Master Thesis

Negotiating the Energy Future: Exploring Small Modular Reactors (SMRs) as Potential Replacement for Coal-Fired Power Plants: A Case Study of the Eemshaven

Final report

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Job Jack Benjamin van Duivenbode

3078833

DR. E.J. AUKES

&

DR. I. IBRAHIM

Master of Environmental and Energy Management

University of Twente, The Netherlands

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Abstract

The Dutch cabinet adopted a law on 11 December 2019, mandating the cessation of coal use for electricity production by 2030, necessitating an urgent transition to sustainable energy sources in the Eemshaven area. This study investigated the potential role of Small Modular Reactors (SMRs) as a replacement for the coal-fired power plant in Eemshaven, exploring how various social groups negotiated this transition within the framework of the Social Construction of Technology (SCOT). Through interviews with representatives from industry, government, environmental organizations, local communities and academic experts, this research identified key themes such as economic feasibility, operational efficiency, safety, environmental impact and social acceptance.

The results showed a complex negotiation process with different perspectives and power dynamics involved. Representatives from industries related to the Eemshaven and some policymakers were highlighting the economic and operational benefits of SMRs, while environmental groups and local communities were raising serious safety and environmental concerns. Within such a context, the role of the ANVS as an independent regulator was paramount to mediate all these dynamics so that stringent safety standards would be maintained.

To be able to describe possible coalitions and consensus-building among social groups, the study employed imaginative negotiation scenarios. It emphasized on the need for inclusive and participatory decision-making processes to address public concerns and build trust surrounding the adoption of new energy technologies. The study contributed to theoretical insights into the process of energy transitions and provided practical implications for policy and practice in the Dutch energy sector.

The study concluded that to be able to assess the feasibility of SMRs and potentially plan a successful adoption into the energy mix, a careful balance of technical, economic, social and environmental factors is required. Future research should focus on longitudinal studies of SMR projects in leading countries, public opinion surveys and integrating SCOT with other theoretical models to deeper understand the social dynamics of technological adoption. Nevertheless, this study built a foundation for well-informed policy decisions regarding the potential adoption of new nuclear energy technologies, and a step closer to fostering a sustainable and resilient energy future for the Netherlands.

1. Introduction

On 11 December 2019, the Dutch cabinet adopted a law in which the use of coal will be prohibited to produce electricity by 2030 at the latest (European Commission, 2020). Together with the remaining developed countries that are members of the Organisation for Economic Co-operation and Development (OECD) (United Nations, 2023). This mandates an urgent need to transition the energy mix of the Eemshaven to cleaner and more sustainable energy sources. The Eemshaven aims to develop into one of the sustainable power hubs of the Netherlands. In an interview regarding the energy transition and market opportunities for the expansion of the Eemshaven, Cas Köning, CEO of Groningen Seaports, port authority and commercial operator of the Eemshaven stated "*We are already the electricity roundabout of the Netherlands, of course we want to grow the production of clean energy. As well as creating jobs, the development contributes to the greening of the chemical industry and thus helping the energy transition. Groningen has traditionally been the energy province of the Netherlands, and we want it to stay that way. The Netherlands is ready for clean and sustainable energy, in which Eemshaven plays an important role*." (Groningen Seaports, 2021).

Besides the offshore wind farms, Vopak Eemshaven Solar Park, commercialized in 2021, is a 19-hectare solar project powering over 8000 households with renewable energy (GlobalData, 2024). Nevertheless, Eemshaven is currently still dependent on floating LNG (liquefied natural gas) import terminal. The terminal started its operations in 2022 and has a capacity of 8 billion cubic meters of natural gas per year. LNG still plays a predominant role in the energy mix as the fuel ensures reliable and secure energy for the Netherlands and North-West Europe, where solar and wind energy due to intermittency challenges, is lacking (Gasunie, 2022).

There are plans to create a green hydrogen value chain by 2025, part of the renewable hydrogen roadmap of the Netherlands (Engie, 2021). However, challenges such as transportation infrastructure upgrades, high initial costs and scalability, effective storage methods, safety and cybersecurity measures, storage and distribution infrastructure, security of supply, public acceptance, and the intermittency of solar and wind energy are prominent and therefore may not fully decarbonize the Eemshaven area. Even though many scientists claim that integrating hydrogen into the Dutch energy systems is crucial for a sustainable future, additional measures combined with alternative energy sources and decarbonization strategies seem to be required to achieve the desired results (Hasankhani, van Engelen, Celik, & Diehl, 2024). The intent to decarbonize the Eemshaven area and partake in the energy transition while ensuring a secure energy supply has led to exploring alternative options such as Small Modular Reactors (SMRs). SMRs are compact nuclear reactors that can be deployed incrementally to match fluctuating energy demands. SMRs offer several advantages in being inherently safe, rely on more passive systems, and include lower construction costs compared to conventional nuclear energy techniques (Liou, 2023).

Moreover, the adoption of SMRs in the Eemshaven area has significant social, political, environmental, and economic relevance. SMRs can offer a low-carbon alternative compared to the coal-fired power plant, reducing greenhouse house gas emissions, mitigating climate change, and reducing dependence on fossil fuels. In addition, the deployment of SMRs can lead to economic growth, domestic manufacturing and competitiveness, job creation, and increased revenue tax. Furthermore, the adoption of SMRs has significant political implications. Government officials and policymakers in determining the future energy mix and shaping the energy transition (Office of Nuclear Energy, 2023). However, social acceptance is crucial for the successful adaption of SMRs and the overall energy transition in the Eemshaven area. Different social groups such as local communities, environmental organisations, government officials, policymakers, industry representatives, and academic experts among others all hold diverse perspectives on the potential benefits and risks associated with SMRs as energy sources (Masters, 2023).

The current state-of-the-art research on how social groups negotiated the potential role of SMRs as a potential replacement for coal-fired power plants at Eemshaven is limited. There is lack a of awareness and understanding among social groups regarding the SMRs' capabilities as opposed to conventional nuclear energy since the technology is relatively new. Furthermore, nuclear energy in general often faces resistance linked to safety, waste management, and potential accidents, increasing the difficulty of conducting research and engaging in negotiations regarding the matter. Moreover, the development and deployment of SMRs are highly dependent on political and regulatory support, while obtaining permits and approval can be challenging. And at last, researching the potential risks and benefits of SMRs requires significant resources, funding, and active engagement of various social groups. Limitations in these requirements have limited adequate research on SMRs in general.

The objective of this research is to examine the adoption of SMRs in the energy mix as a potential replacement for the coal-fired power plant in the Eemshaven area. By addressing the research gap identified in the research problem, the research aims to reach an understanding of how social groups negotiate the role of SMRs in the Netherlands' goal to decarbonize the energy sector including its impact on social, political, environmental, and economic aspects. In this context, "negotiate" refers to the imaginary process in which different social groups would engage in discussions, debates, and decision-making regarding the role of SMRs. The exchange of perspectives, interests, and interpretations among various social groups as they navigate the complexities and implications of the adaption of SMRs into the energy mix at the Eemshaven, will be a key focus of this research. Through the identification of research topics and literature gaps within the field of study, a specific research question is formulated. The research question is, however, dynamic and may evolve as this research progresses. The research question is the main research question of this study and will guide this research with a focus on the following:

"How do social groups negotiate the role of Small Modular Reactors (SMRs) as a potential replacement for the coal-fired power plant in the Eemshaven area, Groningen, the Netherlands, by 2030?"

For a more focused and systematic approach to this research, the main research question has been split up into smaller, and more manageable sub-research questions. The sub-research questions reveal the complexity of the main research question and the scope of this research.

1. Who are the relevant social groups involved in the potential adoption of the SMRs as a replacement for the coal-fired powerplant at the Eemshaven area?

This sub-research question aims to **identify** the relevant individuals, organizations, non-profit groups, businesses, and government agencies that might be involved in the negotiation of adopting SMRs in energy mix of the Eemshaven area.

2. What are the perspectives, values, interests, and power dynamics of each social group involved in the negotiation regarding the adoption of SMRs?

This sub-research question aims to **examine** the specific values, interests, and power dynamics of each social group and how these factors influence their stance on SMRs.

3. How do social groups in the Eemshaven area engage in the negotiation and what discourses, strategies, and tactics do they employ?

This sub-research question aims to **analyses** the discourse, strategies, and tactics used by social groups when negotiating the role of SMRs.

4. To what extent does the negotiation influence the social acceptance of SMRs as a replacement for the coal-fired power plant in the Eemshaven area?

This sub-research question aims to **evaluate** the impact of the negotiation on the acceptance or rejection of SMRs.

2. Literature review

2.1 Small Modular Reactors (SMRs)

Small Modular Reactors (SMRs) are nuclear fission reactors that are characterized by size, modular design, capacity and advanced safety features. Reactor type can vary, however, SMRs are generally one-tenth to one-fourth the size of conventional nuclear energy plants and produce a 300-megawatt electrical (MWe) per unit, which is around one-third of conventional nuclear energy plant (Idaho National Laboratory, 2024). SMRs can be deployed modularly allowing for a certain extent of flexibility in meeting fluctuating energy demands, sited in locations unsuited for larger nuclear plants, connect to existing grids, operate off-grid (Liou, 2023), generate electricity and high energy temperature process heat needed to produce hydrogen, and if combined with energy storage systems such as batteries or hydrogen, would improve grid flexibility and maximize the use of excess electricity (Office of Nuclear Energy, 2023). However, the reactors also pose challenges in nuclear waste management costs (Krall, Macfarlane, & Ewing, 2022) and have limited operational experience, which could affect public acceptance and regulatory approval (Ramana, 2021).

Furthermore, compared to conventional nuclear reactors SMRs pose safety characteristics that reduce the risk of radioactive release during accidents, such as lower operating pressures (Liou, 2023). The robust structural design allows them to withstand extreme conditions, including earthquakes and severe weather (Office of Nuclear Energy, 2018). Next-generation SMR (generation 4) will have advanced passive safety systems that rely on natural phenomena to shut down reactors during emergencies, enhancing their reliability and safety (Butt, Ilyas, Ahmad, & Aydogan, 2016). The economic advantages of SMRs lie in the lower construction costs and modular deployment. Prefabricated and factory-assembled modules facilitate quicker and more cost-effective installation compared to larger reactors that cannot (Moniz, Hezir, Comello, & Brown, October 2023).

2.1.1 Technical Developments

Fair improvements in the technological advancement of SMRs have brought about significant changes in design, safety and operational efficiency. The most recent improvements made in the application of high-temperature alloys and TRISO fuels have increased energy output, reduced waste improved safety and optimized nuclear fuel efficiency (Abbasi, 2023). Due to post-Fukushima safety improvements, such as accident-tolerant fuels, SMRs are more reliable and competitive in the energy market (Tan, et al., 2023). Along with a lifespan ranging between 30 and 60 years and capabilities for load balancing, SMRs could offer a sustainable and adjustable power generation solution (KPMG Advisory NV, 2021).

Moreover, technological advancements in modular construction have played a crucial role too, in the deployment of SMRs. Factory-controlled production of SMR components allows for a better quality control, less construction time and reduced costs compared to traditional nuclear technologies (Liou, 2023). The standardization improves scalability and adaptability across different locations, with China on the frontline of implementing an SMR, as evidenced by the upcoming operation of the LingLong One, in 2026 (World Nuclear News, 2022).

2.1.1 Potential applications in the Netherlands

In the Netherlands, transitioning from coal-fired power to sustainable energy sources highlights the potential need and exploration of SMRs. With the COP28 declaring to triple the global nuclear power capacity by 2050, for the Netherlands achieving an optimal nuclear capacity of 9.6 GWe by 2050 could significantly aid in decarbonizing the energy sector (Fattahi, et al., 2022).

Operational examples of SMRs demonstrate their effectiveness in various contexts. The NuScale Power Model in the USA, the CAREM reactor in Argentina, the KLT 40S in Russia and the Rolls-Royce UK SMR illustrate the diverse applications and benefits of SMR technology (World Nuclear Association, 2024). Specifically, the agreement between Rolls-Royce SMR and ULC-Energy, aiming to realize

SMRs in the Netherlands, reveals their potential for the Dutch energy market (World Nuclear News, 2023).

Moreover, SMRs also offer deployment versatility in onshore, offshore and subsea-based environments. Onshore SMRs can be placed in areas unsuitable for larger plants, especially decommissioned coal-fired power sites (World Nuclear Association, 2024). Offshore SMRs can provide electricity to remote islands and offshore installations, minimizing transmission losses. And subsea-based SMRs can utilize seawater for cooling which offers a novel approach to providing power without substantial land-based infrastructure (World Nuclear Association, 2024).

2.2 Environmental and Economic Implications

The financial and environmental effects of implementing SMRs are a crucial factor as well. The studies and research on the environmental effect of SMRs will be reviewed and the cost-effectiveness and economic feasibility will be assessed. This will offer a grasp of the SMRs' role in replacing the coal-fired power plant.

2.1.2 Comparing environmental performance with coal-fired power plant

When it comes down to mitigating climate change and reducing independence on fossil fuels, SMRS is superior to coal-fired power plants in numerous ways. SMRs are nuclear reactors that generate electricity with significantly low emissions of greenhouse gases, mostly carbon dioxide. Coal-fired power plants, on the other hand, release copious amounts of carbon dioxide, sulphur dioxide, nitrogen oxides, and particulate matter into the atmosphere. Making coal-fired power plants significant contributors to GHG emissions, and negatively impacting both the environment and human health (Carless, Griffin, & Fischbeck, 2016).

When compared to coal-fired power plants, during operation SMRs do not emit direct GHG emissions. However, it is important to note that the construction and mining activities associated with SMRs may have direct emissions. Since SMRs produce electricity without directly emitting carbon dioxide, it is regarded as a low-carbon energy source (Liou, 2023). Furthermore, compared to coal-fired power plants, SMRs have a higher energy efficiency. Nuclear reactors produce less waste heat and use less energy overall because these reactors convert a larger portion of fuel into electricity. At last, SMRs can offer a reliable and sustainable supply of electricity for a considerable amount of time. Nuclear fuel can be recycled and used again, unlike coal, which is a limited resource. This reduces the need for new mining operations and minimizes environmental impact (Vinoya, Ubando, Culaba, & Chen, 2023).

2.1.3 Potential economic benefits

SMRs have the potential to generate income, jobs, and other positive economic effects. A 2010 study found that the installation of a typical 100 MWe SMR could provide $1.3 billion in sales, $404 million in payroll income, and $35 million in indirect business taxes in addition to almost 7000 new jobs (Solan, et al., 2013). Furthermore, the Conference Board of Canada report emphasized the financial effects of SMR implementation in Ontario. Four SMRs being built, run, and maintained at the Darlington site are expected to produce C$ 4.9 billion in tax revenue, 2000 new jobs annually, and a C$15.3 billion boost in Canada's GDP over 65 years (The Conference Board of Canada, 2021). These results reveal that SMRs may have the ability to boost the local economy in the Eemshaven area and national economies, in the Netherlands, by generating revenue, employment opportunities, and economic growth.

2.1.4 Political implications and the role of governmental officials and policymakers

SMRs are vital to the energy transition and have enormous political implications. Facilitating the development and deployment of SMRs is primarily the role of government officials and policymakers as they hold positions of authority and responsibility within the government. These individuals have the power to affect the regulatory frameworks required to reduce risks during crucial project lifecycle stages and to pay private sector project developers fairly. Governments everywhere are stepping up to encourage the development of SMRs, with some aiming to have operational reactors by 2030 (Vercammen, 2024). Leaders such as US President Joe Biden and ex-UK Prime Minister Boris Johnson have demonstrated their political support for SMRs by pledging to include SMR investment in their clean energy plans (Hill, Sabharwal, McDougall, Odynski, & Stehlík, 2021). Governments looking to shift to sustainable energy sources find SMRs appealing due to the reactors' potential to provide reliable, low-carbon energy and the ability to be deployed in various locations.

In the Netherlands, interest in SMRs as possible means to cut carbon emissions, reduce independence on fossil fuels, and diversify the energy mix has also grown, and government officials and policymakers hold a similar role in facilitating development and the deployment of SMRs. The Government officials and policymakers in the Netherlands are responsible for setting the regulatory framework, providing financial support, and ensuring public acceptance of SMRs. They are in charge of evaluating the safety, economic feasibility, and environmental as well as addressing the concerns regarding nuclear waste management and decommissioning. In addition, stakeholder engagement, public perceptions, and possible effects on the current energy industry are of concern to government officials and policymakers as well and must be taken into account (Nuclear Energy Agency, 2023).

2.3 Social acceptance and perspectives of social groups

SMRs have drawn a significant amount of interest as a potential solution for meeting energy demands and producing energy sustainably while reducing carbon emissions. However, for successful implementation, it is important to consider the social acceptance and perspectives of various social groups. A thorough understanding of the attitudes, concerns, and preferences of different social groups is necessary for formulating policies and effective decision-making (Vinoya, Ubando, Culaba, & Chen, 2023).

2.5.1 Perspectives of social groups on potential benefits and risks

The perspectives of various social groups such as local communities, environmental organisations, government officials, and industry representatives are vital in shaping the discourse in the Netherlands about the advantages and disadvantages of SMRs. Comprehending these perspectives is imperative for formulating policies and effective decision-making, and necessary for a successful adaption of SMRs in the energy mix. Concerns regarding the safety and environmental effects of SMRs in the area are common among local communities. Concerns could include the possibility of accidents, nuclear waste management, and the long-term impacts on human health and welfare. Environmental organisations on the other hand, frequently concentrate on the possible risks of SMRs, such as the generation of nuclear waste, the possibility of nuclear proliferation, and the effects of uranium mining on the environment. Instead, environmental organisations commonly support switching solely to renewable energy sources, which, however, also require mining operations (Yusuf, 2021).

The potential advantages of SMRs, such as economic growth, energy security, and decarbonization initiatives, are taken into account by government officials. These individuals weigh the risks and challenges, such as regulatory frameworks, waste disposal, and public acceptance to shape policies and regulations pertaining to SMRs (Bogovič, 2023). Industry representatives frequently highlight the potential advantages of SMRs, including the reactors' capacity to support industrial processes, generate job opportunities, and offer a reliable and low-carbon energy source. Likewise, industry representatives draw attention to the SMRs' potential for economic growth but also technical advancement (European Commission, 2024). However, it is crucial to note that there might be differences within each social group and that these individual perspectives are not exclusive to one another. Addressing concerns, fostering trust, and guaranteeing the successful integration of SMRs in the Netherlands all depend on transparent communication, the engagement of the public, and the involvement of social groups in decision-making processes.

2.5.2 Factors influencing social acceptance

Factors influencing the social acceptance of SMRs generally include safety concerns, nuclear waste management, and possible accidents. These factors are significant in influencing how the general public perceives SMRs and determines the receiving support (Vinoya, Ubando, Culaba, & Chen, 2023). When it comes to nuclear energy, the public's top priority is safety. The possibility of SMR-related hazards, such as radiation leaks, core meltdowns, and reactor failures can have a significant influence on social acceptance. To address these concerns, it is imperative to ensure the implementation of advanced safety systems, transparent communication about safety protocols, and robust safety measures (Broussard, 2020).

Another significant factor influencing societal acceptance is how SMRs manage the radioactive waste that is produced. To avoid contaminating the environment and safeguard public health, radioactive waste must be disposed of safely and stored for an extended period. Concerns regarding the long-term effects of radioactive waste can be reduced by putting waste management techniques into practice, such as the use of secure storage facilities and cutting-edge waste treatment technologies (Broussard, 2020). Although unlikely, the possibility of accidents has a big impact on the social acceptance of SMRs. High-profile incidents such as Chernobyl and Fukushima influence the public opinion of nuclear energy in general. Gaining public acceptance and trust requires showcasing the improved safety features and passive cooling systems of SMRs, which reduce the likelihood of accidents and lessen mitigate consequences (Elaheh Shobeiri, Shobeiri, Genco, Hoornweg, & Tokuhiro, 2023).

2.5.3 Challenges in conducting research and negotiations

There are various challenges to overcome when conducting research and engaging in negotiations regarding the adoption of SMRs in the Netherlands. Creating a regulatory framework that takes into account the unique qualities and safety concerns of SMRs is one of the main challenges. This entails making sure that new regulations are created or that current ones are amended to take into account the unique design and operational characteristics of SMRs. Achieving a balance between facilitating the deployment and operation of SMRs and guaranteeing safety and security is crucial. As previously mentioned, getting support from the general public and interacting with different social groups during the decision-making process presents additional challenges. Adopting SMRs entails addressing issues with waste management, possible environmental effects, and nuclear safety. To resolve these issues and foster trust among social groups, effective communication and engagement techniques are required (Piotukh, 2024).

Furthermore, researching the SMRs' cost-effectiveness and technological viability is crucial to the adoption of the reactors. This entails analysing the economic feasibility and competitiveness of SMRs in relation to alternative energy sources, as well as the performance, reliability, and scalability of the SMR designs. The identification of potential challenges and opportunities for the local supply chain and manufacturing of SMRs should also be a focus of research. Moreover, there are also challenges with infrastructure planning, grid stability, and compatibility when integrating SMRs into the current energy infrastructure and grid systems. To evaluate the effects of SMRs on the electrical grid, determine what needs to be upgraded or modified to make room for SMRs, and maximize the integration of SMRs with renewable energy sources, requires extra research (World Nuclear Association, 2024).

At last, it will take international collaboration and cooperation to negotiate the adoption of SMRs in the Netherlands. This entails exchanging best practices, knowledge, and insights gained from the implementation of SMRs with regulatory bodies, international organisations, and other nations. Concerns regarding non-proliferation, licensing, and international standards should all be discussed during negotiations (Piotukh, 2024).

2.5.4 The role of public engagement and involvement of social groups in decision-making processes

In the Netherlands, the involvement of social groups in decision-making processes plays a significant role in the adoption of SMRs. Effective implementation of SMRs requires the active participation and input of social groups from a variety of backgrounds, including the general public, local communities, non-governmental organisations, industry representatives, and the media. Interacting with these social groups helps to establish confidence in the potential acceptance of SMRs as a reliable and sustainable energy source. It also increases awareness and knowledge of SMRs, which may improve decision-making on the matter. In addition, decisions may become more inclusive and well-informed when further taking into account the concerns, inquiries, and perspectives of the various social groups involved, which in turn, might enhance the chance of a successful integration of SMRs in the Dutch energy landscape.

Social groups from a variety of backgrounds, including the general public, local communities, non-governmental organisations, industry representatives, and the media, must actively participate in and provide input for the successful implementation of SMRs. Engaging with these social groups contributes to building trust, raises awareness and understanding, and enhances confidence in the potential acceptance of SMRs as reliable and sustainable energy sources. When considering the concerns, questions, and perspectives of the social groups involved, decisions may become more inclusive and well-informed. In addition, involving these social groups also makes it possible to identify possible challenges and develop mitigation strategies, enhancing the chance of a smooth and successful integration of SMRs into the Dutch energy landscape (Yusuf, 2021).

3. Theoretical Framework

The adoption and acceptance of technologies, such as SMRs, can be studied using a variety of theoretical frameworks. The business-oriented framework known as the stakeholder theory and the psychological-orientated framework known as the Technology Acceptance Model (TAM) can both offer insightful perspectives. Nevertheless, these frameworks might fall short of capturing the social dynamics and negotiations that are involved in the social acceptance of SMRs in the Eemshaven area. The stakeholder theory primarily focuses on the relationships and interests among various stakeholders, and the TAM framework the individual attitudes and perceptions (Oyetade, Zuva, & Harmse, 2020). This implies that these frameworks might not fully address the complexity of the social factors and interactions that influence the adoption and acceptance of SMRs in the context of the Eemshaven area. However, the Social Construction of Technology (SCOT) framework was revealed to be particularly applicable to the research on how social groups negotiate the potential role of SMRs as a replacement for coal-fired power plants (Marikyan & Papagiannidis, 2023).

3.1 Social Construction of Technology (SCOT) Framework

Within the discipline of Science and Technology Studies (STS), the Social Construction of Technology (SCOT) framework is a theoretical perspective that highlights the social and political shaping of the creation and adaptation of technology. Like every framework, SCOT has received criticism in the sense that the framework concentrates too much on the micro-level social construction of technology while ignoring larger structural implications such as class and institutions (Prell, 2017). Further critiques on SCOT highlight the lack of historical and structural elements, offering clear alternatives or solutions, the agreement on how SCOT should be used, and maintaining theoretical and methodological distinctiveness as opposed to other theories studying technology. In addition, SCOT has certain challenges due to the shift from a “why” to a “how” question that increases the complexity, need for detailed data and interdisciplinary nature of analysis. Furthermore, SCOT shows difficulty to combine it with other theories as fundamental differences in epistemology, methodology and focus makes it challenging to harmonize the approach with more rigid or systemic perspective (Basu, 2023).

However, it is crucial to highlight that, despite these critiques, SCOT has made substantial contributions to the field of technology studies and has had a significant impact on current knowledge of the social construction of technology. The framework is widely regarded as a useful way to emphasize that social factors and interactions between various social groups shape a certain technology rather than the technology holding an inherent positive or negative nature. Through the framework the interpretive flexibility can analysed, which refers to the many interpretations and meanings different social groups can assign to a technology (Johnson, 2024). This enables a more in-depth set of knowledge regarding how various stakeholders shape the acceptance and development of technology. The framework demonstrates its relevance as it is still commonly used and cited in studies related to the sociology of technology and applied in various fields of research (Yousefikhah, 2018).

Furthermore, the SCOT framework is considered to be useful as it can create an understanding of the different social, cultural and political perspectives of current and new technologies, such as the development of biotechnology, blockchain and artificial intelligence (Johnson, 2024). Moreover, the framework can also provide insights into the power- and social dynamics that shape the policy, governance and decision-making processes surrounding technology. This assists policymakers and social groups in understanding the complexities of technology decision-making as well as possible social challenges (Yousefikhah, 2018).

Further examples of SCOT theoretical underpinnings and empirical applications can be illustrated as follows. For instance, the study of Kline and Pinch regarding the development of the automobile in rural America shows how SCOT can open up intricate social processes that front the adoption of technology (Kline & Pinch, 1996). Moreover, further elements from more current studies, for example on the research about the adoption of smart energy systems within Finland, can illustrate a more elaborate understanding of the SCOT in contemporary transitions in technology (Hyysalo, Juntunen, & Martiskainen, 2018). These studies underline dynamic interplay between social groups' frames, power dynamics and sociopolitical contexts shaping technological acceptance, hereby offering a detailed understanding of the ability of SCOT to analyse both historical and modern technological innovations.

The SCOT framework will serve as a theoretical foundation for this study on the social construction of SMRs, relevant social group, their interest, and power dynamics that influence acceptance and/or rejection in the Eemshaven area. Through the lens of the SCOT framework, it will be analysed how these social groups negotiate the role of SMRs and this affects the acceptance and social construct of SMRs. The process through which various social groups discuss, debate, and make decisions about the role of SMRs as potential replacement for coal-fired power plant in the Eemshaven area is referred to in this context as "negotiate". As these social groups work through the challenges and complexities of adopting SMRs to the energy mix, perspectives, interests, and interpretations will be negotiated (Bijker, Hughes, & Pinch, 2012).

The SCOT framework will guide this study by systematically applying the following concepts (Bijker, Hughes, & Pinch, 2012).

- Social groups: identify and categorize the relevant social groups that are involved in the negotiation, such as energy consumers, policymakers, industry representatives, and environmental activists.
- Interest and power dynamics: Examine each social group's values, interests, and power dynamics in relation to the adoption of SMRs. This will be done through interviews and document analysis.
- Negotiation processes: Analyse the discourses, strategies, and tactics that social groups use when negotiating. Qualitative interviews and discourse analysis of relevant documents and media sources can be used to examine this.
- Technical outcomes: Evaluate how much the negotiation influences whether or not SMRs are socially accepted as replacements for the coal-fired power plant. This will be examined by the data of the policy decisions, public opinion, and energy transition progress.

By applying these concepts, the study will provide a thorough analysis of the social construction of SMRs, shedding light on the complex interplay of social dynamics that drives technological acceptance in the Eemshaven area.

3.2 Imaginary and evidence based framing

In this study, "negotiation" refers to the conceptual process in which different groups engage in discussions, debates, and decision-making about the potential role of SMRs. However, the interactions between the social groups will not occur directly, but through separate interviews that reveal parallel narrative regarding the potential role of SMRs. The article by Wolf and Van Dooren (Wolf & Van Dooren, 2017) effectively illustrates the complex interplay between imagination and evidence. By substantiating the SCOT theory with the imaginative and evidence-based framing of the parallel narratives, this research aims to depict the negotiation process between theses social groups.

4. Methodology

4.1 Case selection

In the north of the Netherlands, in the province of Groningen, holds an area called the Eemshaven. The Eemshaven area can be considered a diverse and influential case because it reveals a unique and multifaceted approach within the context of industrial areas with regard to the energy transition and new energy technologies. Unlike other industrial regions in the Netherlands, the Eemshaven has made substantial investments in renewable energy sources and positions itself as the energy hub of the Netherlands (Ferraioli, 2023).

However, if compared to other highly proactive industrial regions such as Esbjerg, the Eemshaven can also be viewed as a typical example of a forward-thinking energy hub. This variety of traits and strategies makes it possible to examine industrial regions' ability to adapt and prosper during energy transitions in greater detail and offers insightful information that may be applied to other areas facing comparable challenges and goals (IRENA, 2023).

Furthermore, the term "influential case" is a specific type of case where the general relationships within a system or population are analysed, and underlying assumptions are challenged (Seawright & Gerring, 2008). The choice of the Eemshaven area within the framework of the SCOT perspective as a case study stems from the necessity to study the negotiations of social groups regarding the role of SMRs as a potential replacement for the coal-fired power plant that must shut down operations by 2030. From a more abstract level, the Eemshaven area is of significance as the implementation of SMRs in this context has the potential to affect the local community, job prospects, economic development, and the environment. Researching the negotiation of different social groups in the Eemshaven area can present opportunities to identify and address factors such as interests, values, and perspectives that influence the acceptance and adoption of SMRs.

At last, SMRs are a nuclear power industry example of technological innovation. Potential advantages of these more compact and modular reactors include lower expenses, higher safety, and more deployment flexibility. However, social factors, such as the interests, values, and concerns of **diverse** social groups, influence the decision-making process, acceptance, and adoption of new technologies. An analysis of how local groups in the Eemshaven area negotiate the role of SMRs can shed light on how this technological innovation is socially constructed and what influences its adoption or rejection.

4.2 Overview of the Eemshaven Area

The Eemshaven is a seaport that currently produces around a third of all energy produced in the Netherlands with a capacity of 8000 MW. Besides housing a solar farm and the largest onshore wind farm in the Netherlands, the area is also connected to the national grid and offshore wind farms of the Netherlands, Norway, and Germany, making it a strategically important location for the production and distribution of energy (Mennega, 2023). Along with providing energy to a number of industries, such as the seaport itself, data centres, and greenhouses that require a significant amount of heat and electricity, Eemshaven has the ambition to build Europe's largest green hydrogen production site before 2030 (Gasunie, 2020).

The area currently relies on stable and reliable electricity generated by a coal-fired power plant with a capacity of 1344 MWe (GlobalData, 2024). However, in order for the Netherlands to meet the climate targets the country, together with the other developed countries that are members of the Organisation for Economic Co-operation and Development (OECD), is set to phase out coal by 2030 (European Commission, 2020). This has created an opportunity for SMRs to replace the coal-fired power plant and provide stable and reliable, low-carbon electricity and heat for the grid and local industries. SMRs would be an addition to renewable energy sources, which, especially wind energy, is abundant but variable.

4.3 Identification of Relevant Social Groups

Table 1 presents the social groups that were identified as relevant to this research. The table presents the organizations and their role with regards to the Eemshaven, the interviewed representatives, and the dates of when the interviews were conducted. The social groups each encompass a broad spectrum of interest, role in decision-making, and perceptions on the potential adoption of SMRs in the Eemshaven that will be further elaborated in the Findings and Analysis of the conducted interviews.

Table 1 Interviewed social groups

Organization	Representative	Date
Potential project developer of SMRs: ULC-energy	Director business development	15-05-2024
Port authority Eemshaven: Groningen Seaport	Business manager logistics & offshore wind	21-05-2024
Environmental organization: Greenpeace	Expert consultant nuclear energy and energy policy	22-05-2024
Academic institution: University of Twente	Academic expert	27-05-2024
Regional authority: Province of Groningen	Coordinator energy systems	30-05-2024
Local community: BBE (Bewoners Belangen Eerst)	Local community	05-06-2024
Governing municipality: Municipality Het Hogeland	Sustainability communications advisor	06-06-2024
Province of Limburg	Policy officer	06-06-2024
Energy company: Vattenfall	Energy transition manager	07-06-2024
Nuclear safety regulator: ANVS (Autoriteit Nucleaire Veiligheid Stralingsbescherming)	Specialist advisor nuclear licensing	10-06-2024

4.4 Data Collection

To address the sub-research questions, a qualitative case study will be carried out through methods such as interviews, and document analysis.

4.2.1 Document analysis

Relevant documents, such as policy documents, industry reports, and media coverage will be analysed to reach an understanding of the historical context, current context, future context, policy frameworks, and public discourses, strategies, and tactics employed by social groups during negotiation. Hereby, patterns or trends in the negotiation will be identified along with the impact on the social acceptance of SMRs.

4.2.2 Interviews

Interviews will be conducted with representatives from different social groups involved in the negotiation to explore different perspectives, interests, and power dynamics regarding the adoption of SMRs. To conduct interviews with representatives of relevant social groups for the study on the adoption of SMRs in the Eemshaven area, it is necessary to analyse the potential representatives from a methodological perspective (Knott, Rao, Summers, & Teeger, 2022). In the end, these representatives should bring a diverse set of perspectives and insights into the negotiation surrounding the role of SMRs. Note that the interviews will not deliberately be executed in the chronological order of the following description.

For the local community representative, it should be an individual who lives in the area surrounding the Eemshaven that would be directly affected by the potential adoption of SMRs. This individual can share the perspective on the social, economic, and environmental impact of SMRs on the community along with insights into the concerns, expectations, and preferences of the residents. Next, a representative from an environmental organisation will be interviewed who has any relationships to the Eemshaven area or is concerned with energy and environmental issues in general. This individual can share the perspective on the potential environmental risk, sustainability considerations, and alternative energy solutions along with insights into the environmental implications of adopting SMRs (European Environment Agency, 2018).

Followed by an interview with a representative from an energy company or organisation that is involved in the energy sector of Eemshaven. This individual can share the perspective on the energy market, energy transition, and the role of SMRs in the decarbonization of the energy sector along with insights into the economic feasibility, technological factors, and potential benefits of SMRs. Ensuing with interviewing a governmental official from a local, regional, or national governmental body that is responsible for or influences energy policy and decision-making. A governmental official can share the perspective on the decision-making process, policy goals, and potential challenges in the implementation of SMRs along with insight into the regulatory framework, policy considerations, and political dynamics surrounding the adoption of SMRs. Lastly, an academic expert will be interviewed who may be a researcher, scholar, or expert in general with knowledge and/or experience in energy, nuclear technology, social sciences, or any other related fields of study (European Environment Agency, 2018).

4.5 Data Analysis

The collected data will be analysed using a qualitative analysis technique. This will be done by conducting a thematic analysis of interview transcripts and document analysis to identify key themes, discourses, and patterns in the negotiation of SMRs in the Eemshaven area. The following six-step approach will conduct the thematic analysis to avoid confirmation bias when analysing the data (Caulfield, 2023).

1. Familiarize: Firstly, a full overview of the data collected will be obtained, such as texts, preliminary notes, transcribed audio, and other relevant data.
2. Code: Secondly, the data will be coded by highlighting certain words, terms, concepts, phrases, and/or sentences, assigning brief labels to explain the context, and providing colour linked to the category. This will allow for the creation of different groups for the data to be identified.
3. Generate themes: Thirdly, patterns will be identified among the created codes to generate themes. The themes may very likely be less detailed than the created codes, and certain codes might appear too vague or not relevant enough to be considered in the themes. These codes may be ignored in the research or become its theme.
4. Review themes: Fourthly, the themes and the data represented are reviewed to ensure relevance to the study. Alterations in codes or themes can be applied at this point, nevertheless, without altering any of the data.
5. Name and define themes: Fifthly, through the final list of themes, the themes will be defined and named. This process involves determining what is precisely meant by each theme and how this in turn will help guide and interpret the data.
6. Writing out the analysis: At last, for the sixth step, the thematic analysis will be written in relation to the research question, aim of the study, approach, and methodology. The results of the thematic analysis will be presented and eventually discussed, describing the frequency of occurrence of particular themes, what this implies, the key takeaways, and how it answers the research question.

4.6 Positionality and Ethical Considerations

Throughout this study, neutral and transparent research will be conducted to maintain integrity and credibility of the research study. This entails being truthful about methods, data and results; refraining from data manipulation or biased extraction of data; guaranteeing precision and quality control; allowing for public research inspection; and being accountable to the scientific community (Moravcsik, 2020). Furthermore, ethical considerations will be considered at every stage of the research, including obtaining informed consent from participants, ensuring confidentiality and adhering to ethical guidelines from the University of Twente for research involving human subjects. Before the interview, participants receive a written (along with the interview questions) and oral explanation of the purpose of my research. The explanation also presents the participants with what is expected from them, and how the data will be used. Participants will be asked for permission to record the interview and reassured that the participants and their organization will stay anonymous throughout the research (paper). The participants are assured that they are free to answer what they want to answer and can stop the interview at any given moment. Lastly, the participants are asked if they want to review the part(s) in which they are referenced in my final paper. If so, the part(s) in which they are referenced will be shared with them after the draft version of the final report. The data of the interviews and recordings will be collected (if permission has been granted) and stored securely on Google Drive/One Drive (UT account), following the GDPR-compliant services, which are only accessible to the researcher of this study.

5. Findings and Analysis

5.1 Thematic Patterns

The interviews conducted with different social groups in the Eemshaven area revealed parallel narratives on the potential role of SMRs presented in APPENDIX I, from which thematic patterns were identified. These thematic patterns are crucial for understanding the imaginary negotiation process surrounding the potential adoption of SMRs. The thematic patterns highlight the diversity of perspectives and the complexity of integrating new energy technologies into an established industrial and social context.

Decarbonization and Energy Transition: A Shared Goal

The goal of decarbonizing the energy sector and supporting the larger energy transition in the Netherlands is a recurring theme in the majority of the interviews. Individuals from various industries, such as energy providers, project developers, and local and regional government agencies, demonstrated a strong commitment to cutting carbon emissions and accomplishing sustainability objectives. This theme emphasizes how crucial SMRs could be as a possible means of accomplishing these objectives, especially in view of the coal phase-out that is scheduled to occur by 2030.

Safety and Regulatory Concerns: A Universal Priority

In addition, safety is also a prevailing theme that emerged from the discussions, most notably on nuclear energy. According to the social groups representing such environmental organizations, local communities, and regulatory bodies, stringent safety measures and vigorous regulatory frameworks are of paramount importance, and public concerns over possible nuclear accidents and radioactive waste management have to be addressed. This pattern indicates that if SMRs do stand as one of the viable alternatives against conventional sources of energy, their adoption is conditional on very robust safety assurances and regulatory compliance.

Economic Viability and Technical Feasibility: Key Considerations

Another recurring topic, especially in the interviews with business representatives and local government officials, was the economic viability of SMRs. The expenses associated with implementation, possible financial gains, and the technological readiness of SMRs were emphasize as crucial elements impacting the decision-making process. This theme reveals a practical approach among social groups, who carefully consider the financial and technical aspects of SMRs in relation to their potential to improve the energy mix in the region.

Social Acceptance and Public Perception: A Crucial Determinant

Moreover, a critical theme that emerged was social acceptance; the social groups responded by indicating that a non-accepting public perception is one major obstacle to successful adoption of the SMRs. Local community representatives, environmental organizations, and policymakers emphasized that the keys towards social acceptance are through open communication, public engagement, and allaying safety concerns. This pattern is indicative of the belief that unless there is social acceptance, the road to the deployment of SMRs will be significantly hard.

Political and Social Dynamics: Influencing Decision-Making

At last, an influential theme in the possible negotiation process was also found to be related to political and social dynamics. The results of the interview showed that opinions and decisions about SMRs are greatly influenced by the social history od the area, especially the legacy of gas extraction and the problems that go along with it, and the political climate, both locally and nationally. This intricate relationship between the adoption of new technologies and the social-political environmental in which they are evaluated is emphasized by this pattern.

5.2 Common and Diverging Patterns

Findings from the analysis of interviews with individuals and members of different social groups regarding the possible implementation of Small Modular Reactors (SMRs) in the Eemshaven region show both typical and unusual trends. Understanding the negotiation process around the integration of SMRs into the energy mix requires an understanding of the various perspectives, concerns, and interests that these patterns reflect. A detailed discussion of these patterns is provided below.

5.1.1 Common Patterns across social groups

Environmental Concerns and Safety Issues

The worry about the effects on the environment and safety came up almost every time an interview was conducted. A number of parties, including Greenpeace, the Province of Groningen, the local community (BBE), and the ANVS (nuclear safety regulator), brought attention to the serious safety and environmental risks related to nuclear energy, particularly SMRs. This mutual worry is a reflection of the general public's fear of nuclear technologies, which has been heightened by past events like Chernobyl and Fukushima. Because of the long-lasting psychological effects of these incidents, safety is the top priority in any conversation regarding nuclear energy.

Furthermore, in order to win over the public's trust, even parties who have a generally positive opinion of SMRs, like Vattenfall and ULC Energy, acknowledged the significance of thorough safety assessments and the necessity of open communication about these matters. Consistent emphasis is placed on safety and environmental considerations in all of the interviews, indicating that prioritizing these factors is necessary for any potential adoption of SMRs in order to gain broader acceptance.

Economic Viability and Investment Challenges

Another common pattern is that SMR economic feasibility and investment challenges are a prime focus. In this respect, both proponents and skeptics of SMRs recognize that high upfront costs, long development timeframes, and uncertain return on investment are among the major barriers. For instance, whereas ULC Energy and Vattenfall have emphasized the potential positive economic impacts of SMRs on job creation and growth in the local economy, these have been balanced against a need for significant financing and a business case that is strong enough to entice investors.

In a similar vein, the Province of Limburg and the University of Twente academic expert emphasized the financial difficulties, citing among them the danger of funding a technology that might not prove profitable until 2035 or later. This common worry implies that in order to successfully incorporate SMRs into the energy mix, policies that support them, as well as possibly public-private partnerships to reduce the associated economic risks, must be in place.

Social Acceptance and Public Perceptions

In every interview, social acceptance surfaced as a crucial component, emphasizing the role that public opinion plays in the decision-making process. In particular, the interviews with Greenpeace, the Municipality of Het Hogeland and the local community (BBE) highlighted the difficulties in winning over the public to nuclear energy projects. In this region, social acceptance is especially important because of the historical background of gas extraction and the subsequent earthquakes that have heightened local sensitivities in Groningen.

Even more technically or economically oriented social groups, like ULC Energy and Vattenfall, acknowledged that the deployment of SMRs would encounter major challenges in the absence of widespread social acceptance. There was a common understanding that technical and economic viability alone would not suffice without public buy-in, as evidenced by the recurring themes of the importance of transparent communication, education and public engagement.

Regulatory and Policy Framework

Another theme that emerged from all of the interviews was the need for a supportive and unambiguous regulatory and policy framework. As the nuclear safety authority, the ANVS underlined the significance of stringent safety guidelines and the difficulties presented by the absence of SMR-specific regulations. In a similar vein, parties with a stake in the matter, such as Vattenfall and the Province of Groningen, emphasized the necessity of clear and consistent national and regional policies in order to encourage the adoption of SMRs.

These interviews have revealed a common consensus that, to get through the bureaucratic approval processes, attract investments, and build up public trust, regulatory clarity and policy support are fundamental. This pattern underlines how governmental and regulatory organizations shape or set the viability and schedule of small nuclear power projects.

5.1.1 Divergent Patterns and Unique Perspectives

Divergent views on the Role of SMRs in the Energy Mix

Although almost all of the participants agreed that SMRs could play their part in decarbonization, there was a difference of opinion about the contribution that such reactors could make to the overall mix. Greenpeace opposed nuclear energy and thus SMRs, since it wanted investment only in renewable sources like wind and solar. In contrast, social groups, including ULC Energy, Vattenfall, and the Province of Limburg, felt that SMRs were either requisite or complementary to renewables in this process, particularly for stable and baseload power generation.

This discrepancy is indicative of larger ideological disagreements about the best course for decarbonization. While some social groups see SMRs as a practical way to meet climate goals and ensure energy security, others see them as a diversion from more sustainable, if intermittent, renewable energy sources.

Varying Levels of Awareness and Expertise

The interviews indicated differences in knowledge and know-how about SMRs among the social groups. For example, initially, the business manager from Groningen Seaports showed limited knowledge regarding the SMR technology, although he became interested after having an introduction to it. In contrast, more advanced knowledge concerning technical and safety problems was delivered by the ANVS and the academic expert at the University of Twente.

These differences in awareness and expertise indicate that the negotiation process is very uneven: some social groups require more education and information to engage in meaningful discussions. This disparity underlines, too, that for the proper contribution of all relevant social groups in decision-making, capacity-building and knowledge-sharing initiatives are very important.

Regional Context and Local Concerns

The regional context of Groningen created a special concern that colored the views of local social groups, in particular the historical impact of gas extraction and related earthquakes. On their part, local community and the Municipality of Het Hogeland have been very critical to any energy project that would introduce such risks, including an SMR. This local sensitivity stands in contrast to the view from a national level, or another region, like the Province of Limburg, where a more pro-active perspective can be taken in exploring SMRs as part of their energy strategy.

This regional specificity could also mean that, although perhaps more acceptable in other parts of the country, their adoption in Groningen will require a unique historical and social contextualization of the area. In other words, regional concern-specific tailoring of the communication and engagement strategies could be important for gaining local support.

Strategic Importance and Future Planning

The stakeholders attached different strategic significance to SMRs within their future planning. For example, the Province of Limburg and Vattenfall considered SMRs in a long-term strategy for diversification of the energy mix while ensuring the security of energy supply, whereas Greenpeace and the local community were more focused on faster, less-risky options like renewables. However, the ANVS showed cautious incremental planning, indicating SMRs still unproven in the Dutch context.

This difference in strategic outlook thus reflects the different priorities and risk appetites of the social groups. Some are ready to invest in, and plan for, SMRs as a future source of energy, while others rather focus on technologies that have proven themselves.

5.3 Imaginary Negotiations of SMRs as a Potential Replacement for the Coal Fired Power Plant

This section synthesizes parallel narratives, the thematic patterns and the commonalities and divergent and unique perspectives, moving beyond thematic listing to an imaginary negotiation. The findings from the interviews with representatives from various social groups in the Eemshaven area reveal a complex and multifaceted negotiation process regarding the potential adoption of SMRs as a replacement for the coal-fired power plant. Through imaginative and evidence-based framing, the interactions, agreements and divergences among social groups are explored, highlighting patterns of social constructions, potential coalitions and the dynamics of power and consensus-building.

5.3.1 Patterns of Social Construction

Visions for the Future of Energy

There is a shared vision across several parallel narratives regarding a sustainable and decarbonized energy future for the Eemshaven. ULC-Energy, Groningen Seaports and the Province of Groningen and Limburg acknowledge the potential of SMRs to provide reliable, 24/7 energy, that aligns with the broader context of the energy transition and the goal to cut carbon emissions. However, there are differences in emphasis. While ULC-Energy emphasizes more on the operational and financial benefits, including lower construction costs and modular deployment of SMRs, Groningen Seaports emphasizes more on the potential integration of SMRs with existing renewable projects, like wind and solar, and the logistical and infrastructural roles. At last, by leveraging the benefits of SMRs, the Province of Groningen could address energy poverty through the alignment of regional and national energy policies, and the Province of Limburg can commit to sustainability and climate neutrality through the alignment of its policy goals with both national and international environmental objectives.

Economic and Operational Concerns

Economic feasibility and operational efficiency of SMRs are dominant topics of discussion. Where ULC-Energy emphasizes lower investment risks and operational costs of SMRs compared to traditional nuclear plants, Vattenfall and the Province of Limburg emphasize the potential of cost-effective energy production and reduced grid congestion. Contrastingly, Greenpeace and the academic expert raised concerns about SMRs with regard to the high initial costs, long-term maintenance, and the unresolved issue of nuclear waste. These concerns touch upon the broader context of the possible economic feasibility and sustainability of SMRs, especially from Greenpeace which is sceptical about nuclear energy's role in the energy transition.

Safety and Environmental Impact

The safety of SMRs is dominant across all parallel narratives. The ANVS stresses non-negotiable safety criteria, rigorous risk assessments and the importance of meeting the same standards for SMRs as for any other nuclear reactor. Greenpeace and local residents express significant concerns about possible accidents, nuclear waste, and environmental degradation. The academic expert, and the Province of Groningen and Limburg, acknowledge these concerns and therefore emphasize on the need for robust safety measures and public reassurance. These shared focus points on safety reflect a critical area where the consensus between social groups is essential for informed decision-making regarding the potential adoption of SMRs.

Social Acceptance and Public Perception

The social acceptance of SMRs is another important factor affecting the possible adoption of the technology in the Eemshaven. Different levels of support and opposition among the social groups are revealed by the parallel narratives. While ULC-Energy and Vattenfall stress the value of transparent communication and public education about SMRs in a larger context to allay concerns and win support for the technology, Greenpeace and locals continue to be largely against nuclear energy use, citing historical accidents with local gas extraction and international and nuclear catastrophes along with cultural preservation. The Groningen Seaports and the Province of Groningen recognize the importance of inclusive decision-making procedures that involve local communities and fully address their concerns. At last, as a pioneer region, the Province of Limburg recommends public debates and knowledge platforms to address public concerns. These varied viewpoints emphasize the difficulties in gaining widespread social acceptance SMRs and stress the significance of social groups actively participating in decision-making processes surrounding the technology.

5.3.2 Imaginary Coalitions and Power Dynamics

Potential Coalitions

Imaginary coalitions between social groups suggest possible alignments based on shared interests and goals, such as ULC-Energy, Vattenfall, Groningen Seaports and the Province Limburg which could form a coalition advocating for SMRs, emphasizing economic benefits, operational efficiency and strategic integration with existing renewable projects. The Province of Limburg would play an important role in this coalition, as it pioneered the first political and societal debate on SMR in the Netherlands. The Province of Groningen might also consider joining this coalition, given its policy goals and focus on addressing energy poverty, however, due to the strong opposition to nuclear energy within the province, this is unlikely to occur. Leading to, Greenpeace, local residents, and to some extent the academic expert and the Province of Groningen that could form an opposing coalition that prioritizes safety, environmental preservation and scepticism about nuclear energy's role in the energy transition.

Power Dynamics

The capacity of these coalitions to shape public opinion, policy decisions and regulatory frameworks determines their strength. With the backing of businesses and (non-local) governmental entities, the pro-SMR alliance possesses considerable financial and infrastructure power. The ability of the pro-SMR coalition to finance and develop energy projects contributes to their influence. In contrast, the ability of the opposing coalition to mobilize public support and use social and environmental arguments to impede the adoption of SMRs is what gives the anti-SMR coalition strength. As an independent regulator, the ANVS would play a critical role in mediating these dynamics to ensure that safety and regulatory standards are upheld and potentially balance the power dynamics between these coalitions.

5.3.3 Imaginary Negotiation Process

Setting the Scene

In an imaginary negotiation setting, representatives from all social groups are brought together to discuss the potential adoption of SMRs in the Eemshaven. The room includes industry leaders from ULC-Energy and Vattenfall, logistical and infrastructural experts from Groningen Seaports, policymakers from the municipality Het Hogeland and Province of Groningen and Limburg, environmental advocates from Greenpeace, an academic expert from the University of Twente and local community representatives.

Points of Agreement and Divergence

The negotiation begins with a shared understanding of how urgent it is for the Eemshaven to switch to cleaner energy sources. The necessity of maintaining energy security along with the overambitious goal of decarbonizing the Eemshaven by shutting down the coal-fired power plant before 2030 are shared by all social groups. However, divergences regarding the feasibility, security and societal acceptance of SMRs, quickly emerge.

Economic Feasibility and Operational Efficiency

Data on the operational advantages and cost-effectiveness of SMRs are presented by ULC-Energy and Vattenfall, contending that SMRs are a more financially feasible than alternative energy solutions due to their modular design and decreased on-site labour requirements. This point of view is endorsed by the Provinces of Groningen and Limburg, which point out the possible advantages for the environment and local economies, however, the Province of Groningen is unable to completely merge because of the strong opposition to nuclear energy within the province. Concerns about high upfront costs and long-term sustainability are raised by Greenpeace and locals, in which Greenpeace provides instances of delayed and overbudget projects in other countries.

Safety and Environmental Concerns

The ANVS assures the social groups that a SMR could only be adopted in the Eemshaven if it would adhere to the highest safety standards according to the ANVS's strict safety regulations and risk assessments. The safety features of SMRs are further emphasized by ULC-Energy and Vattenfall. However, the local residents are still concerned about the risks of accidents, and the academic expert raises questions on the long-term handling of nuclear waste, therefore, demanding more inclusive and transparent safety assessments and the assurance of strong emergency plans. In addition, due to worries about the environment and social cohesion, Greenpeace and some local residents continue to hold a largely negative attitude toward nuclear energy in Eemshaven.

Social Acceptance and Public Engagement

At this point, Groningen Seaports and the Provinces of Groningen and Limburg stress the importance of public engagement and transparent communication and hereby propose educational campaigns and public consultations to address unwarranted fears and misinformation. Greenpeace and local residents insist on a more active role in decision-making processes, advocating for participatory governance models that give communities a direct voice in approving, planning and implementing energy projects. The Province of Limburg shares its experience, challenges and success of their societal debate on SMRs, in building public trust and acceptance.

Consensus Building

The process of negotiating reveals the potential areas of agreement, such as the recognition of economic opportunities and the common objective of switching to cleaner energy sources, however, there are still a lot of disagreements on the subject of SMRs' safety, environmental impact and economic feasibility. In order to reach an agreement, the parties could look into hybrid solutions that combine SMRs with renewable energy initiatives, handle nuclear waste management and safety issues with strict rules and open communication, and guarantee that new energy initiatives benefit the local community in the Eemshaven area.

5.3.4 Imaginary Coalitions and Consensus

Imaginary coalitions could arise around common interests and objectives. With regulatory guarantees from the ANVS, ULC-Energy, Vattenfall and Groningen Seaports could spearhead a coalition promoting the inclusion of SMRs in the energy mix. If the Municipality Het Hogeland and the Province of Groningen's concerns about social acceptance (especially from the local residents) and local economic benefits are assured, they might join this coalition.

Contrastingly, Greenpeace and local residents would form a coalition opposing SMRs and advocating for investment in renewable energy sources instead, emphasizing on the safety and environmental risks associated with nuclear projects. The opposing coalition would push for transparent public engagement and the inclusion of local communities in decision-making processes.

5.3.5 Imaginary Consensus

In an imaginary consensus scenario, the social groups might settle on a phased strategy that combines SMRs with renewable energy projects, investing in long-term renewable solutions while meeting the immediate need for reliable, carbon-free energy. The consensus could be reached through strict safety rules, effective plans for nuclear waste management, transparent public communication and assurance of local communities benefiting economically from new energy projects.

By carefully balancing economic, operational, safety, environmental and social factors, different social groups can strive for an energy transition that meets climate goals, ensures public safety and takes into account the social acceptance of SMRs. This imagined negotiation process offers a way to understand how these varied groups might work together and find common ground to create a sustainable energy future for the Eemshaven area.

6. Discussion

This chapter discusses the findings from the research on how social groups negotiate the potential adoption of SMRs as a potential replacement for the coal-fired power plant in the Eemshaven. By integrating empirical findings with existing literature, along with the SCOT framework substantiated with imaginative and evidence-based framing, this section examines the implications, theoretical contributions and the broader context of the study. The discussion is structured into subsections, including implications of the findings, integration with existing literature, conceptual analysis within SCOT and limitations of the study.

6.1 Implications of the Findings

6.1.1 Theoretical and Practical Contributions

This research enhances the theoretical and practical understanding of the energy transition in the Eemshaven, and to some extent the Netherlands in general, by emphasizing the role of SMRs within the broader landscape of modern energy technologies.

The integration of the SCOT framework allows for an analysis of how different social groups negotiate the potential adoption of new technologies, emphasizing on the interpretive flexibility and social dynamics that are involved in this matter. The analysis is facilitated by identifying the relevant social groups, including industry representatives, government officials, environmental organizations, local communities and academic experts. In addition, SCOT reveals interpretative flexibility of technology as industry representatives see SMRs as economically beneficial and a reliable energy source, while environmental groups might focus on the possible risks and environmental impacts.

SCOT focuses on how social groups negotiate the meaning and role of technology, including the discourses, strategies and tactics used to promote their interests and perspectives. This helps to identify factors that facilitate or hinder consensus-building and social acceptance of SMRs. The findings indicate that the acceptance and potential adoption of SMRs depend not only on the technical and economic feasibility but also on the social construct and power dynamics among different social groups.

The imaginative negotiation process offered a valuable methodological approach, to explore the complex interactions between imaginative and evidence-based perspectives, on the controversial and sentimental subject of potentially adopting SMRs in the Eemshaven. This approach can also be applied to other contexts to provide insights into the broader socio-political and economic implications of adopting sensitively discussed, new technologies. The imaginative negotiation

Scenario planning techniques allow imaginary negotiation processes to build detailed plausible scenarios that will explore future possibilities and its consequences. Using such an approach reveals the arguments, counter-argument and identification of potential areas of concurrence or conflict between social groups. In doing so, the role-play involving representatives of various social groups engages the discussions and debates about SMRs and brings out explicit dynamics of interaction, power relations, persuasive tactics and coalition-building efforts. Hereby, a multi-dimensional exploration of negotiation dynamics is developed by synthesizing empirical data from interviews and document analysis with theoretical insights that SCOT provides. Additionally, it has exploratory and predictive value, identifying emerging trends and critical junctures in the negotiation landscape by imagining how groups might respond to evolving circumstances and new information.

6.2 Integration with Existing Literature

6.2.1 Comparison with Previous studies

The findings of this study align with perspectives presented in existing literature of SMRs. Previous studies have emphasized the flexibility and scalability of SMRs in meeting changing energy demands along with enhanced safety features compared to conventional nuclear reactors (Liou, 2023). This research confirms these benefits, and emphasizes further on the potential economic and operational benefits for the Eemshaven and the surrounding region when adopting SMRs.

However, this study also identified significant challenges with regard to public perception, safety concerns and regulatory frameworks that align with the findings of existing literature (Krall, Macfarlane, & Ewing, 2022). Along with socio-cultural opposition and scepticism toward the possible adoption of SMR in the Eemshaven, public resistance to new energy projects in the area reflects broader trends in public attitudes toward nuclear energy and the overall energy transition, emphasizing the need for open communication and public engagement strategies.

6.2.2 Areas of Agreement or Contradiction

While there is broad agreement on the potential economic and operational benefits of SMRs, this study reveals contradictions in the perspectives of different social groups regarding safety and environmental impacts. Especially environmental organizations and local communities, express significant concerns about the risks associated with nuclear energy, including accidents and radioactive waste management. These concerns are less pronounced among industry representatives and some policymakers, who emphasize the advanced safety features of SMRs and their potential role in achieving climate goals.

These contradictions imply that it will be necessary to address the diverse interests and values of various social groups in order to reach a consensus on the potential adoption of SMRs in the Eemshaven. Bridging these gaps requires effective negotiation processes that consider different perspectives and promote mutual understanding.

6.2.3 Contribution to Knowledge

This research advances the understanding of the social dynamics underlying the (potential) adoption of new energy technologies, within the perspective of the SCOT framework. By examining the negotiation processes among various social groups, with regards to new energy solutions and the use of SMRs in the Eemshaven, this study provides insights into the factors that influence the acceptance and potentially the adoption of the technology. This adds on to the broader discourse on energy transitions by emphasizing the importance of inclusive and participatory decision-making processes. Especially surrounding negotiations with high sentiment, such as nuclear energy.

6.3 Conceptual Analysis Within SCOT

Following the SCOT framework, interactions and negotiations between social groups shape the social construction of technological development and adoption. This study demonstrates the interpretive flexibility of SMRs by showing how various social groups in the Eemshaven area perceive and negotiate the potential role of the technology. The imaginative negotiation process outlined in this study, provided a conceptual lens to understand how social groups navigate the complexities of adopting new technologies, such as potentially, SMRs in the Eemshaven. By incorporating, both evidence-based and imaginative perspectives, this approach captured the dynamic and contested nature of policy development and technological integration.

Using SCOT terminology, this study depicts the negotiation processes and interactions among social groups as a dynamic and repetitive process. The interpretive flexibility of SMRs is evident in the divergent perspectives and interests of different social groups. The findings demonstrate how during the parallel narratives and imaginative negotiation, social groups construct and reconstruct their understanding of SMRs based on factors such as safety concerns, economic feasibility and environmental impacts.

In addition, the study highlights the role of power dynamics in shaping the negotiation process, as certain social groups reveal their ability to influence public opinion, policy decisions and regulatory frameworks. This highlights the importance of considering power dynamics and relations in the analysis of (potential) technological adoption. This reveals alignment between the SCOT perspective and the emphasis on the socially contingent nature of technological development.

6.4 Limitations of the Study

This study has a number of methodological limitations, that should be acknowledged. While providing rich insights into the perspectives and negotiations of social groups, the qualitative nature of the research may restrict the generalizability of the findings. Furthermore, the case study approach mainly focuses on the Eemshaven area. This may not fully capture the range of factors that influence the adoption of SMRs in other contexts. However, the most significant limitation of this research is that, due to the current technical readiness and distant realization horizon of SMRs in the Netherlands (projected at the earliest for 2035), the parallel narratives regarding the potential adoption of SMRs in Eemshaven to replace the coal-fired power plant largely deviated since still a substantial amount of information is needed to accurately negotiate the potential role of SMRs in Eemshaven or the Netherlands as a whole.

The findings of this research might contain biases of the representatives that were interviewed and the way their responses were interpreted. Interviewees might not accurately reflect the opinions of the general public and, although an attempt was made to involve a wide variety of social groups, there is a possibility that some opinions of social groups were not sufficiently represented. Additionally, the exclusive reliance on document analysis and interviews may not adequately capture the informal and emergent aspects of the negotiation process. Even tough, these limitations may affect the interpretation of the finding, the insights gained from this study, offers a valuable foundation for further research and can inform policy and practice in the energy sector.

7. Conclusion

This research explores how social groups negotiate the potential adoption of SMRs as a potential replacement for the coal-fired power plant in the Eemshaven within the framework of the Social Construction of Technology. The research question guiding this study is: "How do social groups negotiate the role of Small Modular Reactors as a potential replacement for the coal-fired power plant in the Eemshaven area, Groningen, the Netherlands, by 2030?". To address this, the study concentrates on; identifying relevant social groups, their perspectives and interests, the discourses and strategies they employ and the impact of their negotiation on the social acceptance of SMRs.

The findings reveal that the negotiation process involves a deep, abstract interplay of social dynamics, power relations and interpretive flexibility. The negotiation process is a complex and multifaceted negotiation process involving a diverse set of social groups, including industry representatives, government officials, environmental organizations, local communities and academic experts. The key themes identified in the negotiation process include economic feasibility, operational efficiency, safety and environmental concerns, social acceptance and public engagement.

Industry representatives, such as ULC-Energy, Vattenfall, and a government official of the Province of Limburg mainly emphasize the economic and operational benefits of SMRs, including lower investment costs compared to conventional nuclear reactors, modular deployment, reduced grid congestion and smaller physical footprint compared to alternative energy solutions. These groups present the benefits of SMRs as a financially feasible option for potentially replacing the coal-fired power plant in Eemshaven. However, these perspectives must be weighed against concerns about high initial costs and the long-term sustainability of the technology, with emphasis on the need for comprehensive cost-benefit analyses.

Safety is a dominant point of discussion with serious concerns about possible accidents, nuclear waste management and environmental impact. The ANVS underscores stringent safety regulations and thorough risk assessments to guarantee nuclear safety in the potential adoption of SMRs. Local communities are generally unaware of ANVS's existence and its role, and along with Greenpeace, they remain sceptical about these safety concerns and the role of nuclear energy in the energy transition. This tension thus underscores the interpretive flexibility of SMRs, where safety is a negotiable construct influenced by historical, cultural and contextual factors.

The degree of social acceptance of SMRs varies between the social groups. Industry representatives and certain policymakers advocate for transparent communication and public education to alleviate concerns and gain public support for SMRs. Conversely, the local community and environmental organizations stress the importance of inclusive decision-making processes and cultural preservation. These dynamics underline the importance of participatory governance models in negotiating the social acceptance for new technologies.

At last, the negotiation process among social groups is significantly influenced by political and regulatory dynamics at the local and national levels, as government officials and policymakers significantly shape the regulatory framework balancing the technical, economic and social dimensions of SMR adoption. Their decisions are informed by the power dynamics among social groups, reflecting the totality of the broader political and economic landscape.

Overall, the negotiation of SMRs' potential adoption in the Eemshaven is characterized as a complex and multifaceted interplay of economic, operational, safety, environmental and social context. The findings indicate that the acceptance and potential adoption of SMRs depend not only on the technical and economic feasibility but also on the social construct and power dynamics among different social groups. This abstraction provides a richer conceptual understanding of the negotiation process, moving beyond specific empirical observations to encompass the broader socio-technical landscape.

7.1 Relevance of Findings

7.2.1 Scientific Relevance

This research contributes to the theoretical insights into the energy transition by examining the potential role of SMRs within the broader context of modern energy technologies. By applying the SCOT framework, this study illustrates the interpretive flexibility of SMRs and the social dynamics associated with their possible adoption in the Eemshaven, and to a certain extent, in the Netherlands. Moreover, the process of imaginative negotiation provides a methodological approach to explore the complex interactions between imaginative and evidence-based perspectives with regard to the potential adoption of controversially perceived technologies. This approach could also be applied to gain insights into the broader sociopolitical and economic implications that may arise in the potential adoption of other new technologies.

7.2.2 Societal Relevance

The findings of this research have significant implications for policy and practice particularly in the energy sector of the Netherlands, and more specifically the Eemshaven. The urgent need to phase out coal by 2030 in the Netherlands, mandates the exploration of alternative energy solutions, such as SMRs. From the potential operational and economic benefits to the increased safety features, various factors make SMRs an attractive alternative for many policymakers. However, public concerns regarding safety and environmental impact must be addressed to successfully execute the potential adoption of an SMR into the energy mix.

Practically speaking, the implementation of SMRs could improve energy security and reliability in the Netherlands while resolving issues related to grid congestion, and intermittency issues with renewable energy sources, like solar and wind. Furthermore, national and Groningen's local energy policies should be more aligned, especially with regard to the tremendous socioeconomic effects of previous natural gas extractions. Taking more interests and concerns into account, by involving relevant social groups in these decision-making processes, will promote a more inclusive and socially acceptable energy transition.

Society can use this research to understand the diverse perspectives and interests of various social groups involved in the energy transition, especially at the Eemshaven. Policymakers can leverage these insights to design inclusive and participatory decision-making processes that address public concerns and promote mutual understanding of opposite coalitions, through transparent communication and public engagement strategies to build trust and support for new energy technologies.

7.2 Next Research Steps

Future research should focus on more empirical studies to obtain additional information on the technical readiness and economic feasibility of SMRs to be able to strategically plan a transition, towards a reliable and carbon-free energy mix before 2050. Longitudinal studies could track the progress of SMR projects in leading countries, such as the UK, Canada, Sweden, Finland and Japan to assess their applicability to the Dutch context. Additionally, surveys and public opinion polls could provide insights into the evolving perceptions of nuclear energy and SMRs among different social groups. Through this additional empirical data, the Dutch energy sector could be able to assess the feasibility of SMRs and potentially plan a successful adoption into the energy mix.

Future conceptual research should investigate the integration of the SCOT framework with other theoretical models. SCOT could be combined with the Technology Acceptance Model (TAM) or/and Actor-Network Theory (ANT) to gain a more holistic understanding of the social- and power dynamics that are involved in the adoption of new technologies, like SMRs. Furthermore, researchers should look into the potential synergies between SMRs and renewable energy sources in order to create hybrid energy solutions that address intermittency issues, improve grid stability and economically benefit local communities in the Netherland. This might bring together the two opposing nuclear energy coalitions in Eemshaven area.

As for future methodological advancements, incorporating simulation models and scenario planning techniques could refine the imaginative negotiation process. These tools could perhaps help visualize the potential outcomes of different negotiation strategies more clearly and assess their impact on the social acceptance and policy decisions more comprehensively. In addition, interdisciplinary research involving engineers, social scientists, policymakers, et cetera, could develop integrated assessment frameworks to evaluate the technical, economic, social and environmental dimensions of SMRs.

7.3 Final Thoughts

By negotiating the potential adoption of SMRs in the Eemshaven, the next step is made towards a sustainable and carbon-free energy future for the Netherlands. However, this negotiation process is complex that involves a wide variety of social groups, which emphasizes the need of inclusive and participatory decision-making processes. By addressing public concerns and fostering transparent communication, policymakers could be able to build trust and support a well-informed negotiation process for controversially and sentimentally charged, new energy technologies. The insights that are gained from this research provide a valuable foundation for further studies, and inform policy and practice in the energy sector, in the Netherlands, especially with regard to the Eemshaven. As society will continue to navigate through the energy transition-related challenges, embracing innovative energy technologies as SMRs, considerations of the social, economic and environmental factors are critical to be able to reach a sustainable and resilient energy future.

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APPENDIX I

Parallel narrative on the potential role of SMRs

This section presents the results of the interviews conducted with different individuals representing relevant social groups and how these social groups negotiate the role of SMRs in potentially replacing the coal-fired powerplant in the Eemshaven before 2030, within the context of the Social Construction Of Technology (SCOT).

Project Developer – ULC Energy

The initial interview conducted with the Director of Business Development at ULC-Energy provided valuable insights into the potential adoption of SMRs in the energy mix of the Eemshaven and the broader Netherlands. The analysis identified eight principal themes discussed during the interview the potential project developer of SMRs, from technical, economic, regulatory, and social perspectives.

Through the thematic analysis of the ULC-Energy interview, the potential and challenges of adopting SMRs in the Dutch energy transition were highlighted. The Vision for the Future of Energy theme emphasizes on the ability of SMRs to provide consistent, carbon free energy, and aligns with the decarbonization goals of the Netherlands, supporting the main research question about the role of SMRs in the national energy transition.

The Operational and Financial Benefits theme revealed that the modular construction design of SMRs results in reduced costs and labour needs compared to traditional or stick-built construction on-site. These benefits present them as a financially viable option, with a potential to replace the coal-fired power plant like the one in the Eemshaven. Furthermore, the Local and National Impact stresses the potential socio-economic benefits of the adoption of SMRs, such as job creation, economic-growth and reduced environmental impact, which could positively affect the Eemshaven region.

Competitiveness shows that SMRs offer more reliability and lower costs than other renewable sources, like wind and solar, which is crucial for investors. The Regulatory Framework theme reassures those existing Dutch regulations, supported by the ANVS, can adequately manage SMR realization, addressing bureaucratic concerns.

Additionally, in the Stakeholder Involvement and Acceptance theme the need for public and governmental engagement to achieve social acceptance is highlighted, with ULC-Energy playing an active role in public education to a certain extend. Challenges in Adoption highlights the political and public perception issues, noting unique challenges in Eemshaven due to unfamiliarity of SMRs, the consequences of previous gas drilling in the region, and fear of nuclear energy.

Lastly, ULC-Energy's proactive approach in the adoption process and its efforts to align with community values emphasize the importance of stakeholder cooperation for the successful implementation of SMRs.

Port authority – Groningen Seaport

The interview with the Business manager Logistics and Offshore Wind at Groningen Seaports provided essential insights into the potential adoption of SMRs in the energy mix of the Eemshaven as port authority. The analysis identified five primary themes that were discussed in the interview with the port facilitator, to the diverse and innovative energy landscape, to the challenges in the energy transition.

Role of Groningen Seaports as Facilitator

Groningen Seaports is an intermediary and facilitator at the Eemshaven, following what is demanded by the board and shareholders. Groningen Seaports provides the infrastructure and logistics for various energy projects. Due to its strategic location with wide ranging energy networks crossing national borders in the North Sea, they are key in the energy supply chain of the Netherlands. To add to this, Groningen Seaports supports a wide variety of new energy projects and technical innovations, showcasing their significance in the energy transition at the Eemshaven and alignment with the negotiation among stakeholders regarding new energy technologies, such as SMRs.

Current and Future Energy Sources

The Eemshaven currently houses a diverse mix of energy sources, including significant wind- and solar energy projects. The commitment of the Eemshaven towards a future of more sustainable energy is further demonstrated by innovations, such as the first Battolyser in the Netherlands that represents a significant step forward in the integration of renewable energy storage and plans for large-scale hydrogen production. This reveals that the energy landscape of the Eemshaven is dynamic and ever-changing, offering a foundation, in which the possible adoption of SMRs can be assessed. The energy industry in the region, continuously seeks to develop, innovate and diversify to essentially reach the larger goal at hand in decarbonizing the Eemshaven.

Challenges in the Energy Transition

The unpredictability of governmental policies makes investments and planning to guide the energy transition in the Eemshaven very difficult. These challenges highlight the difficulties, social groups face in the energy transition at the Eemshaven. The challenges influence decision-making and how the potential role of new technologies, like SMRs, are negotiated in the goal to decarbonize the Eemshaven. Reaching a better understanding of these challenges and their impact is necessary to assess the feasibility and acceptability of new technologies such as SMRs and the energy transition at the Eemshaven.

Potential and Perception of SMRs

The business manager of Groningen Seaports was unaware of the existence of SMRs. Nevertheless, immediate interest into the potential role of SMRs to decarbonize the Eemshaven was acknowledged after reaching notice of the technical performance of the technology. Awareness of SMRs could influence how the role of the technology is negotiated. Furthermore, permits and regulations were deemed critical for the potential adoption new technologies, such as SMRs. On top of that, effective communication and collaboration among stakeholders, especially between the government and key industrial stakeholders in the Eemshaven, such as RWE and Engie, are imperative for the successful energy transition and the potential adoption of SMRs.

Social Acceptance and Local Influence

At last, local and national political decisions, along with the regional sentiment regarding previous earth quacks in the region as consequences of the gas drilling in Groningen, significantly impacts current and future energy project at the Eemshaven. Groningen Seaports must navigate these influences, while following the guidelines of the board and shareholders. This underscores the importance of the local context in the adoption of new technologies, aligning with the Social Construction of Technology. Furthermore, clear communication and transparency of the risks and benefits of SMRs between all social groups could gain acceptance and enhance the chances smooth and informed decision-making, which is crucial a successful integration of new technologies, such as SMRs.

Environmental Advocate – Greenpeace

The interview with the Expert consultant nuclear energy and Energy policy at Greenpeace offered detailed insights into the organization's stance on various energy-related issues, as Environmental advocate. The analysis identified nine primary themes that were discussed in the interview and are elaborated in the following sections.

Climate Targets and Renewable Energy

Greenpeace has set clear and ambitious goals regarding the mitigation of climate change and the role of renewable energy sources in achieving these targets. Greenpeace's approach is to take action quickly and relatively cheap to cut carbon emissions. Greenpeace favours a combination of renewables in the energy mix such as wind, solar, hydro and energy carriers. Greenpeace further urges to not wait on the SMRs as a perfect solution (such as hypothetical “golden bullet”) to solve the climate crisis. This aligns with the broader context of SCOT as it explores how different (renewable) energy sources can contribute to the sustainability of the energy mix, by underlining the importance of a diversification strategy to reach particular climate goals.

Critique of Nuclear Energy

Greenpeace has strong criticism on the use of nuclear energy to decarbonize the Eemshaven or the Netherlands for that matter, mainly due to the catastrophic environmental impact in case of an accident, mining activities, the challenges of radioactive waste management, and the economic feasibility in contrast to alternative options. Greenpeace further argues that nuclear energy is more costly than renewable alternatives, that the costs of nuclear energy are commonly underestimated, and building a new nuclear power plant will take too long in order to meet the climate goals. This fits within the broader context that touches upon the relative cost-effectiveness of various energy sources. The consulting experts implies that nuclear energy investments are detrimental to swift climate actions and that policy makers should prioritize safer and more affordable renewable energy sources over nuclear energy projects when allocating funds.

Development of Renewable Energy

A dominant focus point of Greenpeace is the progress and challenges in developing renewable energy sources. Although there has been a lot of progress with regards to the development of renewables and energy carriers, there are still social, technical, and political obstacles to overcome, and a successfully integrating it into the current energy infrastructure will require a significant amount of work. It is therefore suggested that policy makers should prioritize to fully concentrate on resolving these issues in order to realize the full potential of renewable energy sources.

Social and Political Factors

Greenpeace claims that that social and political dynamics play a significant role in the energy transition in the Netherlands. This is a widely shared perspective that emphasises on the impact that these dynamics can have on the acceptance and implementation of energy projects. Political decisions and societal acceptance are highly influential towards a successful energy project, in which oppositions to a *project* can impact on the pace and course of the energy transition in the Eemshaven and the Netherlands in general. This demonstrates that technical solutions alone are not sufficient to implement an energy project. Suggesting that political and social support is as important as the technical solution itself and that the political and social environment should be considered for a holistically successful implementation.

Economic Considerations

Besides the concerns of catastrophic environmental consequences in case of an accident with nuclear energy in the Eemshaven or the Netherlands for that matter, Greenpeace points out the high costs of nuclear energy compared to alternative renewables and energy carriers as a replacement for the coal-fired powerplant. Economic arguments and cost-benefit analyses play a dominant role in the discussion about nuclear energy versus the alternatives. Renewable energy is not only cheaper but also reduces carbon emissions at a faster pace. This aligns with the broader context of the economic feasibility of different energy options, which suggest that it is financially wiser and more effective to combat climate change through investments and economic resources spend on renewables and energy carriers.

Proliferation and Safety

Greenpeace raises serious concerns about the proliferation risks of nuclear energy. According to the COP28, the global nuclear energy capacity is intended to triple by 2050. This could raise the possibility that knowledge will be exploited for military purposes, as has been observed in North Korea, Pakistan, and India. Though theoretically promising and believed to be of lower risks for military uses, these thorium reactors (generation 4 SMRs) are easier to obtain. However, present a distinct threat due to their ability to produce pure uranium-223, which can be utilized in the fabrication of nuclear bombs. These proposed proliferation risks of nuclear energy could possibly hinder de adoption of SMRs and delay the increase of nuclear energy capacity globally.

Energy Infrastructure and Challenges of Implementing

Since the coal-fired power plant in the Eemshaven is only permitted to run until 2030 and there are currently no SMRs available on the market, the consultancy expert deemed the idea of replacing it with a SMR, absurd. While infrastructure development is important, there isn't a simple substitute for the plant. Furthermore, funding problems and delays have beset several SMR projects, including NuScale and Rolls-Royce SMR. The first GE Hitachi's BWRX-300 SMRs may operate in Canada by 2029, so replacing the Eemshaven plant with SMRs would not be feasible *soon* as the earliest possible implementation of SMRs in the Netherlands would be around 2035.

Local Communities and Participation

Local community involvement and participation in decision-making processes are essential components for a successful implementation of energy projects. One example is the project of Vattenfall in Diemen, intended to run a biomass plant, but cancelled as *strong oppositions* by the local community addressed concerns surrounding the carbon emissions of the project. Together with organizations such as WISE and LAKA, Greenpeace supports grassroot involvement, local initiatives, sharing information, and connecting them with national policy makers.

Future Energy Options

The most practical and sustainable way to meet the climate targets is through the development of renewable energy sources and energy carriers. This should ensure a flexible and resilient energy system that can meet fluctuating demands and different weather conditions. Greenpeace argues that nuclear energy is not a practical solution to combat climate change, because of the lengthy lead times for building nuclear power plants, high costs, serious safety concerns regarding catastrophic accidents and radioactive waste. Instead, Greenpeace emphasized for the need of investments in large-scale renewable energy projects with energy storage technologies, like cutting-edge batteries and hydrogen production, to control the intermittency challenges. Greenpeace further highlights "degrowth" (a reduction of economic activity and consumption levels, hence an overall decrease in energy use and resource depletion), decentralized energy solutions and strengthening local communities to boost energy resilience as essential for a carbon-free future. This perspective on the future energy options aligns with the broader context of environmental sustainability and climate justice.

Academic Expert – University of Twente

The interview with the Academic Expert of the University of Twente provided elaborate insights into the potential adoption of SMRs in the energy mix of the Eemshaven. The analysis identified eight primary themes that were discussed in the interview and are elaborated in the following sections.

Knowledge and Expertise

Knowledge and expertise are crucial elements in the decision-making processes. The academic expert was familiar with SMRs but not a major expert. Most stakeholders have a basic understanding of *SMRs but* lack in-depth technical expertise. *Relevant social groups should* require comprehensive information, sufficient knowledge, and experience to make informed decisions. This could otherwise lead to misunderstandings and incorrect assumptions affecting the decision-making and public acceptance of SMRs. Educational initiatives and technical expertise should be developed among relevant groups to encourage constructive negations about the potential role of SMRs in the energy mix.

Scale and Capacity

The scale and capacity of an SMR could have a big impact on the decision-making surrounding the technology. The capacity of an SMR can be adjusted to match fluctuating energy needs of a particular area, and the scale can be *influenced* to match the related infrastructure, costs and influences the social acceptance of the technology. This information was deemed as crucial to evaluate how social groups could negotiate the role of SMRs, and the technical and financial feasibility of SMRs as a potential replacement for the coal-fire power plant in the Eemshaven.

Safety and Environment

The concerns about nuclear waste management and the safety of SMRs are important factors in the public's perception of the technology, as these are the two main issues that are frequently raised in the negotiation on nuclear energy. These social and environmental factors influence the possible adoption of SMRs despite their advantages over conventional nuclear energy technologies, as the technology is nuclear energy, nonetheless. To increase the public acceptance, reliable information on nuclear waste management techniques, the environmental impact and safety features of SMR should be transparently shared with the public. This would dispel myths and misconceptions, make informed decisions and ultimately build trust fostering a well-informed and supportive community.

Costs and Economic Feasibility

Financial aspects of SMRs are key drivers of its economic feasibility, considering the construction, operation, and maintenance costs involved. These costs require investments and economic analyses to ascertain the feasibility of the technology. Understanding the cost structures and economic benefits are required *to* consider SMRs as a replacement for the coal-fired powerplant in the Eemshaven, or any other application for that matter. The economic feasibility *exerts* huge forces of influence on the willingness to invest and on policy decisions, requiring transparent cost-benefit analyses to support informed decision-making.

Social Acceptance and Perception

The social acceptance and perceptions of SMRs reveal the attitudes of society towards the technology, which influence the negotiation of the technology. Proactive and transparent communication with local communities on the pros and cons of the SMR through a broad engagement seem crucial components to rally support. This relates to the social dynamics that influence the potential adoption of SMRs. Addressing the concerns raised by the community in a participatory manner can be crucial to clarify misunderstandings and build trust to increase the acceptance of the technology.

Policy and Decision-Making Level

The interplay between different levels of national and local policies in the decision-making process exert a strong influence on the potential adoption of new technologies in the Netherlands, such as SMRs. The national and local policies for instance play a role in selecting *an* appropriate site for the potential deployment of SMRs, as well as defining the conditions of decision-making institutionally at both levels. A successful implementation would critically depend on the cooperation and coordination between different levels of government agencies, along with the interplay of national and local policies.

Communication and Participation

Communities should engage in the decision-making process for SMRs through transparent communication procedures and participatory techniques to improve the awareness, acceptance and creating a conducive environment for SMRs. These procedures should include the rational and lucid communication of benefits and risks of SMRs that should create constructive negotiations with social groups and ease the resistance and garner public support. Furthermore, open participation processes could embrace inclusiveness while enhancing social acceptance of SMRs.

Regulation and Investments

The adoption of SMRs is dependent on the necessary legal permits complying with regulations and financial resources. These regulatory and financial aspects often create the most difficult barriers to the introduction of new technologies, that align with the conditions that determine the decision-making of various social groups. The interdisciplinary knowledge on regulations and investments requirements are indispensable for the negation process behind a potential SMR project. A strong legal framework and an effective financial setting are needed to take care of risks and costs, which consequently, underscore the importance of cooperating with the regulatory agencies as well as the investors. This point stresses out the fact that only through a sustainable legal and financial system can ensure the feasibility of a potential SMR project.

Regional Authority – Province of Groningen

The interview with the coordinator of energy system at the province of Groningen provided detailed insights into the potential adoption of SMRs in the energy mix of the Eemshaven as regional authority. The analysis identified six primary themes that were discussed in the interview and are elaborated in the following sections.

Energy Policy and Strategic Goals

The province of Groningen is determined to transform the energy system to zero-emission by 2050 and concentrates on developing an affordable, accessible, reliable, and future-oriented energy infrastructure. The significant expansion of the Eemshaven site for which the new Oostpolder area will be allocating 200 hectares for various energy producing and storage applications, supporting the Netherlands with an integration of 23 gigawatts of energy. The active development of new energy projects and considerations of new technological energy development, has led to a framework which could potentially support the evaluation and adoption of SMRs.

Regulatory Framework and Safety Concerns

The Province of Groningen's regulatory framework and safety concerns highlight the absence of specific regulations for SMRs and existing safety issues. Especially the gas extractions that happened in Groningen in the past, consequently causing earthquakes, extensive damages to buildings and infrastructure, and other environmental, economic, social, and phycological issues, along with historical international incidents like Fukushima and Chernobyl have disadvantaged the potential use of nuclear energy in the Eemshaven. Addressing these safety concerns through comprehensive measures to foster acceptance of SMRs is therefore, of all Dutch provinces, in Groningen the biggest challenge. Establishing a clear and stringent a regulatory framework could help alleviate public fears, reduce resistance, and build trust among and both policy makers, investors, and the public to facilitate the integration of SMRs.

Decision-Making and Negotiation

The Provincial States play a core role in the dynamics of decision-making and negotiation of the province. In this negotiation, many energy options are reflected upon, also nuclear energy, nuclear fusion, and SMRs. The municipality of Het Hogeland (local municipality of the Eemshaven) and other local governments in Groningen share their opinions on these decisions through motions and the formation of local policies. The process of decision-making is a complex, mainly due to the number of social groups who differ along several perspectives on interests. Therefore, multiple parties and research opinions need to be considered for informed decision-making. Interactions at different levels of the government combined with local community input play a huge role in deciding the *outcome*, and for SMRs that will *be* a rather long process. This includes several stages that require both collaboration and agreement between governmental levels and other social groups. Highlighting the importance of transparency and participation in effectively executing these processes and building a supportive community.

Involved Parties and Their Roles

There are various social groups involved in the negotiation on the potential adoption of SMRs. Social groups that join the discourse on nuclear energy in the Eemshaven are the national government, Groningen Seaports, the municipality Het Hogeland, and local communities. Their opinions range from safety and environmental protection to the expected financial benefits. The opinions of these actors and their roles underlines how complex the institutional negotiation is. Such diverse perspectives in each group gives rise to conflict and simultaneously bring about synergy. The negotiation of the potential adoption of SMRs going to require awareness of these dynamics in the decision-making and the appropriate resultant action of integrating the interests of all social groups involved.

Advantages and Potential of SMRs

SMRs could be beneficial because they generate carbon-free electricity and require less land than renewable alternatives and as the province does not have much space and *needs* energy solutions. The residual heat from the SMRs can also be used for local heating networks, which could create explicit benefits for the local community directly involved, increasing social acceptance of their implementation, *if* safety is ensured.

Challenges and Social Concerns

The challenges of adopting SMRs in the Eemshaven are concerns of the safety of nuclear energy, handling radioactive waste, high maintenance costs, long-term viability of the technology, and more specifically with the sentiment related to the previous gas extractions in Groningen, consequently causing earthquakes, massive damages on buildings and infrastructure, environmental, economic, social, and phycological issues, along with the historical international incidents as Fukushima and Chernobyl. For SMRs to be socially accepted in Eemshaven, these challenges and concerns truly have to be addressed. The transparency of the applied safety measures and assurance of nuclear waste management ought to be communicated with detail, coupled with active involvement and participation of the local community in the decision-making.

Local community – BBE

The interview with the BBE revealed several critical insights into the potential adoption of SMRs in the energy mix of the Eemshaven as local community. The analysis identified four primary themes that were discussed in the interview and are elaborated in the following sections.

Significant impact of the nuclear power plant

The BBE share high concerns of the local community surrounding the socioeconomic and environmental impacts of the construction and operation of a nuclear power plant in Eemshaven. The local concerns signify that a detailed environmental impact assessments and community consultations at the local level should be taken when arriving at such decisions within the energy sector to avoid opposition and protests.

Representation by interest organizations

The BBE represents the interest of two local villages surrounding the Eemshaven area which calls for a decentralized and participatory approach to decision-making processes in the Eemshaven area. Effective representation and participation are tantamount to a means of guaranteeing legitimate and socially accepted decisions in technological adoptions such as SMRs.

Negative perception of nuclear energy

There is a dominant negative attitude toward nuclear energy in Eemshaven because it is seen as a threat to their environment and social cohesion. Education, awareness spreading, public involvement and participation could lead to nuanced and informed attitudes towards new technologies, such as SMRs, and decrease resistance and misunderstandings.

Protection of local values

The desire to preserve the unique cultural-historical and natural environment of Eemshaven area, highlights the importance of integrating cultural and ecological considerations with economic and technological factors in policymaking. Successful technological implementation depends on harmonizing new technologies with the existing environmental and communal values.

Governing Municipality – Het Hogeland

The interview with the policy officer at municipality of Het Hogeland provided elaborate insights into the potential adoption of SMRs in the energy mix of the Eemshaven as local municipality. The analysis identified five primary themes that were discussed in the interview and are elaborated in the following sections.

Policy Goals and Local Economy

The municipality aims to improve the economic situation in the weak economic area surrounding the Eemshaven, with the main intent to combat energy poverty. In 2019, the municipality started an new energy policy that together with the regional program, plans to link the development in the Eemshaven with regional prosperity, by integrating new energy initiatives along with the local infrastructure development to address the energy poverty and stimulate economic growth in the region.

Energy Transition and Innovations

The development of new projects and innovations in the Eemshaven should contribute towards the energy transition. Important initiatives include PAWOZ-Eemshaven, which could use offshore wind energy to produce hydrogen and the residual heat from electrolysers and data centres that could be utilized in heating networks, reducing gas consumption.

Nuclear Energy and SMRs

According to the policy officer, despite all the controversies behind the concerns of nuclear energy, with the advantages of carbon-free electricity production and a small land footprint, SMRs could be part of energy mix, contributing to the decarbonization of the Eemshaven. This embodies the complexity of the energy transition at the Eemshaven with potentially adopting SMRs to secure a sustainable energy supply.

Political and Social Dynamics

Both political will and social acceptance significantly influences energy policies and the implementation phase of a new energy project, hence the energy transition. For SMRs, the political processes are complex due to the political divisions on nuclear energy in the Netherlands, and public acceptance is arguably low due to environmental protest and safety concerns towards nuclear energy. This emphasizes the need for an informed and inclusive decision-making process to navigate these dynamics and the possibility of a successful implementation of new energy solutions, such as SMRs.

International Influences and Regulations

International influences and regulations, such as European CO2 regulations and international energy prices are affecting local energy policies and the feasibility of projects in the Netherlands. The European regulations set the framework for the local sustainability ambitions. On top of that, global energy prices dictate targets for the energy mix in the Netherlands, influencing the feasibility of potential energy projects in the Eemshaven. These international factors have a big participation in local decision-making, which emphasizes the relevance of considering the developments in global trends and regulations when planning and implementing local energy solutions, such as potentially, SMRs.

Potential Pioneer Region – Province of Limburg

The interview with the policy officer at the Province of Limburg provided elaborate insights into the potential adoption of SMRs in the energy mix of the Eemshaven as a pioneering province in the social acceptance and implementation of SMRs. The analysis identified six primary themes that were discussed in the interview and are elaborated in the following sections.

Policy Goals and Energy Policy

The policy goals and energy policy of the province of Limburg emphasize on sustainability and climate neutrality, aligning with broader national and international environmental objectives rather than solely an industrial area such the petrochemical industrial cluster in Chemelot (Limburg) or the Eemshaven for that matter. The province aims to enhance renewable energy sources through wind energy and ensuring a stable energy supply for the region by addressing grid congestion. This indicates a supportive policy environment for new energy technologies, aligning the province's goals with the potential adoption of SMRs.

Technological Specification and Localization of SMRs

The adaptability of SMRs to different industrial settings and geographical locations significantly influences the acceptance and potential integration of the technology into the existing energy infrastructure. However, for a practical implementation of SMRs, first the technological specification and localization factors need to be understood to *select* a potential site. The ability to place a SMR in different industrial settings with (depending on the type of SMR) limited cooling water require*d* makes it even a suitable option for land inwards locations, such as the province of Limburg. These details help assess the feasibility and optimal conditions for the potential deployment of SMRs.

Social Acceptance and Public Debate

Social acceptance and public debates play a significant role in successfully implementing of new technologies. Especially for a controversial technology such as SMRs. Establishing public debates and knowledge platforms can increase effective spreading of information regarding a new technology, hereby addressing public concerns and promoting acceptance. The province of Limburg was the first province in the Netherlands to effectively pioneer public debates and knowledge platforms on the potential of SMRs. This engagement, with social groups, may have created more trust and a consensus around a potential SMR project in Limburg through transparent communication, resulting in informed inclusive decision-making and gaining public support.

Political and Regulatory Dynamics

Political and regulatory dynamics can significantly influence the potential adoption of SMRs. It shows that for society is not aware about the existence or roles of certain national and local authority regarding nuclear energy (or SMRs). There is a need for clear regulations through a coherent regulatory framework, and coordination through alignment of political interest to be able to facilitation of smooth implementation of SMRs. This highlights the potential administrative and legal challenges that still need to be addressed before further steps can be taken into the process of potentially realizing SMRs in the first place.

Challenges and Concerns

There are several challenges and concerns that are slowing down the realization of SMRs. There is currently too big of a gap between the realization time of SMRs in the Netherlands, set on 2035, and the risk to invest. Currently, investors are not likely to invest in the 10-year realization horizon of SMRs as opposed to alternative energy technologies. Another dominant challenge is the public concerns regarding safety issues and environmental impact in case of an accident. Recognizing these challenges can increase informed decision-making and overcome these challenges in time through a thorough planning, improving the chances of a successful adoption of SMRs.

Advantages of SMRs

The advantages of SMRs could include economic benefits for the region, reduced grid congestion related challenges, advantages for their industrial applications, and a reduced dependency on foreign energy and resource. These potential advantages would make a compelling case for considering SMRs as part of the energy mix. This reveals the perspective of benefits that SMRs could in the province of Limburg, reinforcing the potential value of SMRs and justifying its consideration as a potential feasible alternative to alternative energy sources.

Energy Provider – Vattenfall

The interview with the energy transition manager at the Vattenfall provided elaborate insights into the potential adoption of SMRs in the energy mix of the Eemshaven as energy provider. The analysis identified six primary themes that were discussed in the interview and are elaborated in the following sections.

Policy Adjustment and Energy Policy

Vattenfall aims to influence energy policy at both national and European levels to support their energy transition goals as policy adjustments can influence the energy transition and Vattenfall's role in it. Vattenfall also pushes for ambitious yet feasible polices to boost new technologies, like SMRs and nuclear energy in general. This reveals the reciprocal exchange in energy politics and the embracing of innovative technologies, specifically, SMRs' part in shifting to cleaner energy.

Energy Technologies and Innovation

Vattenfall focusses on various new energy technologies and innovation such as offshore wind farms, hydrogen production, electrification, and SMRs for their potential benefits such as lower investment risks compared to traditional nuclear plants. While SMRs are promising, significant technological and financial hurdles remain, emphasizing on the importance of continuous innovation and the challenges that must be overcome, in the broader context of evaluating SMRs as a feasible replacement for coal power in Eemshaven.

Regional Energy Transition

Vattenfall also explores the specific role of the regional energy transition of the Eemshaven in the broader context of the national energy transition. Emphasizing on the existing infrastructure, noting factors like the presence of other power plants, the regional energy demands and the potential adoption of SMRs. This reveals how geographic and infrastructural factors can either facilitate or hinder the feasibility of adopting SMRs, which highlights the influence of regional dynamics that can affect decision-making and the negotiation process among social groups regarding the potential adoption of SMRs.

Political and Public Dynamics

Political pressure and how nuclear energy is perceived by the public seem to dictate decision-making processes and negotiations on the potential adoption of SMRs. Political and public dynamics can be a controlling factor when it comes to the potential adoption of SMRs. Addressing the safety concerns of SMRs as opposed to traditional nuclear energy technologies could, therefore, be crucial to enhancing the social acceptance and perception of the technology.

Economic and Financial Factors

Economic and financial factors that are required for the potential adoption of SMRs are investments and financial support, including subsidies and a strong business case. This underlines the economic challenges and considerations that could influence the economic dimensions of the negotiation process on the potential adaption of SMRs.

Nuclear Safety Regulator – ANVS

The interview with the coordinating advisor of the ANVS provided elaborate insights into the potential adoption of SMRs in the energy mix of the Eemshaven as nuclear safety regulator. The analysis identified eleven primary themes that were discussed in the interview and are elaborated in the following sections.

Non-negotiable safety criteria and requirements

In the Netherlands, SMRs and other nuclear installations are subject to strict, non-negotiable safety standards maintained by the ANVS. Ensuring the safety of the public and the environment requires three primary safety metrics that are used to estimate the possible impact of nuclear accidents. The measures are group risk, individual risk and societal risk and create thresholds that cannot be exceeded. As part of its role as an independent regulator, ANVS is committed to nuclear safety, which is reflected in its non-negotiable position. The non-negotiable safety requirements and criteria align with the potential adoption of SMRs within a stringent regulatory framework, and provides insight into the potential impact of these requirements on social group acceptance and negotiations.

Assessment and implementation of SMRs vs traditional reactors

Even though SMRs are smaller and might have different designs compared to traditional, larger nuclear reactors they must meet the same rigorous requirements, undergo the same safety assessment, and follow the same protocols as conventional reactors. The parity in safety requirements and assessment ensures that SMRs are scrutinized just as thoroughly and provides insight into the potential adoption process of SMRs into the existing energy infrastructure, and implications for energy policy and public safety.

Challenges for implementation and safety requirements

The introduction of new nuclear technologies, such as SMRs, is a complex process with political, economic and safety-related challenges. Even though have the potential of lower risks, rigorous proof of safety is still required, and this is especially difficult as there is a lack of historical data and established practices of the technology. This sheds light on how technological advancement and legal constraints interact, as well as how social groups could navigate these challenges in the potential adoption of SMRs in the Eemshaven.

International cooperation and knowledge sharing

The ANVS works closely with regulators from countries like Canada, England, Sweden, Finland and Japan which are pioneers in the development and implementation of SMRs. This collaboration with international regulatory bodies underlines part of the importance of shared knowledge and best practices in nuclear safety, which would allow the efficient assessment of new nuclear technologies, such as SMRs. This reveals that international cooperation and regulation could potentially facilitate a successful adoption of SMRs in the Netherlands by leveraging global expertise and experience.

Independence and decision-making of ANVS

The ANVS, as an independent regulator, plays a crucial role in ensuring nuclear safety by basing decisions purely on safety assessments of potential new nuclear energy projects in the Netherlands. This maintains effectiveness and credibility, ensuring the highest safety requirements that, if it were to be made more publicly aware, could significantly impact the negotiation between social groups regarding the potential adoption of SMRs in the Eemshaven and other parts of the Netherlands.

Licensing process and consultation structures

With an emphasis on the licensing procedure and consultation frameworks, the ANVS clarifies the comprehensive approach to nuclear safety. To guarantee that all safety considerations are carefully considered before awarding a license, preliminary consultations and the issuance of draft licenses, both require thorough review and documentation. Understanding this complex process sheds light on the regulatory challenges and requirements to realize an SMR project, and helps to assess the feasibility and timelines for their potential adoption.

Risk assessment in nuclear decision-making

An important consideration in the ANVS's decision-making process is risk assessment, where quantitative risk criteria are used in the ANVS evaluation offering a binary decision-making framework as an installation, that either satisfies the safety standards or it does not. This emphasizes the impartial foundation for regulatory decisions, further guaranteeing that public safety is maintained. This quantitative risk assessment is consistent with the larger framework to comprehend how objective safety metrics impact the potential adoption of SMRs.

Communication and social acceptance of SMRs

This provides insight into how effective communication strategies would address public concerns and incorporate feedback into the decision-making process to enhance trust and acceptance of new technologies, like SMRs. Communication and consultation thus play a significant role in reaching social acceptance for SMRs. Emphasizing on ANVS's efforts to involve society through information sessions and public consultations in sharing safety measures and gathering feedback to ensure more transparency and inclusivity.

Innovations and new technologies in nuclear safety

Another important focus point is how technological advancements affect nuclear safety. New technologies, like passive cooling systems (generation 4 SMRs), can improve safety considerably but need to be thoroughly validated. It is, however, difficult to demonstrate the reliability of these new technologies as opposed to already existing ones (generation 3 SMRs). This shows how technological development can improve nuclear safety while necessitating more comprehensive safety evaluations.

Environmental considerations in nuclear safety

The ANVS also integrates environmental considerations into the safety assessments. Through a thorough assessment of the potential risks, covering both conventional and radiological environmental impacts during all phases of implementing and operating an SMR, allows for a more holistic assessment.

Future developments in nuclear technology and implementation

According to the ANVS, generation 4 SMRs might not be realized until 2050, but generation 3 SMRs might be operational by 2035. The main variables affecting these timelines are organizational and technical maturity of the technology. Gaining insight into the realistic timeline for potentially adopting SMRs in the Netherlands is crucial to be able to assess their feasibility and strategically plan a successful integration into the energy mix.