will follow through an explanatory paragraph. Here anticipated, the *technical potential* is one of the three elements composing the framework used in this paper.

1.5 The European Pressurized-Water Reactor and its *Technical Potential*

The EPR, a third generation design, is the result of a collaboration started in 1989 between two important nuclear actors at the time, the German firm Siemens and French firm Framatome, to develop a reactor that would get regulatory authorization in both countries (U. Fischer, 1999). The French state now owns 75% of Framatome through EDF, following Siemens being englobed by Framatome, and various other acquisitions (Nuttall, 2022). Building on top of previous reactor designs from both countries, the EPR has a capacity of 1,6GW and improves upon safety systems with the implementation of passive security measures and strengthened containment systems (M. Fischer, 2004). Designed with a 60-year lifespan, it requires refueling every 18-24 months, and either runs on reprocessed spent fuel from other reactors, or 5% enriched uranium (Environment Agency, n.d.; Nuttall, 2022). The latest integrated lifecycle emission assessment from the United Nations Economic Commission for Europe estimates 5,5 CO2eq/kWh for nuclear plants with a 60-year lifespan (UNECE, 2022), hence similar values should also be expected for an EPR. The EPR design had initially taken shape in two first-of-a-kind iterations in Finland and France, plus two subsequent projects in China and in the UK. These are referred as the first wave of EPRs (Nuttall, 2022), and will be looked at in the coming paragraphs.

In Finland, the Olkiluoto-3 EPR was connected to the national grid in March 2022, and achieved commercial operation in December, providing around 14% of the country's electricity needs (WNA, 2022). As the first EPR design to start construction in 2005, Olkiluoto-3 got delayed by 13 years from its original planned date, with a final cost of 11 billion € (Bass, 2023; IEA, 2022). The reactor site is in proximity of the ONKALO underground repository for the disposal of spent nuclear fuel (IAEA, 2022a). In France, the Flamanville-3 EPR started construction in 2007, and similarly to its Finnish counterpart, also encountered lengthy delays and subsequent price surges. Now to be commissioned by the end of 2023 instead of 2012, the plant is projected to cost 12,7 billion € compared with an initial estimate of 3,3 billion € (Bass, 2023; IEA, 2022).

Outside of the EU, the Taishan reactors in China constitute the first EPRs to become operational: construction started in 2009 and finished in 2018 and 2019 for the first and second unit respectively. Nonetheless, the two units also suffered from delays: from an expected construction time of around 5 years to almost 10 years (Bass, 2023; Schneider & Froggatt, 2020). Finally, as the last EPR project to take shape, the ongoing construction of two EPR reactors at Hinkley Point C in the UK, which started construction in 2018 and 2019. Upon completion, likely by the end of the 2020s, these reactors should provide approximately 7% of UK's electricity, enough for the needs of 6 million residents (Nuttall, 2022; PRIS, 2023b, 2023c). To conclude this introductory chapter, the following section will present the RQs that guide this paper.

1.6 The Research Questions

Due to the inherent controversial nature of EPR projects, which have been encumbered by a variety of shortcomings, I deemed appropriate to utilize EPRs as a case study to investigate why nuclear energy is not playing a larger role in the low-carbon transition of the EU to explore how feasible EPRs and new nuclear development are in today's context. To answer this overarching question, I identified two sub-RQs being:

1) How is the current policy context in the EU and in France affecting nuclear development, and what potential measures would increase the pace and scale of new nuclear plants?

2) What narratives do international media publishing in English use to portray EPRs and nuclear energy in France?

In the coming chapter, I will disclose more in detail theory and methodology, presenting the conceptual framework that I employed to address the two RQs.

2 Theory and Methodology

2.1 The Framework of Choice

For the purpose of this thesis, I assessed the feasibility of EPRs using a framework that combines two elements from Nielsen et al. (2020), namely *technical potential* and *initiative feasibility*, but replaces the third element with *narrative analysis*, which draws from the work of Hermwille (2016) (Figure 1). This framework is based on my own interpretation of the tripartite feasibility framework proposed by Nielsen et al. (2020) which focuses on the interplay of two main factors: *initiative feasibility, which* represents the probability of adoption and implementation from a change agent of a mitigation measure, and *behavioral plasticity,* representing how much a target responds to a specific mitigation measure. This interplay, according to the authors, allows for a more holistic feasibility assessment of a potential mitigation solution that is not limited to the assessment of mere technological and economic aspects (Nielsen et al., 2020). This is due to the fact that it also incorporates stakeholder interaction in the analysis to determine how successful a specific climate change mitigation effort, represented by the *technical potential*, could be in a real-world context. In fact, Nielsen et al. (2020) stress how, in order to assess the hindrances to the deployment of mitigation measures, a deeper integration of non-economic, social, and behavioral sciences must be considered.

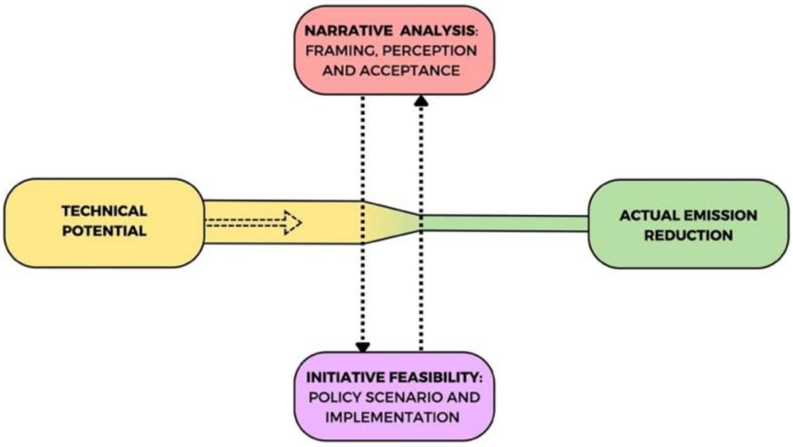

Figure 1. Illustration of the revisited tripartite framework from Nielsen et al. (2020) which now replaces the *behavioral plasticity* factor with *narrative analysis*, inspired by the work Hermwille (2016).

2.2 What are Narratives?

Narratives within a policy context refer in this paper to the description provided by Roe (1994), where they conform to the common definition of simple stories. These are usually composed of premises and conclusions, revolving around consequences that will follow if a certain event materializes (Roe, 1994). Some narratives are created by specific actors, networks or institutions to advocate and justify strategies and action, whereas some others may not become manifested or contribute to intervention, thus remaining marginalized (Leach et al., 2010). With narratives, framing can play a decisive role, as different groups can very well frame identical challenges in diverse, or even conflicting ways, privileging certain dynamics, functions and outcomes over others, which results in different analysis and recommendations (Hermwille, 2014).

In a way, narratives can be thought of as the basic constitutive elements of discourse, or as Urhammer & Røpke (2013) put it, as a phenomena that is embedded in discourse. That said, a narrative does not have to be exclusive of one single discourse nor it ends up defining any given discourse, meaning that a narrative can fit a variety of discourses (Hermwille, 2016). Narratives analysis is more centered around the direct consequences of the use of language in political debate, asking rather what language and speech accomplishes than what it means or assumes, features more related to discourse analysis (Hermwille, 2016; Roe, 1994). The topic of energy transitions, or the whole energy sector in itself, is certainly predisposed to face the challenges of social actors formulating narratives that either support or problematize energy transformation endeavors (Hermwille, 2014), and the nuclear industry is certainly not immune to this phenomenon.

2.3 *Narrative Analysis* and *Initiative Feasibility*

Narrative analysis is an arbitrary name that I assigned to describe the factor that will be accompanying the other original element of the tripartite framework represented by *initiative feasibility*. The inspiration for exploring narratives within the topic of nuclear energy comes from the work of Hermwille (2016), who analyzed them in the context of socio-technical transitions, focusing on how the Fukushima accident shaped the perception of nuclear energy in various countries. As described by Hermwille (2016), understanding narratives can have a fundamental role in comprehending the politics of sustainability, by investigating system framings of the actors that are involved in policy making, as well as the interpretations that are embedded in the collective sphere, since civil society and social movements can influence or limit policymakers reach.

This aspect would then be tightly interconnected to the previously mentioned *initiative feasibility*, which often includes a variety of factors such as public support for policies, or external pressures and political negotiations in legislative bodies. Nevertheless, for the scope of this paper, this factor would also be slightly adapted by having a narrower role, to focus specifically on how current policies affect the nuclear industry and how possible future policies could favor or hinder it, as well as questioning how policies would impact relevant stakeholders and vice versa.

By looking at the graphic representation of the framework above (Figure 1), which depicts the adapted rendition of the tripartite framework to include *narrative analysis*, the reciprocal arrows represent how the policy landscape, together with the influence of narratives, act as interposing or gatekeeping factors in reaching actual emission reduction. *Narrative analysis* and *initiative feasibility* interplay would therefore determine how feasible a specific technical solution would be, or at least how much of its *technical potential* would be achievable. In our specific case we refer to the *technical potential* of EPR reactors as described in section 1.5. The interplay between *narrative analysis* and *initiative feasibility* allows to address one of the main aims of the original tripartite framework, namely risk reduction. As defined by Nielsen et al. (2020), risk reduction refers to pursuing mitigation opportunities that, while having only modest *technical potential,* may still be desirable when the interactions of the two gatekeeping factors (*narrative analysis* and *initiative feasibility*) are favorable. Such initiatives may reduce GHG emissions more in practice, when compared with others having a higher *technical potential* but restrained by adverse narratives and policy contexts.

2.4 Nuclear Energy and its Relation to Narratives

Acceptance of nuclear energy is strictly tied to public perception and its associated narratives. The Nuclear Energy Agency points out how the importance of stakeholder confidence and dialogue are key to address societal concerns and allow further development of nuclear (NEA, 2020). This is particularly true since, in its early days, civil nuclear was seen as an invention capable of providing safe, clean, and plentiful energy. Such perception gradually buckled after the Three-Mile Island, Chernobyl and Fukushima accidents, events leading to waning public support and fear, as well as phase-out policies (Culley & Angelique, 2010; IEA, 2022). In general, when it comes to narratives, as Wellerstein (2016, p. 298) states "Those who oppose nuclear power attempt to mobilize and encourage these fears; those who favor it tend to downplay them, to transmute them into technical discussions of risk". Different stakeholders will therefore try to present different narratives depending on their agenda. These contrasting perspective not only reverberate in domestic debates over nuclear, but also within academia where different interpretations of the subject yield different conclusions (İşeri et al., 2018).

Nonetheless, the risk associated with nuclear goes beyond direct consequences from accidents, but also indirect ones like more stringent regulations on nuclear energy production and changes in public perception which can in turn make nuclear builds more expensive due to costlier safety measures, delay construction times, as well as influencing political decisions such as premature shutdowns or phase-outs policies (IEA, 2019, 2022; Schweitzer & Mix, 2021). These prospects can not only damage the nuclear industry as a whole but, more importantly, can compromise climate change mitigation efforts. Analyzing narratives therefore means recognizing the controversy over the meaning of sustainability of nuclear energy when considering economic, environmental and social factors jointly (İşeri et al., 2018). Following, two explanatory paragraphs on the methodology for answering the two RQs.

2.5 Answering Research Question 1

To answer RQ1 and gather qualitative data on energy and nuclear related policy measures, I resorted to a mixed approach consisting of a systematic literature review of peer reviewed papers complemented with a variety of publications and reports from authoritative agencies in the matter of nuclear energy. This methodology was inspired by Hermwille (2016) approach of not just following a formal protocol-driven search strategy, which meant also including other more informal approaches as these have proven effective with complex and heterogeneous policymaking issues. This is also in line with Greenhalgh & Peacock (2005, p. 1065) who state "Systematic review of complex evidence cannot rely solely on predefined, protocol driven search strategies, no matter how many databases are searched. Strategies that might seem less efficient … are likely to identify important sources that would otherwise be missed".

For the systematic literature review, the search engine *LUBsearch* was utilized with the following keywords: ("nuclear energy" OR "nuclear power") AND policy AND France. This initial search entry was then complemented with further filters to reduce the overall number of total articles and to focus the subject of the papers, as well as their field of studies to increase the possibilities of having more relevant findings for the purpose of my analysis. The first filters limited my search only to papers adhering to the subjects that seemed to fit the topic of my research, these are: *nuclear energy, nuclear power, energy policy, government policies, energy: government policy, government policy*, and *nuclear energy policy*. Then, I further limited my results by publication to exclude engineering or hard science-oriented results that would not be appropriate with my work. The elected publications are *Energy policy*, *Progress in nuclear energy*, and *Energy research and social science*. I then further restricted these results to only show peer reviewed content, as well as restricting the date from 2018 to 2023, to have results within the last 5 years more or less (this search procedure was carried out on April 7th 2023, so a bit more than five years). This allowed me to have both relevant and recent results on policy issues while also having a comprehensive outlook on past policy resolutions. In total, the final number of papers amounted to 28 of which only 17, after reading through each one, were actually selected. This is due to the fact that not every single one contained relevant material in relation to the matter of nuclear policy in France or EU.

This was accompanied by other complementary resources by authoritative agencies in the matter of energy or nuclear power, such as the IEA providing two sources and the World Nuclear Association (WNA), also providing two sources. Finally, I also checked a document from the European Parliament on nuclear energy. While outside of the predefined literature review, these publications allowed me to have an even more complete perspective on nuclear and energy policy matters both in France and in the European Union and undoubtedly resulted in more exhaustive qualitative data. In fact, these sources provided some particularly up-to-date policies developments, relative to recent months, that were not mentioned in the initial systematic literature review. That said, for transparency, I decided to mark results from the WNA in dark red in the results and tables summarizing my policy findings, as it still constitutes an organization that represents the nuclear industry.

The findings were then separated either by *French policy*, *EU policy*, or *Policy recommendations,* as well as by domain, being either *Economic*, *Environmental* and *Societal*. The latter domain subdivision was inspired by the work of İşeri et al. (2018), subdivision which will also be employed for RQ2. The overall findings have been summarized in the table below (Table 1). Some of the findings that seemed to refer to the same policy measures, even if expressed with different phrasing or terminology, have been grouped together to streamline the results and make it more comprehensible, both in written text and in tables. The findings on policy measures are not ordered by date.

Table 1. List of sources for the first RQ. To save space in the results section, each source has been assigned a letter from 'A' to 'V'. Sources in red come from the WNA, organization representing the nuclear industry.

Titles (from the literature review)	**Journal**	**Author(s) and Year**
A. Technology perspectives from 1950 to 2100 and policy implications for the global nuclear power industry	Progress in Nuclear Energy	(Nian, 2018)
B. Investigating the effects of natural gas, nuclear energy, and democracy on environmental footprint and energy risk in France: Does financial inclusion matter?	Progress in Nuclear Energy	(Zeraibi et al., 2023)
C. State or market: Investments in new nuclear power plants in France and their domestic and cross-border effects.	Energy Policy	(Zimmermann & Keles, 2023)
D. Projected electricity costs in international nuclear power markets	Energy Policy	(Rothwell, 2022)
E. Guiding the future energy transition to net-zero emissions: lessons from exploring the differences between France and Sweden	Energy Policy	(Millot et al., 2020)
F. Reducing CO2 emissions in OECD countries: do renewable and nuclear energy matter?	Progress in Nuclear Energy	(Saidi & Omri, 2020)
G. When Safety Is Relative: Ecological Modernisation Theory and the Nuclear Safety Regulatory Regimes of France, the United Kingdom and United States	Energy Research and Social Science	(Toke, 2022)

H. Strategies for Short-Term Intermittency in Long-Term Prospective Scenarios in the French Power System	Energy Policy	(Loisel et al., 2022)
I. Efficiency and dependence in the European electricity transition	Energy Policy	(Percebois & Pommeret, 2021)
J. Bringing Geopolitics to Energy Transition Research	Energy Research and Social Science	(Palle, 2021)
K. The Future of Nuclear Decommissioning: A Worldwide Market Potential Study	Energy Policy	(Volk et al., 2019)
L. Market Strategies for Large-Scale Energy Storage: Vertical Integration versus Stand-Alone Player	Energy Policy	(Loisel & Simon, 2021)
M. Storage cost induced by a large substitution of nuclear by intermittent renewable energies: The French case	Energy Policy	(Percebois & Pommeret, 2019)
N. Cost and climate savings through nuclear district heating in a French urban area	Energy Policy	(Leurent et al., 2018)
O. Do renewable and nuclear energy enhance environmental quality in France? A new EKC approach with the load capacity factor	Progress in Nuclear Energy	(Pata & Samour, 2022)
P. Load-following with nuclear power: Market effects and welfare implications.	Progress in Nuclear Energy	(Loisel et al., 2018)
Q. Are voluntary markets effective in replacing state-led support for the expansion of renewables? A comparative analysis of voluntary green electricity markets in the UK, Germany, France and Italy	Energy Policy	(Herbes et al., 2020)

Titles (from Extra resources)	**Organization**	**Author(s) and Year**
R. France 2021 Energy Policy review	International Energy Agency	(IEA, 2021)
S. Nuclear power and secure energy transitions: From today's challenges to tomorrow's clean energy systems	International Energy Agency	(IEA, 2022)
T. Fact Sheets on the European Union: Nuclear Energy 2023	European Parliament	(Cordina, 2023)
U. Nuclear Power in the European Union	World Nuclear Organization	(WNA, 2023a)
V. Nuclear Power in France	World Nuclear Organization	(WNA, 2023b)

2.6 Answering Research Question 2

For the purpose of investigating narratives, I decided to carry out a content analysis of international news media articles by employing the search engine from Retriever Research, in the media archive database. The string I utilized was "Nuclear AND EPR AND France", by restricting the time-window from the beginning of 2022 up until March 16th, 2023, date when I began the process of data gathering. The choice for this timeframe lies in my interest to analyze a specific period where the energy debate is particularly vivid due to the Russian invasion of Ukraine, event which has had strong implications for energy security. The articles were also filtered to only visualize results in English. Overall, this arrangement provided me with a manageable number of articles consisting of 162 hits.

Table 2. Number of publications per news outlet.

1 Pub.	Anadolu Ajansi (TR), Archynewsy (UK), Big World Tale (US), CTV News (CA), Daily Express (UK), Daily Sun (BA), Electricity Info (UK), Energy Central (US), Energy Industry Review (RO), Euronews (FR), Financial Express (IN), Gulf Times (QA), Hindustan times (IN), Hürriyet Daily News(TR*)*, IEEE Spectrum (US), India Today (IN), Investing.com (CY), The Mail & Guardian (ZA), Market Screener (FR), Morningstar (US), National Post (CA), New Age Bangladesh (BA), Politico.eu (BE), Private Eye (UK), Recharge News (UK), Renew Economy (AU), Russia Today (RU), TekDeeps (US), The Hindu (IN), The Huffington Post (US), The Jakarta Post (ID), The Korea Times (KR), The Standard (US), The Straits Times (SG), The Telegraph (UK), Time News (US), United World (TR), ValueSpectrum (US), World Ports Organisation (SG), YLE (FI)
2 Pub.	World Nuclear News (UK), Montel News (NO), NucNet (BE), Paudal (UK), The Economic Times (IN), The Indian Express (IN), The Indipendent (UK), The Times of India (IN), Urdu Point (PK), US News and World Report (US)
3 Pub.	Deccan Herald (IN), Expatica France (NL), France 24 (FR), Reuters (US), Street Insider (US)
4 Pub.	Macau Business (MN), The Limited Times (US)
5 Pub.	Teller Report (VN)

Nonetheless, by going through every single article, I also ended up excluding those which were irrelevant for my analysis. While containing the keywords I used for my search string, the content of some of these articles was completely unrelated to the topic of nuclear energy. Another issue that I encountered was that some news outlets, mostly lesser-known ones, copied the title and content from other websites. To tackle this issue with duplication, I decided to keep only those articles with an older date. Some were also older edits of the same article, for which I decided to only keep the most recent ones. In a few cases, some articles were either unavailable or their text was partially restricted by subscription restrictions. In the latter case, where possible, I still decided to utilize the partially available content where the stance on nuclear was clear and the text sufficient for the purpose of my analysis. At the end the filtering process, I was left with 88 entries (59 referring specifically to EPRs) with which I conducted the content analysis (see Table 2 for the list of publications per news website).

The next step consisted in extracting excerpts from each article which I found representative of their stance over nuclear energy, allowing me to assess which narrative they were aligning to (see Table 3 for the full list of news articles, sources and country, and sentiment towards nuclear). I later categorized my findings by ideology, being either advocacy, ambivalence, or opposition to nuclear as well as by argument, either economic, environmental, or social. This categorization was inspired by the work of İşeri et al. (2018), as they employed this grouping strategy to analyze contending narratives over the sustainability of nuclear energy in the Turkish context. Some texts did not use a specific argument, but were technical communications that simply reported specific episodes, like the successful delivery of a major reactor component at the plant construction site. The coming chapter will be dedicated to the presentation of the obtained results, which have been separated into two different sections, one for each RQ.

Table 3. News articles separated by relevance to the topic EPR-1 (first wave of EPRs) or not (nuclear in general and future nuclear developments). The articles have also been ordered by date, from newer to older.

News Articles Related to EPR-1

Title	Source (Country)	Date	Sentiment	Reference
France – Flamanville	Electricity Info (UK)	16/03/23	Negative	(Electricity Info, 2023)
Olkiluoto-3 / Electricity Production Resumes At Delayed Reactor, Commercial Operation Scheduled For April	NucNet (BE)	15/03/23	Positive	(Dalton, 2023b)
France to complete new reactor feasibility study by year end	Montel News (NO)	13/03/23	Negative	(Montel News, 2023b)
France mulls nuclear revamp as Ukraine war prompts an energy mix rethink	France 24 (FR)	13/03/23	Ambivalent	(Dodman, 2023)
The questions posed by the law to accelerate the construction of new nuclear reactors	Teller Report (VN)	13/03/23	Negative	(Teller Report, 2023c)
Faced with growing nuclear support in France, environmentalists are fighting back	Teller Report (VN)	11/03/23	Negative	(Teller Report, 2023d)
Discovery of a major crack in a nuclear power plant in France	Paudal (UK)	08/03/23	Negative	(Paudal, 2023b)
Relaunched, nuclear is looking for arms	Paudal (UK)	06/03/23	Negative	(Paudal, 2023a)
British EPR from Hinkley Point, the longest flight of a paper Boeing, Areva whistleblower… The top 3 videos of the week	TekDeeps (US)	04/03/23	Positive	(TekDeeps, 2023)

Bad vibrations	Private Eye (UK)	03/03/23	Negative	(Private Eye, 2023)
Is nuclear power in a global death spiral?	Renew Economy (AU)	02/03/23	Negative	(Green, 2023)
CEO Luc Rémont calls for "collective awareness" to turn the company around	Time News (US)	01/03/23	Negative	(Time News, 2023)
In Pictures: Hinkley Point C's first reactor arrives	World Nuclear News (UK)	27/02/23	Ambivalent	(World Nuclear News, 2023a)
EDF's reactor for its first nuclear plant in the UK for 30 years arrives by ship	Daily Express (UK)	27/02/23	Positive	(Paul, 2023)
First Hinkley Point C reactor gets to Somerset	World Ports Organisation (SG)	27/02/23	Positive	(World Ports Organisation, 2023)
Hinkley Point C / First Reactor Pressure Vessel Arrives Onsite From France	NucNet (BE)	20/02/23	Ambivalent	(Dalton, 2023a)
EDF's UK nuclear reactor faces huge £32billion bill	Big World Tale (US)	20/02/23	Negative	(Big World Tale, 2023)
Ukraine fallout pushes French nuclear giant EDF into historic loss	Daily Sun (BA)	18/02/23	Negative	(Daily Sun, 2023)
Embattled EDF stuck with $30bn bill from ailing nuclear fleet as utility makes massive loss	Recharge News (UK)	17/02/23	Negative	(Radowitz, 2023)
EDF could delay Flamanville EPR repairs for 10 years	Montel News (NO)	17/02/23	Negative	(Montel News, 2023a)
Edf: 2022 Annual results: Significant downturn in results in a context of French power output shortfall and high market prices	ValueSpectrum (US)	17/02/23	Negative	(ValueSpectrum, 2023)
Faced with the war in Ukraine, France must take up the challenge of the coming world	United World (TR)	31/12/22	Positive	(Cheminade, 2022)
In France, after a year of pitfalls for electricity, nuclear power is forced	Archynewsy (UK)	30/12/22	Negative	(Archynewsy, 2022)
13 Intriguing Engineering Milestones to Look for in 2023	IEEE Spectrum (US)	30/12/22	Negative	(IEEE Spectrum, 2022)
"Accelerate on the production of electricity": the elected representatives of the majority visit Flamanville	Teller Report (VN)	29/12/22	Negative	(Teller Report, 2022)

New delay for Finnish nuclear reactor production	Macau Business (MN)	22/12/22	Negative	(Macau Business, 2022d)
Update on the Flamanville EPR	Street Insider (US)	16/12/22	Negative	(Street Insider, 2022b)
Macron's French nuclear farce	New Age Bangladesh (BA)	08/12/22	Negative	(Gunter, 2022)
UK removes China from Sizewell nuclear project, takes joint stake	India Today (IN)	30/11/22	Ambivalent	(India Today, 2022)
Hinkley Point nuclear plant faces risk of 11-year delay	The Telegraph (UK)	29/11/22	Negative	(Millard, 2022)
Welders wanted: France steps up recruitment drive as nuclear crisis deepens	The Standard (US)	29/11/22	Negative	(The Standard, 2022)
Coal-Addicted Poland Is Going Nuclear With U.S. Help. It'll Be A Test For Both Nations.	The Huffington Post (US)	07/11/22	Negative	(Kaufman & Ahmed, 2022)
Minister claims liability issues on Jaitapur Nuclear Plant will be sorted before Macron visit in 2023	Deccan Herald (IN)	18/10/22	Ambivalent	(Ray, 2022)
Finland hopes new nuclear reactor eases energy crunch	Macau Business (MN)	13/10/22	Ambivalent	(Macau Business, 2022c)
China reconnects nuclear reactor after shutdown due to damage	Macau Business (MN)	17/08/22	Negative	(Macau Business, 2022b)
Can nuclear energy come back from the grave?	The Mail & Guardian (ZA)	01/07/22	Ambivalent	(The Mail & Guardian, 2022)
France's troubled EPR nuclear reactor set to go online by end of 2023	France 24 (FR)	16/06/22	Negative	(France 24, 2022b)
EDF hopeful end in sight for long-delayed, budget-busting nuclear plant	Street Insider (US)	16/06/22	Negative	(Benjamin, 2022)
Finnish nuclear reactor OL3 delayed again to December	Expatica France (NL)	15/06/22	Negative	(Expatica France, 2022c)
Can nuclear energy come back from the grave?	Gulf Times (QA)	09/06/22	Negative	(Butler, 2022)
New one year delay at UK Hinkley Point nuclear plant: EDF	Expatica France (NL)	19/05/22	Negative	(Expatica France, 2022b)
Finnish nuclear reactor OL3 delayed again to September	Expatica France (NL)	29/04/22	Negative	(Expatica France, 2022a)
Colby Cosh: Finland's energy blow	National Post	15/03/22	Positive	(Cosh, 2022)

against Russia	(CA)			
Finland's long-delayed nuclear reactor goes online	Hürriyet Daily News (TR)	14/03/22	Ambivalent	(Hürriyet Daily News, 2022)
Olkiluoto 3 reactor plugged into national grid, 13 years behind schedule	YLE (FI)	12/03/22	Ambivalent	(YLE, 2022)
Macron calls for 14 new reactors in nuclear 'renaissance'	The Korea Times (KR)	11/02/22	Negative	(The Korea Times, 2022)
France to get 6 new reactors as Macron bets on nuclear in carbon-neutrality push	The Indian Express (IN)	11/02/22	Negative	(The Indian Express, 2022)
Macron calls for 14 new reactors in nuclear 'renaissance'	France 24 (FR)	10/02/22	Negative	(France 24, 2022a)
France to build 6 nuclear reactors as part of climate goals	CTV News (CA)	10/02/22	Negative	(CTV News, 2022)
Macron announces France is to build up to 14 new nuclear reactors	The Independent (UK)	10/02/22	Ambivalent	(Webb, 2022)
France's Macron bets on nuclear in carbon-neutrality push, announces new reactors	The Economic Times (IN)	10/02/22	Negative	(The Economic Times, 2022)
France to build 6 nuclear reactors as part of climate goals	The Independent (UK)	10/02/22	Ambivalent	(The Independent, 2022)
Macron bets on nuclear 'rebirth' in carbon-neutrality push, France to build up to 14 new reactors	The Straits Times (SG)	10/02/22	Negative	(The Straits Times, 2022)
Macron Bets on Nuclear in Carbon-Neutrality Push, Announces New Reactors	US News and World Report (US)	10/02/22	Negative	(US News & World Report, 2022b)
France to Build 6 Nuclear Reactors as Part of Climate Goals	US News and World Report (US)	10/02/22	Negative	(US News & World Report, 2022a)
Macron to announce new French nuclear power ambitions	The Jakarta Post (ID)	10/02/22	Ambivalent	(Benhamou & Plowright, 2022)
France's new-generation nuclear plant delayed again	Urdu Point (PK)	12/01/22	Negative	(Irfan, 2022)
Update on the Flamanville EPR	Street Insider (US)	12/01/22	Negative	(Street Insider, 2022a)
France sees new nuclear reactors online from 2035	Macau Business (MN)	06/02/22	Negative	(Macau Business, 2022a)

Non-EPR-1 News Articles

Nuclear is back at the heart of the energy strategy	The Limited Times (US)	12/03/23	Positive	(The Limited Times, 2023d)
EDF teams up with Italian partners on SMR development	World Nuclear News (UK)	06/03/23	Positive	(World Nuclear News, 2023b)
Electricite de France: EDF, Edison, Ansaldo Energia and Ansaldo Nucleare have signed a Letter of Intent for new nuclear development	Market Screener (FR)	06/03/23	Positive	(Market Screener, 2023)
Gironde: why is the installation of new nuclear reactors at Blayais controversial?	The Limited Times (US)	03/03/23	Negative	(The Limited Times, 2023c)
Nuclear revival: funding parameters set "by the end of the year"	Teller Report (VN)	01/03/23	Ambivalent	(Teller Report, 2023b)
Nuclear: France wants to accelerate the EPR project in India	The Limited Times (US)	23/02/23	Negative	(The Limited Times, 2023b)
French nuclear major reaches "good level of techno-commercial convergence" with NPCIL, says Chairman	The Economic Times (IN)	20/02/23	Ambivalent	(Chaudhury, 2023)
South Korean Team to Develop SMR-powered Ships	Energy Central (US)	19/02/23	Positive	(Yurman, 2023)
Industrial Metaverse: Shaping the Future of Work	Energy Industry Review (RO)	15/02/23	Ambivalent	(David, 2023)
Bugey nuclear power plant: elected officials mark a 150-hectare plot for the reception of two EPRs	The Limited Times (US)	14/02/23	Ambivalent	(The Limited Times, 2023a)
After its setbacks in 2022, EDF begins a year of all dangers	Teller Report (VN)	14/02/23	Negative	(Teller Report, 2023a)
Sweden turns to France as it looks to buy two new nuclear reactors	Euronews (FR)	03/01/23	Positive	(Euronews, 2023)
France working to double down on nuclear power	Anadolu Ajansi (TR)	03/11/22	Negative	(Mohamed, 2022)
Coal-fired Poland goes nuclear	POLITICO (BE)	31/10/22	Positive	(Kość, 2022)
French President Macron's India visit in early '23 to give push to Maharashtra N-project	The Times of India (IN)	22/10/22	Positive	(Singh, 2022b)
Macron's India visit in 'early 2023' to fast-track N-project at Maharashtra's Jaitapur	The Times of India (IN)	20/10/22	Positive	(Singh, 2022a)
Macron to visit India early next year, Jaitapur on agenda	Deccan Herald (IN)	19/10/22	Positive	(Deccan Herald, 2022b)

France to Start Construction of Second-Generation EPR Reactor by 2027	Morningstar (US)	27/09/22	Positive	(Dore, 2022)
France To Begin Construction Of New Nuclear Reactor EPR-2 Before 2027 - Energy Minister	Urdu Point (PK)	27/09/22	Positive	(Hashmi, 2022)
EDF Leaps as France Offers $10 Billion to Nationalize Europe's Energy Company	Investing.com (CY)	19/07/22	Negative	(Smith, 2022)
Supply of six nuclear reactors: Question mark on Russia inputs, India evaluates French push at Jaitapur	The Indian Express (IN)	13/06/22	Ambivalent	(Mishra & Sasi, 2022)
India, France agree on deeper French involvement in 'Atmanirbhar Bharat' efforts in defence sector	Financial Express (IN)	05/05/22	Positive	(Financial Express, 2022)
France and India call for immediate end to Ukraine hostilities	Hindustan Times (IN)	05/05/22	Ambivalent	(Hindustan Times, 2022)
Emmanuel Macron to talk Ukraine over dinner with Narendra Modi	Deccan Herald (IN)	04/05/22	Positive	(Deccan Herald, 2022a)
France's EDF could sell renewables to focus on nuclear	Reuters (US)	12/04/22	Ambivalent	(Reuters, 2022c)
France's EDF launches 3 billion euro capital increase, shares up	Reuters (US)	18/03/22	Negative	(Reuters, 2022b)
Shutdown this misguided energy policy	The Hindu (IN)	11/03/22	Negative	(Raju & Ramana, 2022)
French power company EDF to hire over 3,000 staff this year in nuclear push	Reuters (US)	11/02/22	Positive	(Reuters, 2022a)
France makes massive nuclear bet	Russia Today (RU)	10/02/22	Positive	(Russia Today, 2022)

3 Results

3.1 Research Question 1: *Initiative Feasibility*

First, the results for *initiative feasibility*, related to the policy findings for RQ1. These have been separated in three sections: *France*, *EU*, and *Policy Recommendations*. Each of these sections contains three paragraphs, respectively for *economic, environmental,* and societal arguments. Summarized findings have been collected below, in Table 4.

3.1.1 The French Environment

Looking at French policies within the economic sphere, there seems to be mostly favorable policies in place for nuclear. Two sources (C, V) refer to the French government intending to extend the life of already operational nuclear power plants. Connected to this, source S specifies how the French 2030 investment plan aims at extending the lifetime of all nuclear reactors, 32 having already received approval for a 10-year extension. Besides, source E references a 2014 carbon tax from the *Energy Transition for Green Growth*, that from just 7€/tCO_2 when first implemented, is supposed reach 100€/tCO_2 by 2030, which should favor low-emissive energy sources like nuclear. According to source L, the *NOME Act*, requiring to produce and reserve 100TWh from nuclear generation for foreign energy market, is also contributing to nuclear continuing to play a central role in electricity production in France. Source R mentions how the French government has also been programming the *COVID-19 Recovery Plan* which, together with the *Programmation Pluriannuelle de l'Énergie* offers funds for a low-carbon energy transition, comprising of 8 billion € for energy technology investments. Source V mentions a draft bill approved in January 2023 by the French senate, for improved construction exemptions and permissions, as well as immediate land possession procedures to facilitate new reactor builds. Three sources (S, V, C), highlight how France is intending to construct six new reactors, two sources (S, V) specifying the parliament approval in March 2023 of a 52 billion € investment starting in 2027/2028 for six new generation EPR reactors. Source S also mentions a 1 billion € investment by the government by 2030 for innovative reactor designs. Lastly, source J remarks how the French nuclear industry has historically been prone to policy and financial support from the state.

There are mainly three policy measures which I identified as more environmentally centered and are all seemingly in favor of nuclear. Mentioned by three sources (C, E, R), either with *National Low-Carbon Strategy for 2050* updated in 2020 either with the *National Climate Plan*, or the *Energy and*

Table 4. Summarized results of the policy findings separated by *French* and *EU* domain, as well as *Policy Recommendation*. Plus, a further division by argument, either *economic, environmental*, or *societal*. In red, for transparency reasons, the findings from the WNA, association that represent the industry. The numbers added after some of the policies refer to the number of sources referring to the same measure.

Domain	Economic	Environmental	Societal
France ↳ + = pro - = con	+ French government planning on extending operation of existing nuclear plants. (1+1) + French 2030 investment plan aiming at extending the lifetime of all nuclear reactors, 32 having already received approval for a 10-year extension. + 2014 carbon tax introduced via the *Energy Transition for Green Growth Law*: from €7/tCO_2 to reach €100/tCO_2 by 2030. + The French *NOME Act* requires to produce and reserve 100TWh of nuclear energy generation for foreign energy market. + *COVID-19 Recovery Plan* together with the *Programmation Pluriannuelle de l'Energie* offering green funds for the energy transition, comprising of 8bln€ for energy technology investments. +French Senate January 2023 draft bill for exemptions on permissions for the construction of new reactors; and immediate possession procedures to obtain land on which to build new reactors. + France's Parliament approval in March 2023 of 52bln€ governmental investments on nuclear to construct six next-gen EPRs starting in 2027/2028. (1+1) + 1bln€ investment by 2030 for innovative nuclear reactor designs. + French nuclear industry being historically prone to policy and financial support from the state.	+ *National Low-Carbon Strategy for 2050 / Energy and Climate Law / National Climate Plan* towards the goal of carbon neutrality by 2050. (3) + Government planning for fossil fuel phase-out, while investing in renewables and nuclear power. + The 2021 *Climate and Resilience Law* to speed up climate action by 2030, both at regional and local levels.	- Plan of reduction of nuclear in the French energy mix from 70% to 50% by 2035 via the 2019 *Energy and Climate Law*, increasing renewable generation to compensate for 14 ageing plants. (9) - French government aiming to increase the share of renewables in electricity generation to 40% by 2030. + French Senate January 2023 draft bill maintaining nuclear generation at more than 50% by 2050. + Past policies implementing *SCRAM* systems in French nuclear plants as well as stress tests to increasing overall safety. + French Regulatory agencies promoting the implementation of devices to mitigate radioactive releases in case of accidents. + Since the 80s investments for the implementation of tools to adapt French nuclear plants to supply/demand fluctuations, together with improved safety (2). + Macron planning to build 6 new reactors (evaluating further 8) to increase electricity supply by 60% together with renewables, to decouple from fossil-fuels and secure energy sovereignty.
EU ↳ + = pro - = con	+ EU labelling certain nuclear activities as valuable in achieving climate objectives, promoting private investments [adherence to EU's green	+ *European Green Deal* for 55% reduction in greenhouse	+ EU's *Sustainable Nuclear Energy Technology Platform* in support of safer, more reliable, and competitive GenII/GenIII nuclear

	taxonomy] (2) + *European Green Deal* with *Fit-for-55* package to increase carbon pricing, favoring investments in low-carbon energy generation. + European Commission's *Net-Zero industry Act* favoring SMR development. - Nuclear safety in France, being non-conditional as set by EU law, makes safety objectives a priority no matter the costs. This can lead to increasing building costs for nuclear installation to satisfy new safety directives. - Compliance to deregulated EU markets causing uncertainty in recovering costs, leading to decreasing market shares. - Change in safety regulation leading to delayed constructions. - EU's 2016 *Winter Package* policy, only targeting expansion of renewables, and an increased integration of EU's energy markets. - Unlike renewables, EU policies do not stipulate future deployment levels for nuclear as many member states do not support the technology. - *Fit-for-55* and renewable energies directive setting binding targets for states of 40% renewables by 2030. - European Commission's 1trn€ investment in sustainable development in the next decade not financing new nuclear power plants.	emissions by 2030, from 1990 levels. + *Emission trading systems* and *emission allowances* to reduce greenhouse gas emissions. + The *European Energy Roadmap to 2050*, setting four routes for decarbonization, not only involves high rates of renewables, but also a significant contribution from nuclear in countries where pro-nuclear policy is pursued.	systems; low-carbon cogeneration of process heat and electricity, and the promotion of fast reactors to preserve resources and minimize the burden of radioactive waste.
Policy recc. ↳	• Momentum deploying GenIII/III+ PWR designs must be maintained, to leverage the already accumulated experience, which is somewhat lacking in other GenIII/III+ designs. • Additional governmental economic support for nuclear is required to improve its infrastructure and cost-effectiveness, in order to achieve carbon neutrality more easily, and help replacing ageing plants. (3) • Necessity of costs transparency for	• Need for policy measures that prioritize nuclear energy and renewables development over gas, to truly transition away from fossil-fuel electricity generation. (2) • French government must	• Increased investment in nuclear to lower electricity prices in France and neighboring countries. • Need for a stricter carbon tax, accompanied by price subsidies for low-carbon electricity generation, to tamper societal backlash (2) • Need for future nuclear developments to focus on addressing capacity overflows and cover gaps from intermittent

nuclear builds: investment underestimation undercuts initiatives in support for nuclear. • Necessity in increasing efforts to complete unfinished nuclear builds, to start financing future builds. • Government intervention for lowering real interest rates to around 3% for new nuclear builds, similarly to Russia. • Need for improved carbon taxes and pricing, subsidies for low-emission tech, and regulations to favor net-zero targets. (3) • Need to introduce the cost of the negative economic externalities linked to intermittency: the cost of storage must be accounted for in the marginal cost of renewables. • Policy to support research and development in green and nuclear energy technologies, as well as investments in energy efficiency. • EU policy to increase spot prices to reward nuclear low-carbon baseload energy generation, making it more competitive. • Need for financing frameworks and long-term support for the industry to help deliver projects on time and on budget. • Need for consistent long-term strategies in energy policymaking, to anticipate investments in nuclear and carbon capture and storage.	implement policies to achieve faster implementation and tracking of decarbonization targets. • Measures to ensure safety regulators have the resources and skill to go through controls and review faster and develop harmonized safety criteria in new designs.	sources. • Necessity of modernizing French ageing nuclear fleet to extend operation, thus supporting a secure and affordable low-carbon transition. (3) • Nuclear plants must be planned with socioeconomic factors as a priority (energy security, district heating). • Necessity for regulations that discourage electric and gas boilers, and that promote district heating solutions. • Need to deploy nuclear waste management solution by involving citizens in the process.

Climate Law, the aim for France to reach the goal of carbon neutrality by 2050, measures supposedly favoring all low-carbon solutions. Source H mentions another policy measure from the government focusing on fossil fuel phase-out, and planning investment in renewables and nuclear power. Finally, the 2021 *Climate and Resilience Law*, mentioned by source R, to speed up climate action by 2030, both at regional and local levels, which would indirectly favor all low-emissive solutions.

Looking within policies that have primarily societal impacts, such as energy security and safety, only two are against nuclear development and it has actually been mentioned by nine sources. These sources (B, C, E, H, K, M, N, O, R) refer, with slightly different wording, to the 2019 *Energy and Climate Law*, which planned to reduce nuclear in the French energy mix from 70% to 50% by 2035 through an increase of renewable energy generation to compensate for fourteen ageing nuclear plants. Source O also specifies how the government aimed at increasing the share of renewables in the French energy mix to 40% by 2030. Nonetheless, the more recent January 2023 draft bill from the French senate apparently goes against the previously set targets, at least in the long term, planning to still maintain nuclear energy generation at more than 50% by 2050 (V). On the security side, source G remarks how past policies led to the implementation of *SCRAM* systems in French nuclear plants as well as stress tests to increase nuclear safety. Source G also mentions French regulatory agencies promoting the implementation of devices to mitigate radioactive releases in case of accidents. Two sources (H, M) remark how France has invested in the nuclear industry for the implementation of tools to follow electricity supply and demand fluctuations together with improved safety measures, source M specifying that this has been happening since the 80s. This feature would support France implementation of more renewables in the mix, consolidating a synergistic relationship between nuclear and renewables. Lastly, source V, refers to how prime minister Macron had also announced in January 2022 plans to build six new reactors and evaluating further eight, to increase electricity supply by 60%, not only to decouple electricity supply from fossil-fuels with nuclear and renewables, but also to secure energy sovereignty.

3.1.2 The EU Side

Looking at the results for the EU policy backdrop, the context is less favorable. Starting with supportive economic policies, two sources (H, T) mention how the EU has approved the labelling of certain nuclear activities fitting specific requirements as valuable in achieving climate objectives, thus promoting private investments in nuclear. This refers to the EU revising its terms for its *green taxonomy*. Source R mentions the EGD with its *Fit-for-55* package to increase carbon pricing, which will subsequently favor investments in low-carbon energy generation. Source U also mentions how the European Commission's *Net-Zero Industry Act* would favor the development of future nuclear modular reactors. Looking at policies against nuclear in the economic domain, source G specifies how EU law resolves nuclear safety as non-conditional, which makes safety objectives a priority no matter the costs. This can lead to increasing building costs for nuclear installations to satisfy new safety directives. Connected to this, source D refers to policies that change safety regulations as causing delayed constructions times, since new reactors builds have to adjust accordingly, which in turn leads to economic loss. Source D also stresses how France complying to deregulated EU electricity markets leads to uncertainties in recovering costs, leading to decreasing market shares. Source I mentions

EU's 2016 *Winter Package*, which focuses only on renewables expansion and aims at increased integration of EU's energy markets, most likely hindering nuclear, as one of nuclear's main advantages is the low prices of electricity generation. Source U mentions how, unlike for renewables, EU policies do not stipulate future deployment levels for nuclear, as many member states do not support it, which probably hinders a harmonized nuclear development across the union. Source U continues with EU's *Fit-for-55* program in relation to the fact that it sets binding targets of 40% renewables by 2030, which could affect member states having high percentages of nuclear energy generation in their mix. Finally, source U also mentions how the European Commission's plan for 1 trillion € investment over the next decade for sustainable development will not finance any new nuclear plants.

Looking at EU policy affecting the environmental domain, there are two main favorable policies in place for nuclear. As a whole, the EGD aims at reducing greenhouse emissions by 55%, from 1990 levels (I, U). The other policy implementation consists in *Emission Trading Systems* and emission allowances to reduce emissions, which rewards energy systems and industries that reduce their environmental footprint and penalizes highly emissive ones (I). These two policy measures do not specifically target nuclear directly, but theoretically favor all low-emissive means of energy generation. Moreover, source P refers to the *European Energy Roadmap to 2050*, which suggests paths to decarbonization. It not only expects high rates of renewables, but also a significant contribution from nuclear in countries where pro-nuclear policy is pursued.

Concluding the EU section, one final favorable measure is mentioned, which I categorized as societal policy. Stated by source U, it's the *EU Sustainable Nuclear Energy Technology Platform* in support of safer, more reliable and competitive Gen-II and Gen-III nuclear systems; as well as encouraging low-carbon cogeneration of process heat and electricity, together with the promotion of fast reactors to preserve resources and minimize the burden of radioactive waste.

3.1.3 Policy Recommendations for Nuclear Development

The following paragraph gathers all the relevant policy recommendations in favor of nuclear generation that I found through my qualitative data collection. This allows to identify in which direction policymaking should direct it efforts if it aims to support the development of nuclear energy.

First, all of the policy recommendations for nuclear which mainly fit the economic domain will be mentioned. Source A refers to the necessity of maintaining momentum in deploying Gen-III/Gen-III+

Pressurized-Water Reactor designs (like EPR), to leverage the already accumulated experience with the technology, element which is somewhat scarce for other Gen-III/III+ designs. Three sources (C, E, I) mention, with slightly different wording, the need for additional governmental economic support for nuclear, in order to improve its infrastructure and cost-effectiveness, and to achieve carbon neutrality more easily, and presumably help replacing ageing plants. Source D refers to the necessity of improving costs transparency for nuclear builds, since investment underestimation can undercut initiatives in support for nuclear. Additionally, source D highlights the necessity to increase efforts in completing unfinished nuclear builds, a fundamental step to start financing new reactors. Moreover, Source D also stresses the need for government intervention for lowering real interest rates for new nuclear builds to around 3%, similarly to what Russia does. Three sources (B, E, I), with slightly different formulation, refer to the need for improving taxes and carbon pricing, as well as subsidies for low-emissive tech, and regulations to favor net-zero targets. Source M refers to the need of introducing the cost of the negative economic externalities that are linked to intermittency such as the cost of storage, which must be accounted for in the marginal cost of renewables. Source O stresses the necessity for policy to support the research and development of green and nuclear energy technologies, as well as investments in energy efficiency. Two sources (Q, S) refer to the need for EU policy to increase energy spot prices to reward nuclear low-carbon baseload energy generation, thus making it a more competitive energy source. Source S also mentions the necessity for improved financing frameworks as well as securing long-term support for the industry to help deliver projects on time and on budget. Finally, source E mentions the necessity for consistent long-term strategies in energy policymaking, to anticipate investments in nuclear together with carbon capture and storage.

Looking at policy recommendations within the environmental domain, two different sources (H, I) refer to the need for policy measures that prioritize nuclear energy and renewables development over gas, to truly transition away from fossil-fuel electricity generation and avoiding simple gas substitution with coal. Two sources (O, R) state how the French government must implement policies to achieve faster implementation and tracking of decarbonization targets, which would allegedly have an impact in French nuclear development. In this case, source O refers specifically to EU's 55% emission reduction target by 2030. Lastly, source S emphasizes the necessity for measures which ensure that nuclear safety regulators have at their disposal the resources, competence, and capabilities to go through controls and review faster and develop harmonized safety criteria in upcoming reactor designs.

To conclude the results for RQ1, the policy recommendations which have mainly societal implications. Source C refers to the need for increased governmental investment in nuclear energy in order to achieve lower electricity prices in France, but also in neighboring countries. Source E mentions the necessity for a stricter carbon tax, but it must be accompanied by price subsidies for low-carbon electricity generation (aspect also mentioned by source B), to tamper societal backlash from the public. Source H stresses the need to focus future developmental efforts in nuclear energy to specifically address capacity overflows and cover gaps from intermittent sources, supposedly to secure energy inertia and grid stability and better integrate nuclear baseload with renewable's intermittency. Connected to this, source N emphasizes how new nuclear builds must be planned first and foremost prioritizing socioeconomic factors, such as safeguarding energy security and using waste heat from nuclear plants for district heating. Furthermore, source N also mentions the necessity for policies that discourage electric and gas boilers, and to promote district heating solutions, to make use of plants' waste heat. Four sources (C, O, R, S) stress the necessity of modernizing and maintaining the ageing French nuclear fleet to extend its operation, which would secure an affordable low-carbon transition for the country. Lastly, source S mentions the need to deploy nuclear waste management solutions by involving citizens in the decision-making process.

3.2 Research Question 2: *Narrative Analysis*

Results for RQ2 will follow. The first part will look more broadly into the numbers from all entries, whereas the second part will look more into detail at those articles that refer specifically to the first wave of EPRs.

3.2.1 Overall Findings

When it comes to the perception of nuclear energy deducible from the news outlets which have been scrutinized, the main findings prove overwhelming media negativity towards EPRs (Figure 2 and Figure 3). In fact, looking at the results for articles strictly related to the topic of EPRs, there is a strong tendency to portray the technology in a rather negative fashion: the articles that align with a negative outlook are 41, consisting of almost 70% of all the articles on the topic of EPRs, whereas the ambivalent ones are only 12, consisting of around 20% of all articles on EPRs. Finally, the articles that portray EPRs in a positive light are a small minority, only 6, which make up just about 10% of the articles on EPRs.

On a different note, articles that are not strictly discussing the first wave of EPR reactors but just deal with the topic nuclear energy in general, show a much different trend. In fact, the numbers confirm that negative articles amount to only 7 entries, analogous number of ambivalent ones. In this case, each of the two sentiment accounts for less than a quarter of the aggregate number of non-EPR articles. Conversely, positive articles comprise more than the sum of negative and ambivalent ones, with 15 total entries. This translates to more than 50% of non-EPR articles.

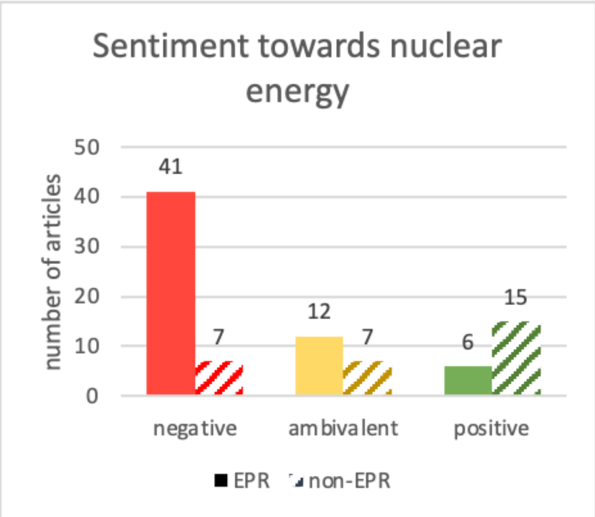

Figure 2. Numbers of news articles by sentiment. Striped columns refer to non-EPR ones. Filled columns refer to EPR-related ones.

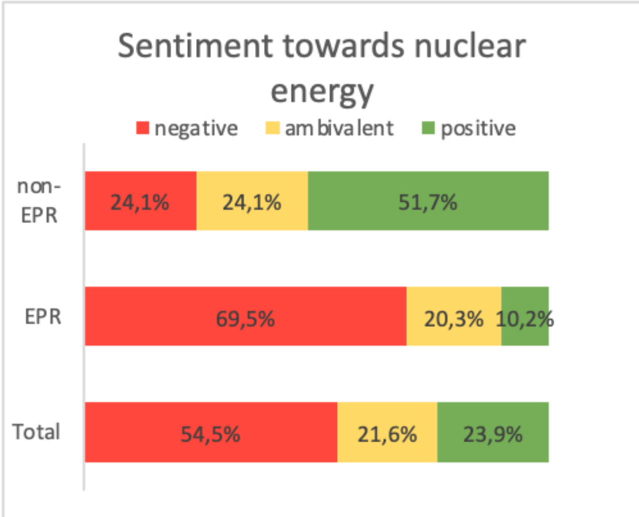

Figure 3. Percentages for each sentiment in relation to the topic (EPR, non-EPR, and total number).

Regardless, when looking at the broader overall picture, we can assert how the majority of articles are still mostly negative, being almost 55% of the total, while ambivalent and positive entries make up similar percentages, roughly 22% and 24% respectively. This is due to the fact that articles on EPRs are nevertheless numerically greater, with 59 entries (against 29 non-EPR).

These findings are also in line with the 11 news articles from within the EU that specifically refer to EPRs (22 also considering articles from the UK which, while not EU, is part of Euratom as associate state, and is constructing an EPR plant). In fact, 7 of these EU articles denote a negative stance (or 14 including UK ones) while only 1 (or 2 including the UK one) is positive. Therefore, almost two thirds of EU-based narratives are against EPRs. The country origin of each news article can be checked in the article list at the end of the previous chapter (Table 3).

Moving to the second part of the results for RQ2, I found 11 arguments aligned with *advocacy*, 11 with *ambivalence*, and 16 with *opposition* to EPRs (Table 5). Small clarification: not all ambivalent arguments are unique, some may have already been mentioned in *advocacy* or *opposition*. More balanced viewpoints and the concurrence of positive and negative voices are the distinctive feature of *ambivalence*. I now analyze the arguments behind each ideology more in detail, by looking at some representative cases.

Table 5. Summarized narratives on EPRs, sorted by arguments and categorized in the three ideologies.

Ideology	**Economic**	**Environmental**	**Societal**
Advocacy ↳ Positive sentiment towards EPR on the grounds of…	+ Nationally produced electricity + Independence from expensive fossil fuel imports + Nuclear energy would be cheap, but prices are tied to EU's energy market inflated by gas	+ Clean energy generation + Great potential for CO_2 emission reduction + Nuclear waste being manageable	+ Abundant/secure energy generation for millions of households + Potentially lower energy bills for users + Independence from Russia's gas + Finland able to enter NATO due to independence from Russian gas
Ambivalence ↳ Balanced sentiment towards EPR on the grounds of… + = pro - = con	+ Delays are not attributable only to the design's fault, but to external factors + Being labeled *green* by the EU helps attracting investors - Underestimation of construction delays, construction costs and inflating future reactor expenditures	+ Clean energy generation + Great potential for CO_2 emission reduction - Nuclear waste still being an issue	+ Public opinion reconsidering nuclear due to surging energy prices and climate change + Abundant/secure energy generation for millions of households + Independence from Russia's gas - Risks of shutdowns for maintenance and reliance on costly imports
Opposition ↳ Negative sentiment towards EPR on the grounds of…	- Great underestimation of construction times, construction costs and inflating future reactor expenditures. - Commissioning for future builds is delayed - EDF suffering its greatest operational crisis - Investors distrust - Affected by supply issues during COVID pandemic - French government having to support EDF's failing efforts	- Safety Risks due to corrosion and leakage occurred to older EDF plants - EPR parts needing replacements sooner than expected - Leakages and technical issue at operational EPRs - Nuclear being *green* in EU's taxonomy only due to France heavy lobbying	- Difficulty in attracting and hiring thousands of skilled workers each year - Planning energy security on a technology that does not work - Risks of shutdowns for maintenance and reliance on costly imports and fossil fuels - Not suitable for a fast green transition and rapidly rising electrification needs as it takes too long to build - General concerns over nuclear accidents and toxic waste

3.2.2 Advocacy: A Nuclear Renaissance?

When it comes to the few articles advocating for EPR technology, economic arguments are mostly limited to the advantage of producing electricity within national confines, indipendence from expensive fossil fuels, and the inherent low prices of electricity generation from nuclear. One article, referring to the EPR located in Hinkely Point's, UK, mentions how *"Britain will have a ramped-up supply of homegrown power that could help slash its reliance on expensive fossil fuel imports and push it on a path to energy indipendence"* (Paul, 2023). Another article expresses how French nuclear's *"ensured low costs for France* [but] *previous governments gave in to pressure from the EU to fix the European electricity market price … with the sanctions imposed on Russia, the price of gas rose to levels that have become unbearable for households"* (Cheminade, 2022), overall lamenting how adjusting to expensive gas prices hindered one of nuclear's main advantages, being cheap energy generation.

Referring to the environmental arguments in favor of EPRs, one article refers to nuclear energy as *"clean"* (Paul, 2023), whereas another emphasizes how EDF's *"two EPR reactors will offset 9 million tonnes of carbon dioxide emissions a year"* (World Ports Organisation, 2023). One states how Finland's EPR *"will halve its energy imports at one blow. Ninety percent of the national grid is now said to be supplied by "clean" sources"* (Cosh, 2022). The same article also highlights how Finland *"solved domestically"* the nuclear waste problem with a *"520-metre hole, ready to accept the spent fuel … drilled into the Finnish mainland just a few kilometers away* [from the EPR]."

The societal arguments mostly focus on energy abundance and security: *"Finland 1,600MW EPR plant will now be producing electricity 'mostly at full power'"* (Dalton, 2023b), again *"1,600 megawatt is an awful lot of energy, about one-seventh of Finland's entire electricity demand"* (Cosh, 2022). Referring to UK's EPR, one article mentions how *"the facility will provide low-carbon electricity for around 6 million homes"* (World Ports Organisation, 2023), or looking at future implications of UK's EPR, one states how *"Energy Secretary Grant Shapps has vowed to make Britain's energy bills the lowest in Europe"* (Paul, 2023). Lastly, one source also stresses how *"Finland is now better able to conduct a previously unthinkable domestic political debate about its relationship with NATO because it can unhook its power grid safely from Russian gas"* (Cosh, 2022).

3.2.3 Ambivalence: The Nuclear Limbo

The articles communicating a balanced stance on EPRs tend to underline a variety of negative and positive aspects which are also found in oppositional and advocacy narratives. Looking at economic arguments, different outlets stress construction delays and rising costs: *"the first-generation EPR … in Flamanville is now more than a decade behind schedule and whose cost has ballooned from an initial €3.3 billion to four times as much"* (Dodman, 2023). The same is said for EPRs in all countries: *"the cost of building Hinkley Point C is set to increase to £32bn … up by almost 30% on previous estimates of £26b … while its completion date has stretched from 2025 to 2027"* (Dalton, 2023a); and *"Olkiluoto 3 was originally scheduled to start up more than 12 years ago, in 2009, but was beset by a long series of technical delays, legal disputes and cost overruns"* (YLE, 2022); and *"EPR reactors in China … have been hit by technical issues"* (Webb, 2022). While here I listed only some of the outlets mentioning these issues, it's mostly a recurrent message throughout all of the ambivalent articles. On more positive remarks, one article states how the responsibility for delays are not attributable to the EPR design alone: "*There are currently four EPRs under construction … there is delay in execution of all of these projects, but the delay is not attributable to the technology"* (Ray, 2022), while some other mention how *"after over a decade of delays … Finland's new Olkiluoto 3 nuclear reactor … will be able to ease the coming winter's challenges as Europe battles soaring energy prices following Russia's invasion of Ukraine"* (Macau Business, 2022c). Another optimistic point raised by one source is that, while EPRs have been hindered by delays and cost overruns *"nuclear power* [being] *labelled as "green" by the European Commission … means it can attract funding as a climate-friendly power source"* (Benhamou & Plowright, 2022), indicating how this policy measure should help the development of the industry as a whole.

Looking at environmental arguments, one article mentions concerns over EPR designs due to complications in other older French plants, as some *"threaten to throw a spanner in the works, just days after the country's main nuclear watchdog … reported the latest case of corrosion cracks at a nuclear facility"* (Dodman, 2023), therefore stressing preoccupation over possible environmental contamination. Another source, while recognizing the potential of the technology, also states how it will *"produce radioactive waste that remains deadly for tens of thousands of years"* (The Indipendent, 2022). That said, many ambivalent articles also mention a variety of positive environmental factors: *"France-supplied EPR … will help provide enough low-carbon electricity for 3-million homes and will be vital in helping Britain achieve net zero and stronger energy security"* (Dalton, 2023a); or again *"Finland's long-delayed and costly new nuclear reactor … will boost the Nordic country's electricity self-sufficiency and help to achieve its carbon neutrality targets"* (Hürriyet Daily News, 2022); and *"*[Flamanville's EPR] *will allow France to meet its commitment to reach carbon neutrality in 2050 and help reduce the country's dependency on imported fossil fuels"* (The Independent, 2022); and finally *"it enables us to produce carbon-free electricity, it helps give us energy independence, and it produces electricity that is very competitive"* (Benhamou & Plowright, 2022).

Societal factors are often mentioned in ambivalent stances. The main negative societal aspect, mentioned by one of the sources is how *"Last November, a record 26 of France's 56 nuclear reactors were shut for repairs or maintenance, forcing the country to import electricity from Germany"* (Dodman, 2023), referring to the risk of shutdowns as an issue of energy security and energy independency. That said, many positive points were also raised, such as: *"polls suggest … public opinion steadily warming to the industry as surging energy prices weigh on French consumers and memories of Japan's 2011 Fukushima disaster fade"* (Dodman, 2023); and again *"Nuclear and renewables … are seen as critical to ramp up Britain's energy security, after … Russia's invasion of Ukraine sent gas and electricity bills rocketing across Europe"* (India Today, 2022); and "*Given the prospect of a long conflict in Ukraine limiting trade with Russia, and with electrification likely to become increasingly important as we move to a low-carbon world, the potential for nuclear power is huge"* (The Mail & Guardian, 2022); and finally *"The* [EPR] *reactor … will cover an estimated 14 percent of Finland's total electricity demand, reducing the country's need to import electricity from Norway, Russia and Sweden"* (Hürriyet Daily News, 2022). These positive remarks clearly show how, even within ambivalent voices, preoccupation over energy security and independence are recurring factors.

3.2.4 Opposition: EPRs are a Farce

News articles conveying a negative outlook on EPRs comprise the majority. Again here, only some representative articles for each argument will be mentioned. Starting from economic factors, two sources, similarly to many others, refer to EPRs massive costs and time underestimations all over Europe *"United Kingdom and France are each building one new nuclear power plant … years delayed and wildly over budget. It took famously technophilic Finland 17 years to finish its own new reactor, and there are already problems postponing its coming online"* (Kaufman & Ahmed, 2022), or specifically mentioning the Flamanville EPR being *"expected to cost around four times the initial budget of 3.3bn€"* (France 24, 2022a). One source refers to EDF's severe financial difficulties as *"earnings and debt both worsened dramatically in 2022 as EDF struggled with a drop in electricity output after shutting down a big chunk of France's nuclear plants to fix corrosion problems, and a heatwave reduced hydro-power production"* (Daily Sun, 2023), or again another source *"in 2022, EDF crossed the "biggest operational crisis since its creation" in 1946"* (Time News, 2023). One source mentions how commissioned future EPR builds are already being postponed and face inflating costs *"Britain's flagship Hinkley Point C nuclear power station is facing the risk of an 11-year delay … In January 2021, that was pushed back to June 2026, and in May 2022 it was pushed back again to 2027, with EDF blaming the pandemic and supply chain issues. Costs are now expected to be as high* *as £26bn"* (Millard, 2022). One article mentions investors increasing distrust *"EDF has been slammed after the company told investors that the costs of building the Hinkley Point C nuclear plant in the UK could balloon to 32bl£"* (Big World Tale, 2023). Another source mentions the French government having to financially support EDF which *"has become a byword for its failings and an embarrassment for the government, which owns 84% of EDF and is banking on nuclear to blunt the impact of a European energy crisis"* (Benjamin, 2022).

Looking at the environmental side, one source denotes safety issues over *"a corrosion phenomenon … uncovered in pipes crucial for the safety of the power plants, forcing the many reactors shut down for checks and repairs"* (Paudal, 2023b), or even *"*[EDF] *has experienced multiple technical setbacks with the Flamanville plant, with the national nuclear watchdog identifying problems with welding in 2019 which had to be redone"* (Irfan, 2022). Some denote the questionable promotion of nuclear in EU's taxonomy, as one source remarks how the French government has *"lobbied hard for nuclear to be labelled as sustainable under new European Commission rules on green financing"* (The Economic Times, 2022), and similarly, one outlet highlights how *"anti-nuclear activists have denounced the French push to promote that power source"* (CTV News, 2022).

Finally, the social arguments will conclude the results for RQ2. One source mentions how *"one "big challenge" was the need for the nuclear industry to hire 10-15,000 workers per year"* (Montel News, 2023b), one source also states how *"companies … have a lot of trouble recruiting boilermakers and welders. This problem has also been identified as one of the reasons for the delays of the Flamanville EPR."* (Paudal, 2023a), or again *"in France such skilled workers are in short supply"* (The Standard, 2022). One source denotes how *"troubles at France's nuclear fleet last year also contributed to drive up power prices across much of Europe, which had already been under severe stress due to the curtailment of Russian energy flows"* (Radowitz, 2023), or "[in France] *as winter sets in, there are warnings of power outages"* (Gunter, 2022). Another source refers to nuclear as *"a costly option which does not respond to the urgency to get, as soon as in the next decade, a low-carbon electricity without disruption"* (US News & World Report, 2022a). Finally, one source denotes societal concerns over security as *"nuclear safety still divides Europe after Japan's Fukushima disaster in 2011",* and *"nuclear plants … produce radioactive waste that remains deadly for tens of thousands of years"* (US News & World Report, 2022a, 2022b).

4 Discussion

This section of the thesis will be dedicated to answering both RQs and the discussion of the findings, and to look at some wider implications.

4.1 Answering the Research Questions

To summarize, nuclear has always played an important role in energy generation in France, despite waning support in most EU countries, especially after Chernobyl and Fukushima. That said, controversy over current EPR builds has been increasing, due to skyrocketing construction times and costs. The French case, with its EPR design, was investigated for this thesis, to try to understand why nuclear energy is not playing a larger role in the EU's low-carbon transition and to explore how feasible EPRs and new nuclear development are in today's context. To explore these wider implications, I identified two RQs being: 1) How is the current policy context in the EU and in France affecting nuclear development, and what potential measures would increase the pace and scale of new nuclear plants? 2) What narratives do international media publishing in English use to portray EPRs and nuclear energy in France?

To answer RQ1, the French policy context, as of right now, seems quite favorable for further development of nuclear energy, especially due to all the measures that aim at decarbonizing electricity generation and the apparently strong governmental support for the nuclear industry and EPR design as a whole, no matter the delays and rising costs. On the other hand, EU policy, while not directly hindering nuclear energy with phase-out policies, focuses mostly on renewables expansion, which indirectly discourages investments in new nuclear developments. The necessity for more effective policy implementations has been confirmed by the findings in the policy recommendations section, meaning that there are still obstacles for nuclear development, especially outside the French context.

For RQ2 we can state that the majority of international news outlets, almost 55%, tend to adhere to negative narratives which reflects the controversial nature of nuclear technology, struggling to strike a secure and widespread support. Looking at the results more closely, we can nonetheless distinguish how most of the oppositional voices specifically address EPR builds, stressing construction delays and rising costs as unsurmountable obstacles. When looking more broadly at nuclear outside of the first wave of EPRs, narratives tend to be more favorable with advocacy of almost 52%, signifying that nuclear as a technology may be going through a phase of reevaluation.

4.2 The Interplay Between *Narrative Analysis* and *Initiative Feasibility*

Referring to the framework, where *narrative analysis* and *initiative feasibility* act as interposing factors for the *technical potential* of EPR, we can conclude how the obstacles in achieving support for EPR as a climate mitigation measure, are plentiful. This is true especially outside the French context mainly due to unfavorable narratives surrounding EPR projects, which can hinder public acceptance for the technology, together with EU policies that almost entirely focus on renewables alone, while not adequately discouraging fossil-fuel dependencies. This is in line with the introductory remarks of this thesis: while EPR's technical potential is undeniable due to its great capacity for low-carbon electricity generation, its levitating costs, and delay-prone constructions, together with a general distrust for the nuclear industry and concern over possible environmental externalities, can constitute big obstacles in its adoption.

From this research, it was nonetheless interesting to notice how the issues related to nuclear waste and safety were not nearly as prevalent as the economic factors, which constitute the preponderant element of oppositional narratives. This may be due to the French context, whereby specific policies targeting nuclear safety were introduced in the past, to implement SCRAM systems, stress-tests, and other radiation mitigation measures to increase security. On top of this, the non-conditional safety measures imposed by EU law, while being an economical drawback leading to increased construction and retrofitting costs, represent nonetheless an extra step in guaranteeing nuclear safety.

Still, negative narratives surrounding economic arguments, especially the delays and levitating costs of EPRs, are an issue that cannot be understated. While the French government may still be intentioned to support economically its debt-laden nuclear industry with specific policies by securing investments and simplifying construction permits to allow faster project delivery, it still constitutes a controversial strategy. If future EPR projects still end up failing to meet deadlines and costs become unmanageable, it may signify an incredible loss for the French nuclear industry, demonstrating its inability to learn from first-of-a-kind issues and reach the necessary inertia needed to keep its operation afloat and expand. This could be even more the case if difficulties for the French nuclear industry persist in securing thousands of new skilled workers every year, which is necessary to support nuclear expansion plans, element mentioned in oppositional narratives which still needs to be addressed by targeted policies.

These considerations apply even more outside of France, where nuclear power does not enjoy, as established by this thesis, the same favorable and synergistic policy environment and economic support of the industry. EU policy, while aiming at a reduction of emissions of 55% by 2030, which could in theory favor nuclear, being one of the least CO_2-emissive energy sources, in practice translates to renewables being the sole focus, with a 1 trillion € sustainable development plan from the European Commission that will not address nuclear development. Furthermore, EU setting a binding target of 40% renewables by 2030 could lead to France having to either decrease nuclear generation or pay sanctions for non-compliance, despite having some of the lowest electricity emissions in the EU (Our World in Data, 2022).

To achieve the technical potential of EPRs and support future nuclear endeavors as climate mitigation efforts, as highlighted in the *policy recommendation* section (3.1.3), both EU and nation-wise measures are needed. Among the most mentioned, it is fundamental to increase EU's carbon pricing on fossil-fuel-dependent electricity generation, as well as subsidizing low-emissive electricity generation technologies, especially to avoid simple substitution of coal with gas. In France, more economic support from the government is required to improve nuclear industry's infrastructures and cost-effectiveness, in preparation for the substitution of end-of-life plants. At the same time, whenever possible, older plants need to be modernized to extend their longevity. This would be an economical way to secure affordable low-carbon electricity generation. Such provisions should be accompanied by long-term EU policies and financing frameworks to support countries that choose to have nuclear in their mix as part of their low-carbon transition, as well as reforming the energy market to reward nuclear's baseload generation which can help stabilizing renewables' intermittency. In France, future support for EPR designs must be secured to leverage almost 20 years of accumulated know-how from first-of-a-kind issues, to be able to deliver future plants earlier and cheaper. This should be accompanied by assuring that national safety regulators possess enough resources to review plants faster. Nationally, these measures need to be supplemented by a final waste repository plan with community participation, as well as shifting towards district heating to harvest nuclear plants' surplus waste heat, and to discourage heating through boilers, especially gas ones.

4.3 Final Considerations

In short, this research discloses that, despite mostly unfavorable narratives surrounding EPRs, the policy environment in France is supportive of the technology even if recent first-of-a-kind projects have been plagued by cost overruns and construction delays, meaning that the French government is aware of such difficulties but does not attribute the unsatisfactory turnout solely on the design, but to the concurrence of a variety of other factors. Newly planned policies show that France wants to maintain the central role of the nuclear industry through measures that allow for faster construction permissions to proceed with new nuclear builds, as well as extending the life of existing plants, together with considerable economic investments. It seems that such strategy, may in a way represent a big bet from the government which hopes to reduce first-of-a-kind issues that have hindered the first wave of EPRs. Such plan may represents the will to maximize and compound the effects of experience accumulation, increased construction capacity and efficiency obtained with the first difficult projects, to improve delivery times and costs of newer builds over time, to secure in the next decades energy sovereignty and low-carbon energy generation, while at the same time diversifying its energy mix with the gradual increase of renewables.

Nonetheless, to tackle risk reduction from investing in a climate mitigation measure that could encounter backlash, most EU member states should look elsewhere, especially due to the high upfront costs. Being unable to secure widespread nuclear approval, both politically and publicly, translates into difficulties in ensuring long-term nuclear strategies. When this is the case, renewables constitute a more feasible solution, which also has lower upfront costs. However, to enjoy the advantages of low-carbon baseload energy generation from nuclear, with lower risk of hindering long-term national energy strategies, neighboring countries could consider participating in financing future French nuclear builds to secure some baseload energy quotas. This would not only contribute to a country's energy security, but also secure investments in an industry that needs financial support to improve its capacity and pace of supply.

This thesis also demonstrates how conventional high-capacity nuclear plants, like EPRs, constitute a difficult option for most EU countries that plan to have nuclear in their mix, as only few states have the established capabilities of carrying out such huge projects, as well as public support and adequate policy. These considerations also extend to private investments, which are highly discouraged.

Nevertheless, there are also important implications for supporting French nuclear efforts when it comes to geopolitical matters. With North America's anticipated decrease in nuclear generation capacity in the coming decades, and with 27 out of 31 reactors having started construction in 2017 being from Russia or China, the latter set to become leader producer by 2030 (IAEA, 2021a; IEA, 2022), there's the risk for a concentration of civil nuclear technology in the hands of non-democracies. This prospect is not dissimilar from the geopolitical issues surrounding renewables, where rare earth materials sourcing, necessary for the production of wind turbines, photovoltaic panels and batteries are almost entirely dependent on China (Criekemans, 2018).

This also comes in light of Ukraine's invasion from Russia, which unilaterally decided to stop gas supply to many EU countries, causing volatility of prices and uncertainties of supply (European Council, 2023a). For Germany, this translated to the necessity to restart old coal-powered plants to secure energy through the winter causing higher CO_2 emissions (Connolly, 2022). This concurred with planned shutdowns from the German government of three nuclear plants by the end of 2022, that were nevertheless delayed until April to face the energy crisis (Brady, 2023). While drastic reductions in electricity consumption and efficiency improvements must nonetheless be a key priority in policymaking as pointed out by the IPCC (2018), it's unclear how fast different EU countries will operationalize these goals. The energy crisis has showed how the EU is still very dependent from baseload energy generation from fossil fuels with 350 billion $ in subsidies in 2022 to reduce energy bills, demonstrating how it's critical to invest in structural changes rather than relying on emergency aids (IEA, 2023). The EU should consider these factors alone as a sufficient reason to not only increase renewables deployment drastically, but also support other low-carbon sources like nuclear power with targeted policies.

4.4 Sustainability Science Pertinency

Matters of energy and electricity production are strictly linked to sustainability science due to how much these play a major role in a transition towards a decarbonized society. With the energy sector being responsible for more than 73% of all global greenhouse emissions (Ritchie et al., 2020), evaluating viable solutions to mitigate correlated environmental externalities is of fundamental importance. Similarly to Nielsen et al. (2020), this research, with its conceptual framework, tries to integrate the study of feasibility and contextuality of a mitigation measure in a multi-domain approach by putting together elements typical of social and political science. This approach tries to respond to what Jerneck et al. (2011) refer as the need for integrated understanding and synergistic implementation across sciences and domains in response to complex sustainability issues. The purpose of this thesis is exactly to provide knowledge to support societal decision making and create solutions that guide a transition towards sustainability, as formulated by Miller (2013). Analyzing the intricate subject of climate mitigation measures' deployment through the gatekeeping effect of narratives and policies, allows to acknowledge the inherent complexities at play without limiting the issue to sheer technical considerations. This methodology could nonetheless be transferred outside the subject of energy to analyze other mitigation measures. Finally, while the aim of this thesis is to provide actionable knowledge by combining knowledge from outside academia and incorporate diverse variables, key challenges in transformational sustainability research (Wiek et al., 2012), I acknowledge that my contribution can only partially seize the complexities and interactions of such systems and, as Funtowicz & Ravetz (1993) suggests, can only provide guidance for problem-solving and not certainty.

4.5 Limitations

Inability to work in French, not knowing the language, made it impossible to directly source French policy documents and French news outlets, which required me to resort to English literature and documentation for policy findings, and international English news media for content analysis. Furthermore, for both RQs categorizing economic, societal, and environmental factors was not a clear-cut process as the results often adhered to more than one domain, which lead to inevitable simplifications. Another struggle lied in summarizing all policy findings in a manageable list, later condensed in a table trying to merge together similar findings although worded differently, especially with policies without a specific 'label', causing uncertainties in knowing whether some policies were the same or not. Another limitation of this work, is that results in both RQs are not ordered by date neither in tables nor text, except where specific time indications are stated. At times, it was also challenging to discern mere statements from governmental actors to actual effective policy applications. Moreover, some policies targeting general decarbonization were put as favorable for nuclear, due to nuclear being low carbon, even if said policies did not specifically address nuclear.

Besides, this thesis was definitely not a linear process. Initially the focus was on the French context alone, but after gathering my findings I also decided to look at broader implications for the EU. I reckoned my results and discussion would have benefitted from a more comprehensive vision. This is why 'EU' is not present as keyword in my search entries in the methodology. Moreover, the findings from the news media analysis hinted to some policy developments that the original literature review did not touch upon. This is why I ended up supplementing the literature review with documentation that filled that small temporal gap. Finally, the biggest limitation lies in the scope constriction of this work: this feasibility study would have delivered superior results if EPRs and nuclear had not been analyzed in a bubble, but instead compared to other technical mitigation measures such as wind, solar, biomass, or even socio-economical ones such as de-growth. Plus, narrative and policy analysis can be approached in different ways from the one I opted for. Perhaps these last few observations leave space for future work to address this gap.

5 Conclusions

With this study, I investigated the role of nuclear power in France and in the EU through the French EPR design to explore how feasible EPRs and new nuclear development are today in the EU. This overarching enquiry was addressed with two research questions. The first implied the analysis of the policy context in the EU and France to assess how it affects nuclear development and evaluate policy suggestions. The Second, led to the gathering of narratives around nuclear and EPRs from international media publishing in English. The overall findings disclose a multifaceted landscape shaped by mostly oppositional narratives, and policy dynamics that differ contextually. France displays a somewhat paradoxical policy environment where the government still supports nuclear energy despite major delays and rising costs in the construction of EPRs. This is driven by the desire to secure energy sovereignty and decarbonize the energy sector. However, EU policies predominantly favor renewables, indirectly discouraging new nuclear investments. International media narratives highlight the controversial nature of EPR designs, with the prevalence of negative voices, particularly regarding economic arguments, while signaling a potential reevaluation of nuclear energy in general. This study, through its conceptual framework, highlights the intricate relationship between *narrative analysis* and *initiative feasibility* as interposing factors in the realization of a climate mitigation measure. In this case, the fulfillment of EPRs *technical potential* seems to be limited to France. In the EU, negative narratives and inadequate policies hinder EPRs' adoption as a climate mitigation measure. That said, targeted policy measures could help harness the potential of nuclear endeavors. The EU must increase carbon pricing on fossil-fuel-dependent electricity generation, subsidize low-emissive electricity generation, and reform the electricity market to reward nuclear energy's dispatchability. In France, government support must enhance the industry's infrastructure and cost-effectiveness, by leveraging the know-how acquired from first-of-a-kind issues from the first wave of EPRs. Policy must also address long-term waste disposal, district heating integration, as well as securing new workforce. This study, in its adherence to sustainability science, highlights the importance of integrating different domains when evaluating mitigation measures, in this case social and political, to not limit feasibility assessments to mere technical evaluations. Future research could expand upon this work by comparing nuclear energy with other mitigation measures, not just in terms of electricity generation technologies, but also socio-economic theories, as well as adopting alternative approaches in tackling narrative and policy analysis.

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7 Annexes

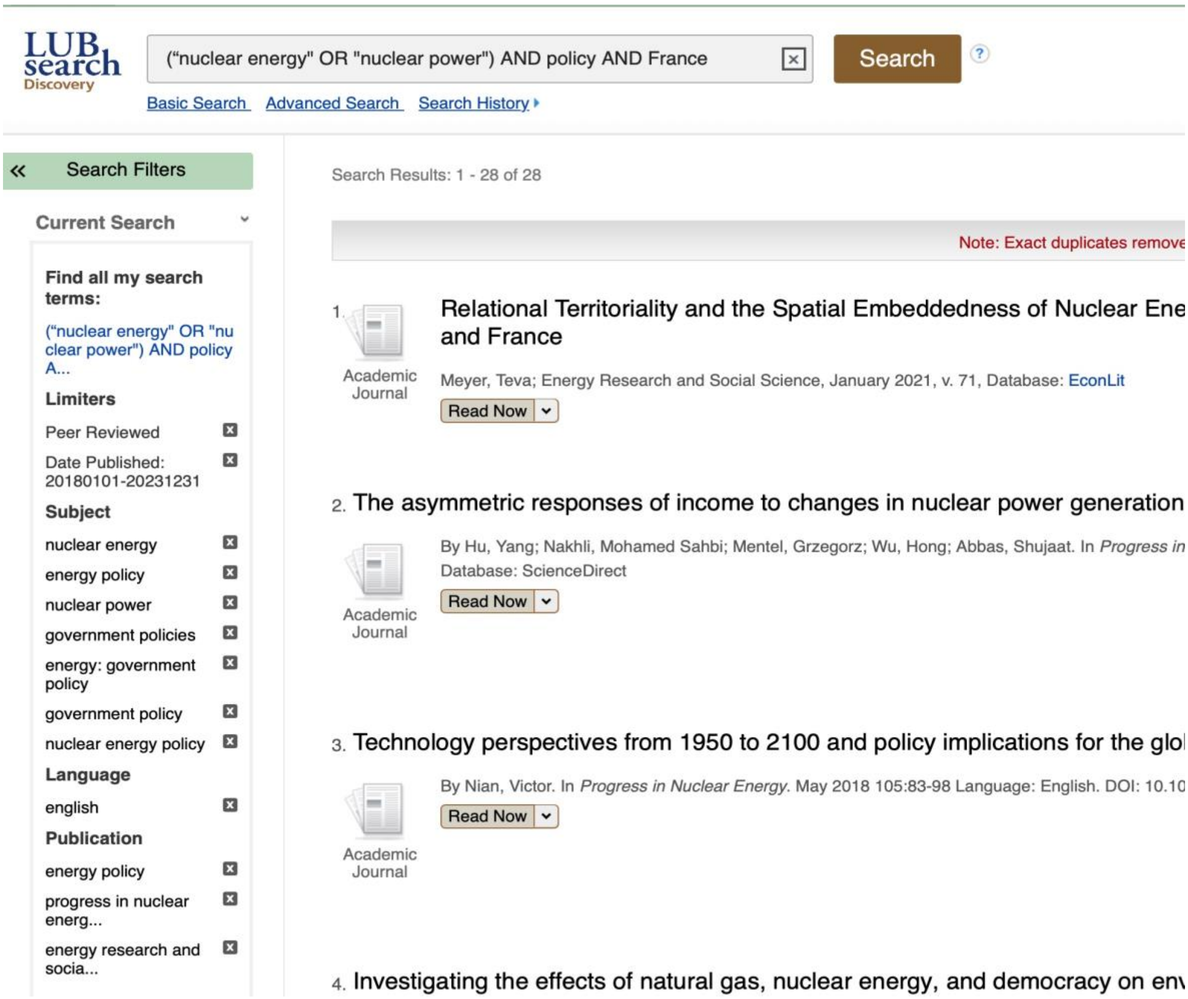
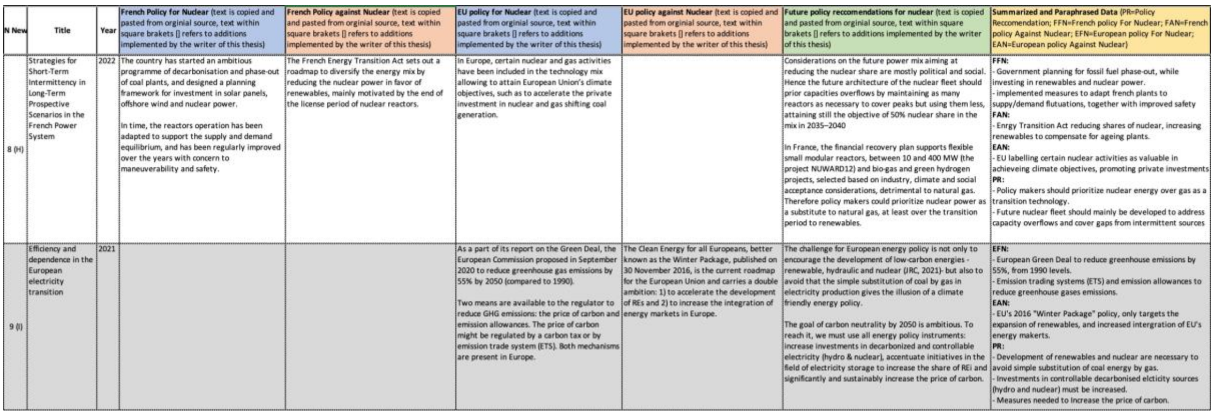


Figure 4. Screen capture of the source gathering process for the systematic literature review for RQ1. Here the keywords and filters used in *LUBsearch* are visible.



N New	Title	Year	**French Policy for Nuclear** (text is copied and pasted from orginial source, text within square brakets [] refers to additions implemented by the writer of this thesis)	**French Policy against Nuclear** (text is copied and pasted from orginial source, text within square brakets [] refers to additions implemented by the writer of this thesis)	**EU policy for Nuclear** (text is copied and pasted from orginial source, text within square brakets [] refers to additions implemented by the writer of this thesis)	**EU policy against Nuclear** (text is copied and pasted from orginial source, text within square brakets [] refers to additions implemented by the writer of this thesis)	**Future policy reccomendations for nuclear** (text is copied and pasted from orginial source, text within square brakets [] refers to additions implemented by the writer of this thesis)	**Summarized and Paraphrased Data** (PR=Policy Reccomendation; FFN=French policy For Nuclear; FAN=French policy Against Nuclear; EFN=European policy For Nuclear; EAN=European policy Against Nuclear)
8 (H)	Strategies for Short-Term Intermittency in Long-Term Prospective Scenarios in the French Power System	2022	The country has started an ambitious programme of decarbonisation and phase-out of coal plants, and designed a planning framework for investment in solar panels, offshore wind and nuclear power. In time, the reactors operation has been adapted to support the supply and demand equilibrium, and has been regularly improved over the years with concern to maneuverability and safety.	The French Energy Transition Act sets out a roadmap to diversify the energy mix by reducing the nuclear power in favor of renewables, mainly motivated by the end of the license period of nuclear reactors.	In Europe, certain nuclear and gas activities have been included in the technology mix allowing to attain European Union's climate objectives, such as to accelerate the private investment in nuclear and gas shifting coal generation.		Considerations on the future power mix aiming at reducing the nuclear share are mostly political and social. Hence the future architecture of the nuclear fleet should prior capacities overflows by maintaining as many reactors as necessary to cover peaks but using them less, attaining still the objective of 50% nuclear share in the mix in 2035–2040 In France, the financial recovery plan supports flexible small modular reactors, between 10 and 400 MW (the project NUWARD12) and bio-gas and green hydrogen projects, selected based on industry, climate and social acceptance considerations, detrimental to natural gas. Therefore policy makers could prioritize nuclear power as a substitute to natural gas, at least over the transition period to renewables.	**FFN:** - Government planning for fossil fuel phase-out, while investing in renewables and nuclear power. - implemented measures to adapt french plants to suppy/demand flutuations, together with improved safety **FAN:** - Enrgy Transition Act reducing shares of nuclear, increasing renewables to compensate for ageing plants. **EAN:** - EU labelling certain nuclear activities as valuable in achieveing climate objectives, promoting private investments **PR:** - Policy makers should prioritize nuclear energy over gas as a transition technology. - Future nuclear fleet should mainly be developed to address capacity overflows and cover gaps from intermittent sources
9 (I)	Efficiency and dependence in the European electricity transition	2021			As a part of its report on the Green Deal, the European Commission proposed in September 2020 to reduce greenhouse gas emissions by 55% by 2050 (compared to 1990). Two means are available to the regulator to reduce GHG emissions: the price of carbon and emission allowances. The price of carbon might be regulated by a carbon tax or by emission trade system (ETS). Both mechanisms are present in Europe.	The Clean Energy for all Europeans, better known as the Winter Package, published on 30 November 2016, is the current roadmap for the European Union and carries a double ambition: 1) to accelerate the development of REs and 2) to increase the integration of energy markets in Europe.	The challenge for European energy policy is not only to encourage the development of low-carbon energies - renewable, hydraulic and nuclear (JRC, 2021)- but also to avoid that the simple substitution of coal by gas in electricity production gives the illusion of a climate friendly energy policy. The goal of carbon neutrality by 2050 is ambitious. To reach it, we must use all energy policy instruments: increase investments in decarbonized and controllable electricity (hydro & nuclear), accentuate initiatives in the field of electricity storage to increase the share of REi and significantly and sustainably increase the price of carbon.	**EFN:** - European Green Deal to reduce greenhouse emissions by 55%, from 1990 levels. - Emission trading systems (ETS) and emission allowances to reduce greenhouse gases emissions. **EAN:** - EU's 2016 "Winter Package" policy, only targets the expansion of renewables, and increased intergration of EU's energy makerts. **PR:** - Development of renewables and nuclear are necessary to avoid simple substitution of coal energy by gas. - Investments in controllable decarbonised elcticity sources (hydro and nuclear) must be increased. - Measures needed to increase the price of carbon.

Figure 5. Screen capture of a section of the excel document where I categorized the qualitative data for RQ1. For each article, I copied and pasted in the relevant cells the text excerpts that provided policy-relevant data based on the domain. I then summarized and paraphrased the findings in a separate cell. The full document is available in the attached zip file of this thesis.

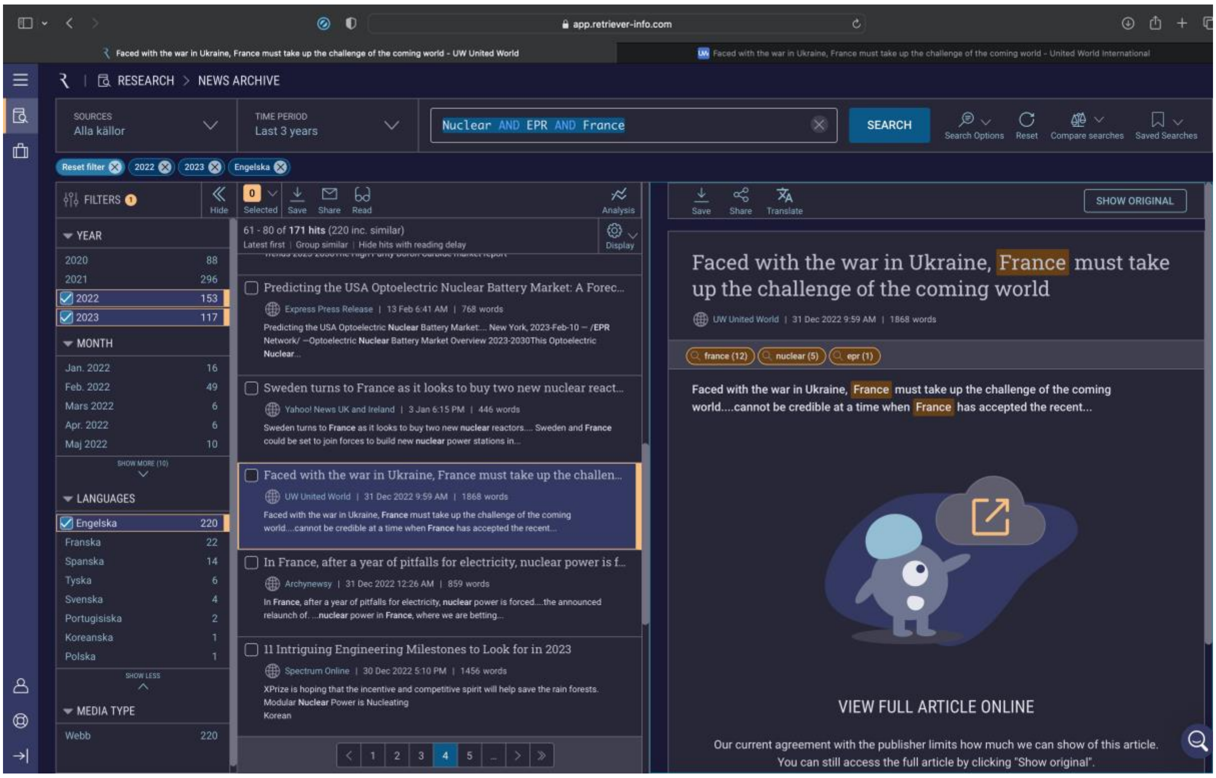
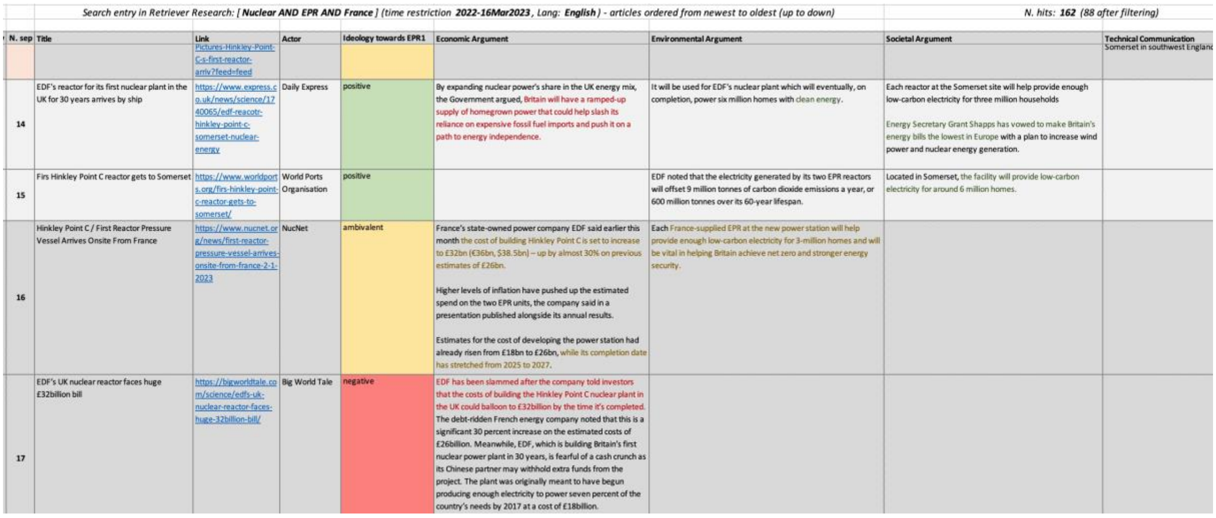


Figure 6. Screen capture of the source gathering process for the news articles' content analysis for RQ2. Here the keywords and filters used in *Retriever Research* in the *news archive* section are visible.



Search entry in Retriever Research: [**Nuclear AND EPR AND France**] (time restriction **2022-16Mar2023**, Lang: **English**) - articles ordered from newest to oldest (up to down) N. hits: **162** (88 after filtering)

N. sep	Title	Link	Actor	Ideology towards EPR1	Economic Argument	Environmental Argument	Societal Argument	Technical Communication
		Pictures-Hinkley-Point-C-s-first-reactor-arriv?feed=feed						Somerset in southwest England
14	EDF's reactor for its first nuclear plant in the UK for 30 years arrives by ship	https://www.express.co.uk/news/science/1740065/edf-reacotr-hinkley-point-c-somerset-nuclear-energy	Daily Express	positive	By expanding nuclear power's share in the UK energy mix, the Government argued, Britain will have a ramped-up supply of homegrown power that could help slash its reliance on expensive fossil fuel imports and push it on a path to energy independence.	It will be used for EDF's nuclear plant which will eventually, on completion, power six million homes with clean energy.	Each reactor at the Somerset site will help provide enough low-carbon electricity for three million households Energy Secretary Grant Shapps has vowed to make Britain's energy bills the lowest in Europe with a plan to increase wind power and nuclear energy generation.	
15	Firs Hinkley Point C reactor gets to Somerset	https://www.worldports.org/firs-hinkley-point-c-reactor-gets-to-somerset/	World Ports Organisation	positive		EDF noted that the electricity generated by its two EPR reactors will offset 9 million tonnes of carbon dioxide emissions a year, or 600 million tonnes over its 60-year lifespan.	Located in Somerset, the facility will provide low-carbon electricity for around 6 million homes.	
16	Hinkley Point C / First Reactor Pressure Vessel Arrives Onsite From France	https://www.nucnet.org/news/first-reactor-pressure-vessel-arrives-onsite-from-france-2-1-2023	NucNet	ambivalent	France's state-owned power company EDF said earlier this month the cost of building Hinkley Point C is set to increase to £32bn (€36bn, $38.5bn) – up by almost 30% on previous estimates of £26bn. Higher levels of inflation have pushed up the estimated spend on the two EPR units, the company said in a presentation published alongside its annual results. Estimates for the cost of developing the power station had already risen from £18bn to £26bn, while its completion date has stretched from 2025 to 2027.	Each France-supplied EPR at the new power station will help provide enough low-carbon electricity for 3-million homes and will be vital in helping Britain achieve net zero and stronger energy security.		
17	EDF's UK nuclear reactor faces huge £32billion bill	https://bigworldtale.com/science/edfs-uk-nuclear-reactor-faces-huge-32billion-bill/	Big World Tale	negative	EDF has been slammed after the company told investors that the costs of building the Hinkley Point C nuclear plant in the UK could balloon to £32billion by the time it's completed. The debt-ridden French energy company noted that this is a significant 30 percent increase on the estimated costs of £26billion. Meanwhile, EDF, which is building Britain's first nuclear power plant in 30 years, is fearful of a cash crunch as its Chinese partner may withhold extra funds from the project. The plant was originally meant to have begun producing enough electricity to power seven percent of the country's needs by 2017 at a cost of £18billion.			

Figure 7. Screen capture of a section of the excel document where I categorized the qualitative data form the news articles, necessary for RQ2's content analysis. For each article, I copied and pasted in the relevant cells the text excerpts that were telling of the sentiment. This allowed me to assess the overarching ideology (either positive, ambivalent, or negative) of each article. The highlighted excerpts represent those that have been chosen to be presented in the results sections of the thesis, since it would have been impossible to show all of them. The full document is available in the attached zip file of this thesis.