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The green shift and nuclear energy – an economic, environmental, and societal-readiness perspective for rural districts in Norway

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Abstract

As global imperatives to combat climate change intensify, the need for more reliable, cost competitive and low-carbon energy has never been more pressing. This MSc thesis explores the reasons why Norway should consider integrating nuclear energy (SMRs) into its power matrix in its local communities through the following theme:

"How can nuclear energy contribute to the green shift, viewed through the economic, environmental, and societal-readiness perspective for rural districts in Norway?"

The theme is then broken up into three research questions to allow a more accurate discussion of each of the categories: economy, environment, and society.

Employing the Flourishing Business Canvas as a framework, this analysis integrates key theoretical frameworks such as strong versus weak sustainability, triple bottom line, the nine planetary boundaries, and the United Nations 17 Sustainable Development Goals. As the public discourse on the topic has been polarized for decades, theories regarding epistemic challenges and transdisciplinarity were used to frame the data received during data collection.

Utilizing an explorative method design, the aim of the thesis is to investigate the feasibility and implications of introducing nuclear power as an energy solution in rural Norway. Six informants were selected based on their stance and visibility in the public debate on nuclear power. Using a semi-structured guide, to ensure consistency of data collection, the informants were interviewed in turn. A literature review was performed to gather secondary data that was used in the discussion to support or reject claims made by the informants.

The discussion proved that the topic is still contentious on the three categories in question. The environmental discussion stood out with starker disagreements. The polarization seen in the public debate was also present in the informant group, effectively splitting the group in two. For economy one group cited high capital costs, while the other expected effective returns, but projecting a higher future energy price. SMRs seemed to provide a substantial boon to environment and preventing global warming but comes with inherent risk – which is greatly reduced from earlier nuclear plant technologies. The readiness of Norwegian society was contested, but there was consensus that the actual implementation would be at least a decade into the future. The conclusion is that SMRs are an interesting up and coming technology, that could provide positive effects in Norway on both district and national level. With it comes risks and challenges that will need to be considered going forward. This thesis offers a foundation for future discussions and actions on this critical area of energy policy.

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Best regards,

Mohamad Hussein Mohamad Ali,
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Glossary

Term	Description
AGR	Advanced gas-cooled reactor. Type of nuclear power technology
DSA	Norwegian Radiation Protection Authority
EPR	European (or evolutionary) pressurized reactor - Type of nuclear power technology
FBC	Flourishing Business Canvas
ESG	Environmental, social, and corporate governance Evaluation of a company's awareness and readiness for social and environmental factors
GHG	Greenhouse gas
GMO	Genetically modified organisms
GWP	Global warming potential Impact assessment unit expressing integrated radiative forcing over time (usually 100 years) of a greenhouse gas relative to that of CO2
HLW	High-level waste
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
ILW	Intermediate-level waste
IRES	Intermittent Renewable Energy Sources
ISO	International Organization for Standardization
kWh	Kilo Watt / hour
LCA	Life cycle assessment
LCOE	levelized cost of electric
LLW	Low-level waste
MWh	Mega Watt / hour
MWth	Mega Watt thermal / hour
NOU	*Norges offentlige utredninger* (NOU) er en serie statlige rapporter. NOU-rapportene har som formål å presentere og drøfte kunnskapsgrunnlaget og mulige handlingsvalg eller strategier for utvikling og iverksetting av offentlige tiltak for løsning av samfunnsmessige problemer og utfordringer.
NPP	Nuclear power plant

NSD	Norwegian Centre for Research Data
RQ1, 2, 3 and 4	Research question 1, 2, 3 and 4
SDG	Sustainable Development Goals
SMR	*Small modular reactors* (SMRs) are advanced nuclear reactors that have a power capacity of up to 300 MW(e) per unit.
SSB	Statistics Norway
TJ	Terajoule 1012 J = 106 MJ, unit of energy
Triple bottom-line	Sustainability framework that measures a business's success on three distinct axes: profit, people, and the planet.
TW	Terawatt 1012 W = 1012 J/s, unit of power
TWh	Terawatt hour 1012 Wh = 109 kWh = 3.6 109 MJ = 3.6 PJ (petajoule)
UiB	University of Bergen
VLLW	Very low-level waste
WNA	World Nuclear Association

Introduction

Background

In the record of human history, few resources have shaped the modern world as profoundly as petroleum. Its dense energy content propelled the industrial revolution, revolutionized transportation, and powered the global economy for over a century. (Regjeringen 1, 2021). However, as the world grapples with the escalating impacts of climate change, a critical juncture has been reached in the energy landscape. The shift from petroleum-based energy to renewables has emerged as a pivotal step towards a sustainable future.

Renewable energy, encompassing sources like solar, wind, hydro, and geothermal power, represents a beacon of hope in this transition. Unlike finite fossil fuels, renewables harness the Earth's natural processes, offering an infinitely sustainable supply of energy. They produce little to no direct emissions and significantly reduce our collective carbon footprint. The challenge with renewable sources like these is that infrequency is a significant hurdle as solar and wind power generation is dependent on weather conditions, meaning energy production fluctuates and may not align with demand. By embracing a diverse energy portfolio to meet this fluctuation is needed. In addition, there is a need for a renewable power source that can replace the high energy density of petroleum. Therefore, including nuclear power alongside renewables can be a pragmatic approach to meet the demands of a rapidly changing world while safeguarding the environment for generations to come. Additionally, the decentralization of renewable energy systems empowers communities to take control of their energy production, fostering a more resilient and democratic energy landscape. (United Nations [(3)], 2023).

However, the energy transition is not without its challenges. The infrequency and variability of renewable sources require innovative solutions to meet the green transition in addition to a stable energy demand. Furthermore, transitioning from established petroleum infrastructure demands substantial investment and political will. A just transitions for communities and industries is heavily reliant on that fossil fuels are imperative to ensure that no one is left behind in this transformation. (DNV, 2023).

Governments, industries, and communities across the globe are now recognizing the urgency of this paradigm shift. Policies, subsidies, and incentives are being implemented to accelerate the adoption of renewable technologies. Technological advancements in energy storage, grid integration, and efficiency are rapidly reducing the cost and increasing the viability of renewables.

Based on the idea that the energy transition from petroleum-based sources to renewables is not merely a shift in technology, but a pivotal moment in human history we decided to look at one aspect related to the paradigm: nuclear power. It can represent a commitment to a more sustainable, equitable, and resilient future.

As the public discourse is highly fragmented and highly affected by entrenched biases, our aim is to collect and aggregate the most current knowledge for the three topics that are recurring in the discourse: economy, environmental and societal readiness. We are presenting our findings using the Flourishing Business Modell Canvas (Osterwalder, et.al, 2010). Supported by additional models for the topics, we hope to provide a current snapshot of nuclear energy as a viable business case in Norway. With researchers biased both for and against nuclear energy, we hope to provide a neutral and balanced view on the subject.

We have therefore formalized the following theme:

"How can nuclear energy contribute to the green shift, viewed through the economic, environmental, and societal-readiness perspective for rural districts in Norway".

We would like to define and operationalize the following terms: the green shift, nuclear energy, environment, economy, and societal readiness.

- **Environmental:** The impact of nuclear energy on the environment. This thesis will look at nuclear energy considering safety record, pollution, greenhouse gas emissions and waste disposal, as these are the common caveats in the nuclear discourse.
- **Economy:** How competitive nuclear power per kw/h is in comparison to other sources of energy in today's interconnected electricity market and how the economy can benefit.
- **Societal readiness:** Does Norway have the academic and engineering expertise available to initiate a nuclear energy project. Do the society accept the nuclear energy today.

While the main topics will be discussed in relation to rural districts, certain topics will in addition be viewed on a national level due to the fact that some aspects of nuclear energy effects the nation as a whole.

Each term above presents a potential depth that could be its own thesis. We would like to treat the public discourse as a case study, where we would like to perform qualitative interviews with key participants, to get an initial overview. The findings, organized in the Flourishing framework, can then be used as a launch pad for future studies to delve deeper into. And due to the selected terms, mapping with the triple bottom line as proposed by John Elkington, (Jakobsen, 2019) the findings might serve as an inspiration for triple bottom line implementation for future companies.

History

"Nuclear power is generated by splitting atoms to release the energy held at the core, or nucleus, of those atoms. This process, nuclear fission, generates heat that is directed to a cooling agent-usually water. The resulting steam spins a turbine connected to a generator, producing electricity." (National geographic, 2019).

Nuclear energy history goes back to the 1930s after physicist Enrico Fermi showed that neutrons could split atoms. At the University of Chicago, later in 1942, a team led by Fermi made the first nuclear chain reaction, which was the first step towards nuclear energy. Several events happened during the 1950s which resulted in achieving the first electricity from nuclear reactions in Idaho's Experimental Breeder Reactor I in 1951. Then in Obninsk in former Soviet Union built the first nuclear power plant in 1954 (National geographic, 2019).

Today, there are around 440 nuclear reactors in the world which produce around 10% of the world's electricity (Elements, 2022 [(1)]). On top of the list, you find the USA with around 93 active reactors that are generating 19.7% of the electricity mix in the country and around 31% of world's total nuclear energy production. France and China come next having 58 and 50 reactors and counts for 13.3% and 13,5% respectively. At the same time, nuclear energy in France counts for 70% of the country's total electricity mix (Elements, 2022[(2)]). Other countries on the list we find, Russia, South Korea, Germany, Spain, Sweden, Ukraine, UK, India, Canada, Belgium, and other countries.

According to Elements (2022 [(1)]) the top 10 countries constructing new nuclear power reactors are: China 21 reactors, India 8, Turkey 4, South Korea 3, Russia 3, UK 2, UAE 2, Japan 2, USA 2, and Bangladesh with 2 reactors. The total number of new reactors close to, or currently being built worldwide is 59 reactors which makes the total operating reactors around

500 reactors worldwide. Many countries are planning nuclear reactors. Asia dominates on top of the list with hundreds of planned reactors lead by China and India (Elements, 2022[2]).

Throughout the history of nuclear power there has been several big incidents, where the most severe and infamous was the Chernobyl accident in Ukraine in 1986. Several other incidents occurred between 1957 and 2011 where the more recent being the Fukushima incident that occurred following the tsunami that hit Japan 2011.

The debate on nuclear power in Norway

The public debate on nuclear power in Norway has been ongoing for several decades. Norway is a country with a large hydroelectric power capacity, which has made it less reliant on other sources of energy such as nuclear power. Nevertheless, the topic of nuclear power has been frequently debated in Norway, with strong opinions on both sides of the argument.

The first discussions about nuclear power in Norway began in the 1950s, but it was not until the 1970s that the debate really gained momentum (Nikel, 2021). At that time, Norway's neighbor Sweden was rapidly expanding its nuclear power program, and there were concerns about the potential effects of nuclear accidents and how the radioactive waste could challenge Norway's environment (Nikel, 2021). These concerns led to protests and demonstrations against nuclear power, and the formation of several anti-nuclear organizations.

One of the most prominent anti-nuclear groups in Norway is the Norwegian Society for the Conservation of Nature (Norges Naturvernforbund). The organization has been active since 1914, however, it was not before the 1970s they directed their focus on environmental issues, including nuclear power. The organization has consistently argued that nuclear power is not a safe nor a sustainable energy source, and that Norway should instead focus on developing renewable energy sources. (Naturvernforbundet, 2023).

Despite the opposition, there has also been supporters of nuclear power in Norway. One of the main arguments in favor of nuclear power is that it is a low-carbon energy source that could help Norway reduce its greenhouse gas emissions. Some proponents also argue that nuclear power is a reliable and a cost-effective form of energy, and that Norway could benefit from developing its own nuclear power program (NRK, 2022).

During the 1960s and 1970s Norway had a plan to build nuclear power plants. And in the 1980s, the Norwegian government conducted a series of studies on the feasibility of nuclear power in Norway. These studies found that Norway's geology and seismic activity made it unsuitable for nuclear power plants, and that the risks associated with nuclear power outweighed the benefits. In 1979 there was a parliamentary decision to postpone these plans following the Three Mile Island accident. And shortly after, in 1986 the Chernobyl accident happened. As a result, there was a parliament decision not to pursue nuclear power and instead focused on developing its hydroelectric power capacity (DSA, 2023).

In recent years, the interest in nuclear power in Norway started again. In 2015, a group of scientists and experts published a report arguing that Norway should consider building small modular nuclear reactors (SMRs) to provide low-carbon energy. The report argued that SMRs would be safer and more cost-effective than traditional nuclear power plants, and that they could help Norway meet its climate targets (IAEA, 2015).

However, the proposal has faced significant opposition from anti-nuclear groups and some political parties. The Green Party, for example, has until recently consistently opposed nuclear power and argued that Norway should focus on developing renewable energy sources instead. Other opponents argue that nuclear power is too risky, and that Norway should not take any chances with its environment and public health (Strømme, S H. 2021).

In conclusion, the public debate on nuclear power in Norway has been ongoing for several decades, with strong opinions on both sides of the arguments. Ultimately, the decision on whether to pursue nuclear power in Norway will depend on a range of factors, including the country's energy needs, its climate targets, and the opinions of its citizens.

Revitalizing Norwegian districts

Based on the ongoing debate on possible implementation of nuclear power generation several districts have voiced their interest in hosting potential power plants. The districts have argued that increased power generation would be a prerequisite for increased local industrial activity. The National report 'NOU 2020: 15', ordered by 'Kommunal- og moderniseringsdepartementet', explored these demographic challenges facing the Norwegian rural districts (NOU: 15, 2020). Rural districts are defined in the report as counties with low level of centrality. (SSB, 2020). The mandate of the report is borne out of the vision that a vibrant rural county contributes to higher diversity and a more sustainable Norwegian society. Taking a closer look at the demographic challenges, the report focuses on 'decreasing population', 'aging' and 'low population density'. The report acknowledges that it will demand a concentrated effort on a national level to reverse the negative trend of people moving away from the districts. And that the trend can be reversed and stabilized by 2040. But this alone is not enough to secure the sustainability of future rural districts. The main body of the report then presents different aspects and challenges regarding demographics in rural Norway and proposed solutions to some of the challenges found.

The term «Samskapingskommunen» (The co-creating county), from the ambition chapter of the report, means a county where politicians and employees create solutions and services together with the end user. This has inspired us to write this thesis as a 12th chapter of the report, nuclear energy, and its impact on rural districts, albeit with theory and formatting in accordance with a thesis.

The Norwegian debate and the government stated interest in revitalizing rural Norway has led us to explore nuclear energy's potential role in developing rural districts while ensuring the national energy self-supply.

"Det er det gode samfunnet som settes som målet for utviklingen, ikke vekst i seg selv."
(NOU: 15, 2020, p. 14)

Research questions

Considering the background and the operationalized terms in the introduction, the main objective of the thesis is the following:

> *How could nuclear energy contribute to the green shift, viewed through the economic, environmental, and societal-readiness perspective for rural in Norway.*

To provide a manageable framework, the objective is further divided into three research questions. The questions will mainly be covered from a district perspective but will be lifted to a national level were deemed necessary. These research questions will provide an opportunity for detailing and operationalizing our main question:

1. Pros and cons with nuclear energy plants contributing economically on the national and rural level?

Research question 1 (RQ1) is focused on providing insights into what contributions nuclear energy can provide nationally and on a district level. The parameters for answering the question are how nuclear power in Norway is estimated to perform from a cost perspective compared to comparable power sources (national), and what economic impact a power plant will have on a Norwegian district (local). With the implementation of nuclear energy on a local level there are some elements that need to be addressed on a national, or even a global level. Emissions, national regulations, standards, prices, fuel, waste, and transport of energy on the electricity grid need to be addressed on a broader specter.

2. Pros and cons with nuclear energy plants impacting the environment on national and district level?

Research question (RQ2) will explore the environmental impact of establishing a nuclear energy plant. Looking at the immediate environmental impacts which will incur locally, and then acknowledge the larger impacts, like mining, transport hazards and waste handling nationally. Would nuclear energy be considered as a green energy source and help reduce the environmental print accompanied by other energy production methods.

3. Pros and cons with the Norwegian society regarding the implementing of nuclear energy into its energy mix?

Research question 3 (RQ3) will then look at the social readiness of Norway regarding nuclear power: political leanings, nuclear know how, education, competing industries, infrastructure and the “not in my backyard” sentiment”. What about the general populace acceptance and interaction with the nuclear energy topic.

By answering those three research questions we will be able to summarize the findings on the main objective and categorize the findings according to those three terms: economy, environment, and society.

Delimitation

The thesis objective is wide and can’t be thoroughly and deeply covered in this thesis, hence it is focusing on answering the three main research questions presented above in terms of available theory and data gained from interviews. The thesis doesn’t aim to answer a yes or no question nor does it aim to provide a clear answer for nuclear energy fit in in the energy mix of Norway and especially rural districts but rather to shed the light on the different opinions for and against nuclear energy.

Structure (Design)

The thesis will first present the theoretical framework that we will use for the discussion. Further on we will elaborate on the chosen methodology and our selection of literature. Due to the large number of figures found in the literature, we have provided a chapter after describing the method where we detail our main reports and secondary data that we employ in the discussion. Considering this, the thesis will then present our main findings in our primary data before entering the discussion proper. A conclusion will be summarizing our findings from the discussion. References and attachments are added at the end.

Theory

The main theoretical framework for navigating the issue of nuclear energy in Norway is Flourishing Business Canvas (Flourishing Business, 2023). The framework will reflect the environmental, societal, and economic aspects of our paper. Using this established framework will give us a structured approach to lean on while exploring the topic, and a well-known structure for readers to review the paper's conclusion. To support this framework the Triple bottom line will also be used.

Considering the width of the topics contained in the thesis, we will involve theories relating to transdisciplinary as described by Manfred Max-Neef, Gunnar Skirbekk, and Ove Jakobsen. This will also be rooted in the United Nations sustainability goals.

When looking at the environmental aspect we will be looking at the impacts through Zadeks weak and strong sustainability (Zadek, 2001, p.145). And to weigh the different environmental impacts we will employ The Nine Planetary Boundaries by the Stockholm Resiliency Centre (Rockström et al., 2019).

And finally, as a meta perspective on a highly debated topic, the paper will consider the epistemic challenges related to the nuclear energy debate.

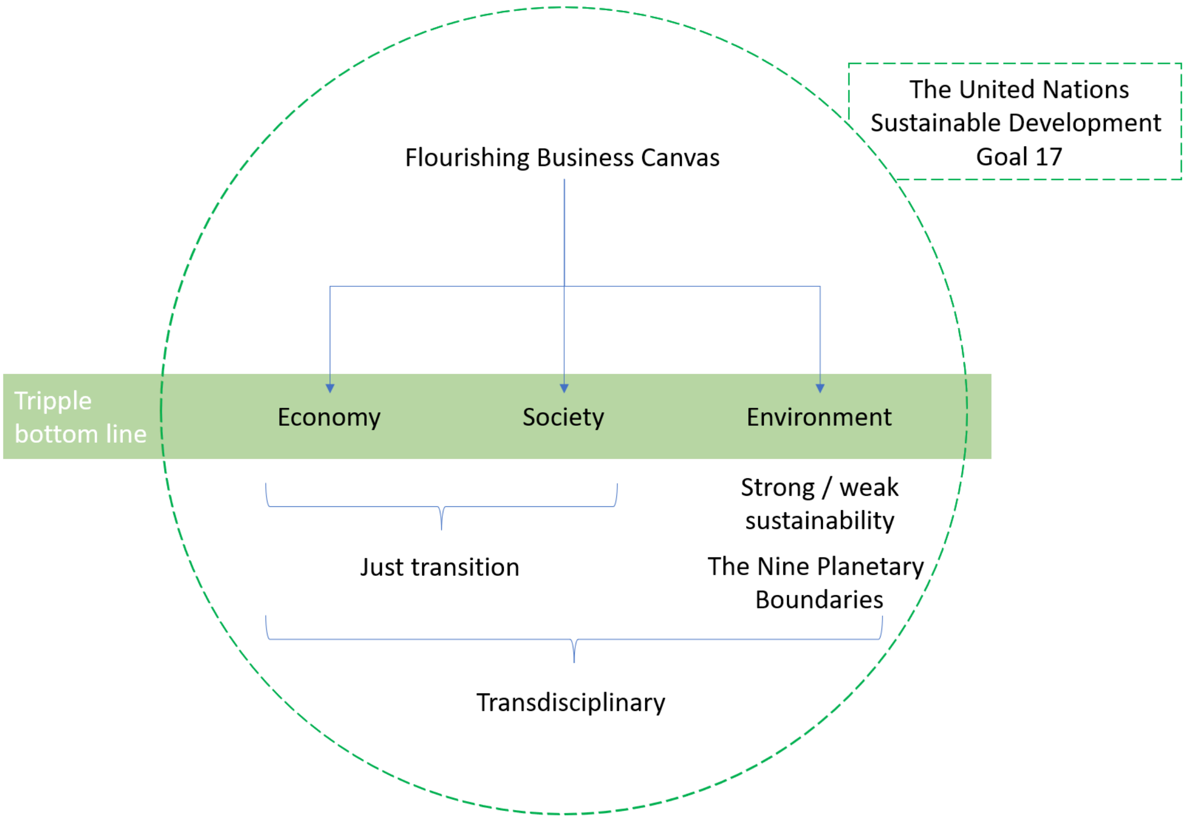

Figure 1: Thesis overview

Strong VS weak sustainability

Strong sustainability doesn't consider natural and manufactured capital as interchangeable and there is a defined balance between human capital and Natural capital (United Nations [(4)], 2023) like producing new product by the utilization of 100% consumer scrap.

Weak sustainability considers natural and manufactured capital as interchangeable, and the weakening of natural capital can be replaced easily by technical solutions.

Zadek, (2001, p.145) describes that strong sustainability is characterized by the fact that individual resources are not substitutable, the resources must each be sustainable. This means that there are strict management requirements where no economic actors can, either now or in the future, consume non-renewable natural resources (Nystad, et al., 2008). Weak sustainability is characterized by the fact that individual resources can be utilized if it makes sense. The prerequisite is that the resources are mutually substitutable, that is, when there is too little of one particular resource, other resources can be used instead to satisfy the need. Concretely, this means that lost natural capital in a generation, for example, can be compensated with new knowledge and technology. In this way the total resource base is not reduced to the next generation (Nystad, et al., 2008). Based on Zadeks theory we consider the nuclear energy transition to be considered as weak sustainability.

When looking at the challenges with weak and strong sustainability it's clear that you need a multidisciplinary approach so that the integrity of the sustainability practice is ensured. This is especially relevant when implementing strong sustainability as it requires a trans-disciplinary approach for identifying and conserving critical natural capital (United Nations [(4)], 2023). In the next chapter we will look at the importance of a transdisciplinary approach when considering nuclear energy as a part of the energy transition.

Transdisciplinarity

Transdisciplinarity is a concept that has gained significant attention in recent years as a response to the complex challenges faced by modern societies. It represents a shift from a more traditional disciplinary approach towards integrative and holistic way of understanding and addressing challenges. Three notable authors who have made significant contributions to the field of transdisciplinarity are Manfred Max-Neef, Gunnar Skirbekk, and Ove Jakobsen. When investigating nuclear energy through the implementation of transdisciplinarity it involves integrating knowledge and perspectives from various disciplines to gain a comprehensive understanding of the topic. As we will mention later in this assignment, we have done a broad investigation getting perspectives from different stakeholders to where we base our research.

Gunnar Skirbekk is a Norwegian philosopher, as we will describe more in the following chapter, he has explored the epistemic challenges in a modern world, including the proliferation of "fake news" and the erosion of truth. Skirbekk's work addresses the complexities of knowledge production and dissemination in contemporary societies, considering the role of technology, media, and societal dynamics. His analysis offers valuable insights into the challenges of navigating truth claims and the importance of critical thinking, media literacy, and a nuanced understanding of knowledge in the face of misinformation and subjective perspectives.

Manfred Max-Neef, a renowned Chilean economist and environmentalist, has been instrumental in articulating the foundations of transdisciplinarity. In his work, Max-Neef emphasizes the need for an inclusive approach to knowledge generation and problem-solving. He advocates for the integration of diverse forms of knowledge, including scientific, experiential, artistic, and traditional wisdom. Transdisciplinarity, more than a new discipline or super-discipline, is a different manner of seeing the world, more systemic and more holistic (Manfred, 2005, p. 15). Max-Neef's perspective on transdisciplinarity highlights the importance of engaging with multiple stakeholders, considering different perspectives, and promoting sustainable and socially just outcomes.

Ove Jakobsen, a Norwegian economist, and researcher has contributed to transdisciplinary approaches in the context of ecological economics. Jakobsen challenges the traditional economic paradigm and argues for the integration of various disciplines, including economics, ecology, sociology, psychology, and philosophy, to tackle ecological problems. He emphasizes the recognition of diverse forms of knowledge and the active involvement of local communities and stakeholders in the research process. Jakobsen's work highlights the potential of transdisciplinarity in promoting a more sustainable and integrated understanding of the complex relationships between the economy and the environment.

Together, the perspectives of Max-Neef, Skirbekk, and Jakobsen shed light on the multifaced nature of transdisciplinarity. Their works emphasize the importance of collaboration, inclusivity, and a broader understanding of knowledge to tackle the complex challenges faced by our societies. By integrating various disciplines and perspectives, transdisciplinarity offers a promising framework for generating innovative and sustainable solutions to pressing social, economic, and environmental issues.

Epistemic challenges in a modern world

"Epistemic Challenges in a Modern World” by Gunnar Skirbekk is a publication that explores the epistemic challenges we face in the context of modern societies. Particularly regarding the rise of phenomena like "fake news" and "post-truth." Seeing the polarization in the debate on nuclear power Skirbekk insights are highly relevant. Skirbekk delves into the underlying factors that contribute to these challenges, focusing on the role of science, risk perception, and societal dynamics.

In his book, Skirbekk begins by examining the concept of "fake news" and the erosion of truth in the public sphere. Skirbekk analyzes the factors that have facilitated the spread of misinformation and the blurring of facts, including the digital revolution, media fragmentation, and the influence of social media platforms. He argues that these phenomena pose significant challenges to the foundations of knowledge and rationality, as they undermine public trust and distortion of public discourse (Skirbekk, 2019, p.103).

Furthermore, he then explores the notion of "post-truth," which refers to a climate where emotions, personal beliefs, and subjective perspectives often outweigh objective facts in shaping public opinion and decision-making. He investigates the societal and psychological mechanisms that contribute to this phenomenon, including cognitive biases, tribalism, and the role of identity politics (Skirbekk, 2019, p. 65). Skirbekk argues that these epistemic challenges have profound implications for democratic processes and the functioning of a healthy public sphere.

Through the book he also delves into the complex relationship between science, risk perception, and decision-making in modern societies. Skirbekk highlights the challenges of communicating scientific knowledge and uncertainties to the public, especially in areas of complex and contested issues such as climate change, genetically modified organisms (GMOs) and nuclear energy. He discusses the role of expertise, public engagement, and the need for fostering a more nuanced understanding of scientific methodologies and their limitations (Skirbekk, 2019, p. 29).

In a modern world characterized by rapid advancements in technology, globalization, and complex societal issues, there are several epistemic challenges that arise. These challenges relate to the acquisition, validation, and application of knowledge. Modern risk-societies are “science-based” in a double sense: due to a need for a wide scale of scientific and scholarly expertise, and due to a need for enlightened citizens, especially in modern democratic societies. (Skirbekk, 2019, p. 13).

Skirbekk emphasizes that the epistemic challenges discussed in the book are not isolated issues but reflect broader societal dynamics. He explores how social and cultural factors, such as polarization, populism, and the erosion of trust in institutions, contribute to the proliferation of "fake news".

Foundations of transdisciplinary

In Manfred Max-Neef commentary in the Ecological Economics he explores the concept of transdisciplinary and its potential for addressing complex problems in various fields.

He begins by examining the limitations of disciplinary approaches in dealing with the interconnected challenges of the modern world. Max-Neef argues that the fragmentation of knowledge and the compartmentalization of disciplines hinder our understanding of complex issues such as poverty, environmental degradation, and social inequality.

In response to these limitations, Max-Neef introduces transdisciplinarity as an alternative approach that transcends disciplinary boundaries. He defines transdisciplinarity as a mode of thinking and problem-solving that integrates different forms of knowledge, including scientific, experiential, artistic, and traditional wisdom (Manfred, 2005).

Max-Neef emphasizes the importance of engaging diverse stakeholders, including local communities, in the process of knowledge generation and problem-solving (Manfred, 2005). He argues that transdisciplinarity should be participatory and democratic, allowing for the inclusion of multiple perspectives and the empowerment of marginalized voices.

The text outlines a set of principles and methodologies for transdisciplinary research, including the use of systemic thinking, holistic analysis, and the recognition of value pluralism. Max-Neef also discusses the role of ethics and values in transdisciplinary work, highlighting the need for sustainability, social justice, and respect for cultural diversity (Manfred, 2005).

Throughout the book, Max-Neef provides numerous case studies and examples that illustrate the application of transdisciplinarity in various contexts, such as sustainable development, community empowerment, and conflict resolution. These examples demonstrate the potential of transdisciplinary approaches to generate innovative solutions and foster meaningful social change.

The text offers a comprehensive exploration of the theory and practice of transdisciplinary. Max-Neef advocates for a paradigm shift in our approach to knowledge and problem-solving. Emphasizing the importance of integration, participation, and the values in addressing complex challenges such as climate change actions and energy transitions.

Ecological economics – Transdisciplinarity, by Ove Jakobsen

Ove Jakobsen, a Norwegian economist, and researcher, challenges the traditional economic approach and argues for the need to include more perspectives and subject areas in the study of economics and the environment. "Transdisciplinarity" in the book "Ecological economics" by Ove Jakobsen is a central theme that explores the integration of different disciplines in the study of ecological economics.

In his book, he begins by analyzing the limitations of conventional economic thinking and how it has contributed to ecological problems such as climate change and resource depletion. Jakobsen claims that a more holistic and integrated approach is necessary to deal with these problems and achieve a sustainable economy.

Transdisciplinarity is presented as a method for integrating knowledge from different disciplines, including economics, ecology, sociology, psychology, and philosophy. Jakobsen argues that bringing together experts from different disciplines can lead to a deeper understanding of complex economic and ecological issues. An example of transdisciplinary research is when economists, ecologists and sociologists are invited to write about the climate crisis from each of their points of view (Jakobsen, 2019, p. 25).

Jakobsen emphasizes the importance of recognizing and respecting different forms of knowledge and perspectives. He also emphasizes the importance of active participation from local communities and stakeholders in the research process. Through open dialogues and collaboration, transdisciplinary research can contribute to finding solutions that are relevant and acceptable to all parties involved.

Through the integration of different subject areas and perspectives, this approach can contribute to a more holistic understanding of complex economic and ecological problems when discussing the potential of nuclear energy in rural Norway. By promoting collaboration and dialogue between stakeholders, transdisciplinary research can also contribute to developing sustainable solutions that are relevant and inclusive.

Triple bottom line

Transdisciplinarity relates to the “the triple bottom line” in that they both recognize the complexity of societal challenges and advocate for a multidimensional approach to problem-solving. As discussed above, by embracing transdisciplinary approaches, businesses and organizations can incorporate diverse perspectives and knowledge from multiple disciplines to better understand and address the social, economic, and environmental dimensions of their operations. This can lead to more innovative and sustainable solutions that go beyond narrow disciplinary boundaries. Triple bottom line can also contribute to regulatory compliance by integrating perspective far beyond those of economic aspects making sure that the business complies with laws and regulations related to environmental and social issues. The Triple bottom line also promotes engagement with a wide range of stakeholders, including customers, employees, investors, and the community.

John Elkington, a prominent British author, entrepreneur, and environmentalist first introduced the concept of the triple bottom line in his 1994 book "Cannibals with Forks: The Triple Bottom Line of 21st Century Business.". The triple bottom line framework expands the traditional notion of business success beyond financial profits to include social and environmental considerations (Elkington, 1998).

Elkington argued that businesses should not solely focus on financial gains but also take into account their impact on society and the environment. He proposed that a comprehensive assessment of a company's performance should be based on three dimensions:

- **Economic Bottom Line:** This dimension emphasizes the need for businesses to generate profits and create value for shareholders. It involves efficient resource allocation, revenue growth, and financial stability.

- **Social Bottom Line**: Elkington highlighted the importance of considering the impact of business activities on people and communities. This includes fair treatment of employees, ethical business practices, and active involvement in social issues. Businesses are encouraged to contribute positively to society through initiatives such as corporate philanthropy, employee volunteering, and community development.

- **Environmental Bottom Line:** The environmental dimension of the triple bottom line addresses the ecological impact of business operations. Elkington advocated for businesses to adopt sustainable practices, reduce carbon emissions, conserve natural resources, and manage waste responsibly. This involves integrating environmental considerations into decision-making processes and adopting environmentally friendly technologies and strategies.

The triple bottom line approach promotes a holistic perspective on business success, recognizing that financial performance is intertwined with social and environmental responsibility. By considering all three dimensions, businesses can pursue long-term sustainability and contribute to a more equitable and environmentally conscious society (Jakobsen, 2019, p. 214).

The United Nations 17 Sustainable Development Goals

Acknowledging a fractured and inconsistent debate, we have employed UNs 17 Sustainable Development Goals (SDG) to illustrate the concerted challenges and goals that are intrinsically linked on our planet. By implementing transdisciplinarity and the triple bottom line approach, we can enhance the effectiveness and impact of these goals in social, economic, and environmental challenges. Furthermore, we evoke the SDG Wedding Cake, published by the Stockholm Resiliency Centre where they demonstrate that all economical and societal growth is ultimately contained inside the constraints of the biosphere (Stockholm Resilience Centre, 2016).

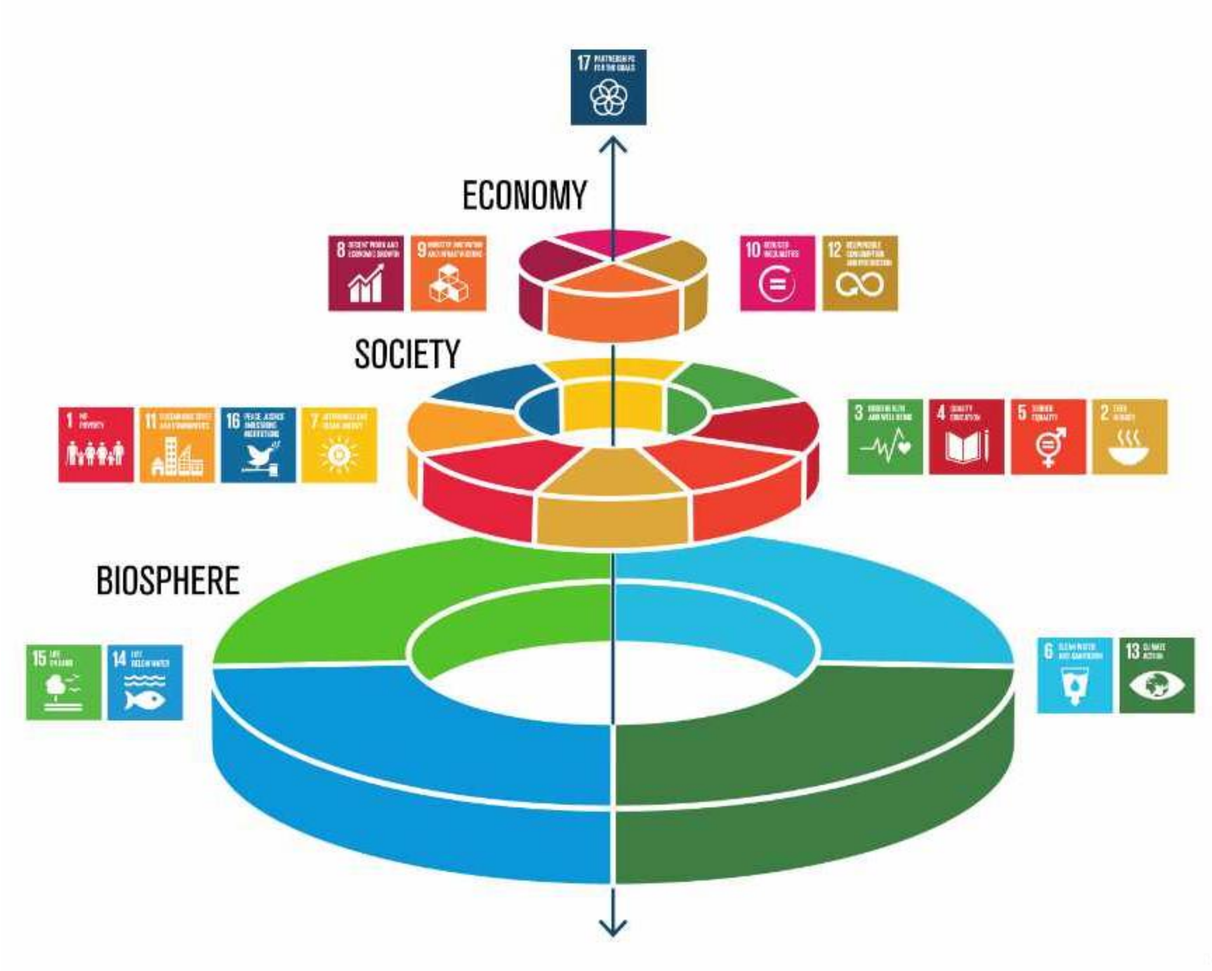

Figure 2: SDG Wedding Cake (Stockholm Resilience Centre, 2023)

The status per 2023 is that only 12% of the goals towards 2030 are considered on track, which indicates that business as usual is failing and new and alternative solutions are required (United Nations [(1)], 2023, p. 2).

The goals are very interconnected and must be solved in concert as mentioned by Skirbekk earlier. We will indirectly touch upon most of these in our discussion section later. As energy access touches upon every part of our society, and is the world's main source of CO2 emissions, we evoke the 17th goal in particular, Partnerships for the goals. The mission statement is "Strengthen the means of implementation and revitalize the global partnership for sustainable development". This will help us identify the cooperative strategies and perspectives in both our selected model and in the discussion (United Nations [(2)], 2023).

Another aspect that will not be investigated further in this assignment, but worth mentioning is how the green transition towards renewable energy and how it can lead to a possible increase of consumption. When energy becomes more abundant and affordable, industries and households may be inclined to increase their energy usage. The shift to electric heating, cooling, and appliances, for instance, is a positive move, but it could elevate overall electricity consumption.

Just transition

Just transition is an integral part of realizing twelve of the seventeen Sustainable Development Goals (SDGs) from the UN charter. It addresses that the transition needs to be inclusive leaving no one behind providing decent work, social inclusion, and poverty eradication on the path towards an environmentally sustainable economy.

EUs Just Transition Mechanism is a fund aimed at protecting and re-skilling people, sectors and regions that would be negatively affected in the process of transitioning towards a climate-neutral economy. Per today it is built on three financing pillars: the Just Transition Fund, InvestEU "Just Transition" scheme, and the new Public Sector Loan Facility with an estimated funding of €25.4b, €10-15b, and €18.5 respectively (European commission, 2023).

Considering the interconnectedness of our shared goals, the natural constraints that our economy and society operate under, and goal 17 - Partnership for Sustainable Development we've selected a model that encompasses all the above-mentioned business contexts.

Flourishing Business Canvas

To structure our data, we have employed the business model Flourishing Business Canvas (FBC). The model was first proposed as part of a graduate thesis at York University, then later expanded upon by Antony Upward and Peter Jones in 2015 (Upward, 2015) and furthermore by the Flourishing Business Canvas community (Flourishing business, 2023).

Based upon the works of Alexander Osterwalder and his Business Modell Canvas (Osterwalder et al., 2010). Upward and Jones recognized the constraints on sustainability in the current business models due to singular focus on profitability. Familiar to anyone that has used Osterwalder's Business Model Canvas, FBC also captures what the model calls the three business contexts: environment, society, and economy. This in turn is viewed through the four perspectives: people, process, value, and outcomes which will be further detailed below. Illustrating the complete value provided by the business proposal, both in terms of co-creations and co-destructions, we will obtain a holistic transdisciplinary overview.

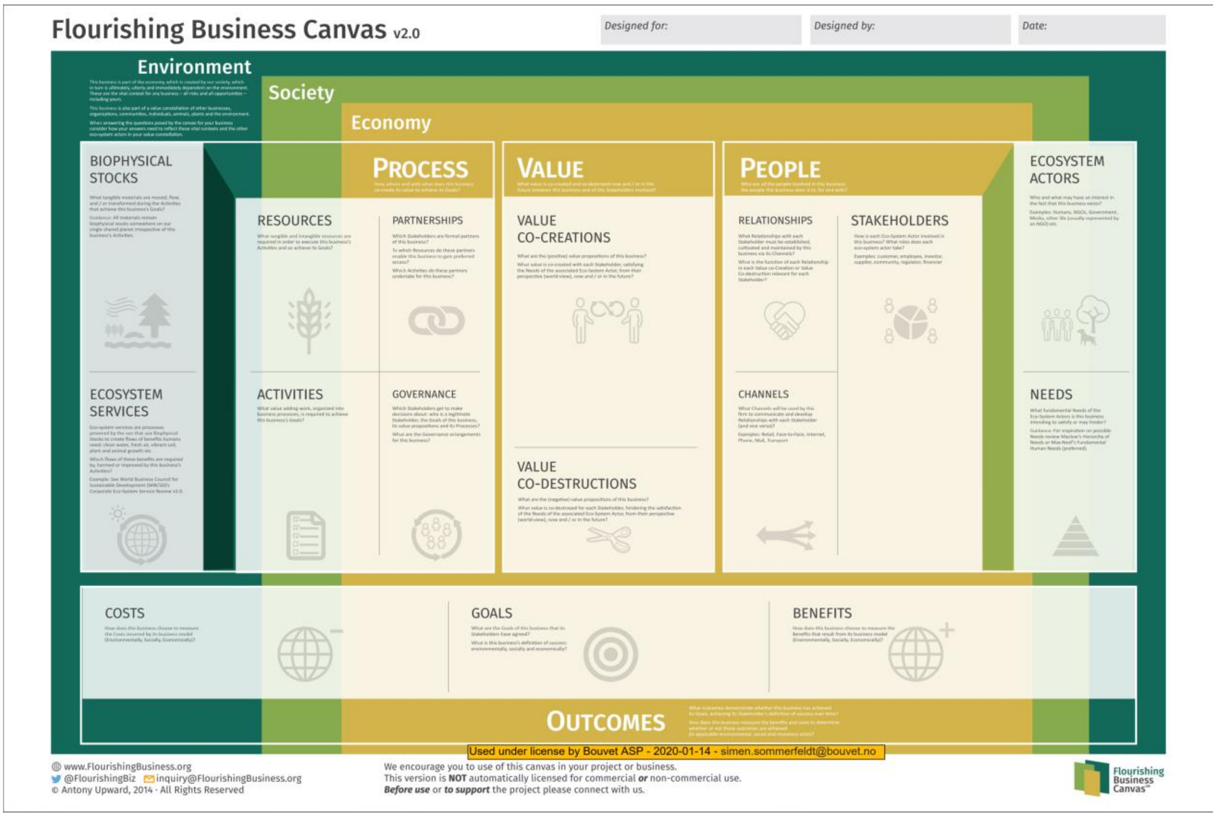

Figure 3: Flourishing Business Canvas (Kolmes E. F., 2018, p. 18)

The three business contexts

The core of the business canvas model, FBC illustrates that all economic activity happens in a societal context, and society is ultimately a part of the natural environment. This illustrates the intrinsic dependencies and interconnections that are missing in profit-centered business models.

- **Environment** is the first major addition to traditional business canvases. The context encompasses the whole model and considers all impacts proposed from implementing a business case. This is achieved by including traditionally externalized shareholders, costs and benefits that do not impact the business directly, like biophysical stocks and ecosystem actors with representatives from the natural world.
- **Society** is the context where the model maps the activities, infrastructure, stakeholders, and regulations impacted by the business case. The economic context is contained as part of the societal context.
- **Economy** provides the context of monetary, relational, social costs and benefits. Considering traditional business models, FBC introduces co-creations and co-destructions in addition to business centric profit context. This uncovers the positive

and negative impact of the business case on stakeholders with the aim of providing a more holistic overview of the total cost / benefit for society and the non-human aspects of the world.

The four perspectives

Process

The how, where and what that's needed for the business to achieve its goals and co-create value. It includes all activities, locations and tangible / intangible resources needed to create value in the business proposal, covering economic, social, and environmental contexts.

Subject	**Description**
Biophysical stocks	All physical material involved in business activities that are moved, changed, or transformed.
Ecosystem services	The natural processes that the business activities affect or are reliant on, like plant regrowth or water cycles.
Resource	Tangible and intangible materials needed for the business to perform its Activities.
Activities	Business processes proposed to generate value towards reaching the defined Goals in the model.
Partnerships	Formal Stakeholders that contribute to the business Activities or provide Resources.
Governance	The decision structure of the business could involve private, public or others.

Value

The present and future value, co-created or co-destroyed, with all Stakeholders and Eco-System Actors. Including all expected changes in value for all stakeholders involved under the three business contexts when implementing the business proposal.

Subject	Description
Value co-creations	Positive value proposition provided by the business case in relation to each Stakeholder and the Needs of Ecosystem Actors from the present and into the foreseeable future
Value co-destructions	In contrast to co-creation, covers the negative value proposition for involved Stakeholders and Ecosystem Actor Needs in the same timeframe.

People

Who and what is involved in relationship to the business proposal. A wide-ranging set of groups, individuals, and the relationships in between considered in the three business contexts. The natural world is represented through human organizations, like WWF and other naturalist societies.

Subject	Description
Ecosystem actors	The who and what that has an interest in the existence of the business. Stakeholders are a subset of Ecosystem Actors, where Ecosystem Actors also includes the natural world and/or subsets therein and abstract societal actors like media and government.
Needs	Needs of the Ecosystem Actors that the business proposal will either aim to satisfy or hinder.
Stakeholders	A subset of Ecosystem Actors and the roles they display in relation to the business proposal.
Relationships	Relationships between Stakeholders that the business must maintain to perform its functions in Value co-creation and Value co-destruction. The communication channels needed to maintain these relationships are defined as Channels.
Channels	The forms of communications that the business will rely on to establish and maintain Relationships with the relevant Stakeholders.

Outcomes

Outcomes are the business' parameters for measuring success over time. The three outcomes are all measured in the context of environment, society, and economy.

Subject	**Description**
Costs	Parameters that the business selects to measure costs incurred through operations on an environmental, societal, and economic scale.
Goals	The definition of success defined by the business Stakeholders
Benefits	Parameters measured by the business to establish the degree of success that has been achieved on environmental, societal, and economic scale.

Employing the contexts and perspectives together on the same canvas, flourish business canvas will allow us to get a structured overview of our findings and the interconnectedness of our primary and secondary data. Furthermore, we will look at the data needed to employ the model to its full extent. The Nine Planetary Boundaries model was selected to present the sustainability issue and hence we are going to describe the model in the next section.

The Nine Planetary Boundaries

To put it all in context, we have selected a model to guide the discussion to the most critical issues on sustainability. And to shed the light on sustainability we will employ 'The nine planetary boundaries model'. The model was first proposed in the 2009 paper 'Planetary Boundaries: Exploring the Safe Operating Space for Humanity' by Rockström, J., W. Steffen, K. Noone, Å. Persson, et.al. (2009) and then further developed and illustrated in 2015 (Steffen, et.al. 2015) and 2023 (Richardson, et.al. 2023).

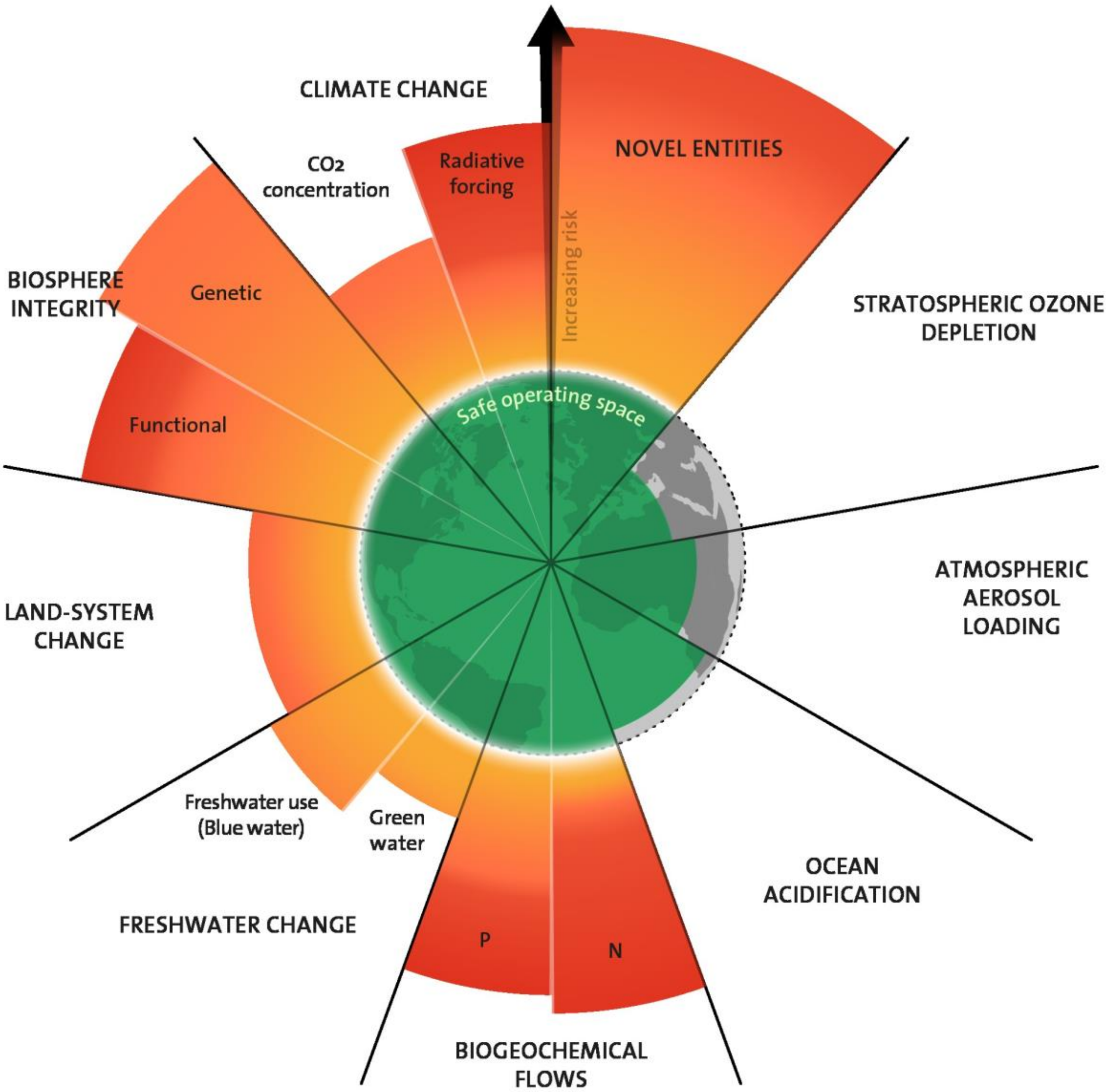

Figure 4: The Nine Planetary Boundaries (Stockholm Resilience Centre, 2023)

The model proposes the safe operating limits of our planet, and illustrates the pressure and/or exceedance of human activity on nine parameters:

- Climate change
- Ocean acidification
- Stratospheric ozone depletion
- Interference with the global phosphorous and nitrogen cycles
- Rate of biodiversity loss
- Global freshwater use
- Land-system change
- Aerosol loading

- Chemical pollution

In the discussion we will use the model to help us balance and prioritize the environmental arguments found in our data.

The same institute also provide a comparative model showing the development over time since the model was first published illustrating our rapid exceedance of the sustainable limits:

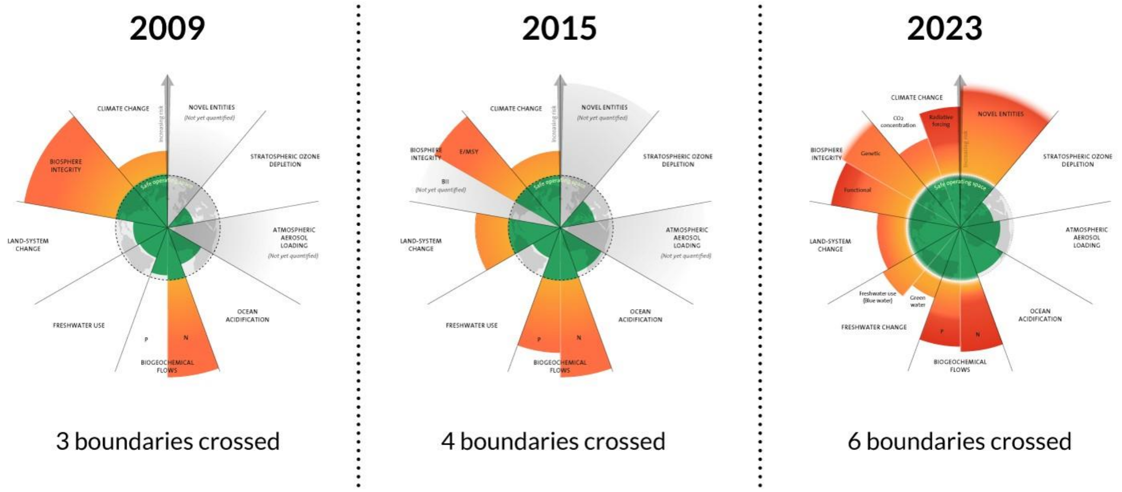

Figure 5: Comparative model of The Nine Planetary Boundaries (Stockholm Resilience Centre, 2023)

The model illustrates the rapid development of negative impact of human activities, and the urgent need for action as pronounced by the UN Secretary-General Antònio Gueterres in his opening speech at 27th Conference of the Parties (COP27) in 2023:

"We're on a 'highway to climate hell with our foot still on the accelerator. Humanity has a choice: cooperate or perish. It is either a Climate Solidarity Pact – or a Collective Suicide Pact." - UN Secretary-General Antònio Gueterres (United Nations, 2022).

Method

Methodical elements

Do nuclear energy reactors have a place in Norwegian district policy? In this master's assignment we are looking at nuclear energy's potential role in developing rural societies in Norway. The subject will be analyzed in relation to the national report (NOU: 15, 2020). The assignment itself will be formatted as an additional chapter to the final NOU 2020: 15 report.

The role of nuclear energy in the public debate is highly politicized, and arguments are often simplified or fragmented, leading to little apparent consensus. In this paper we have aimed to gather, analyze, and collectively present the arguments of the 3 topics that we find most pertinent in the public discourse: economic, environmental, and societal readiness.

Our method primarily relied on an exploratory design, of the public debate of nuclear energy, and qualitative interviews with prominent participants in this discourse. Secondary we supplemented the approach with a descriptive section where we looked at the most prominent reports and research on the topic, both domestic and international, in comparison to our primary findings.

In the following, we present the method applied when writing this thesis.

Theoretical literature

As the debate on nuclear power is so fragmented and covers a broad spectrum of opinions, we set out to employ theories that could encompass the breadth of the subject matter. We selected prominent theories grounded in ecological economic thinking and holistic views on implementation of business cases. The selected theories were also peer reviewed and reflected some "facts" that are necessary for answering and enlightening the research questions.

We needed a framework to help us identify the trade-offs when implementing a new power source and therefore we found it relevant to include the theory on weak vs strong sustainability. Our theory on weak vs strong sustainability described in this thesis is based on Zadeks (2001) interpretation where in weak sustainability nature can be substitutable with human capital and where strong sustainability trade-offs should be severely limited.

Addressing the subject of nuclear energy, you need a multidisciplinary approach so that the integrity of the sustainability practice is ensured. Here we decided on using the transdisciplinary theory described by Manfred Max-Neef and Ove Jakobsen when addressing the possible implementation of nuclear energy in rural Norway with the focus on environmental, economy, and societal factors. To frame it we decided to use the triple bottom line by John Elkington and later described by Ove Jacobsen in his book on Ecology. The triple bottom line seeks to encapsulate the economic, social, and environmental as equally important and t3herefore reinforcing an awareness all of those subjects need to be considered.

The opinion on nuclear power is broad and diverse leading to a public polarization debate where arguments are not always based on liable sources. We therefore felt that Skirbekk insights were highly relevant with his studies on the "fake news" and "post-truth" phenomenon.

Initially we planned on using Osterwalders Business canvas as a structural framework for our findings but discovered the Flourishing Business Canvas to be a more complimentary framework for the rest of the selected theory.

Ultimately, we saw a need for a model to weigh up the findings and concerns provided by the informants regarding the climate and environmental impacts. This led us to also include The Nine Planetary Boundaries by the Stockholm Resiliency Centre, which we were familiar with from the Master of Business Administration, MBA course.

The main theoretical frameworks of this thesis are then as follows:

#	Authors	Published	Title
1	Simon Zadek	2001	The Civil Corporation: The New Economy of Corporate Citizenship
2	John Elkington	1998	Cannibals with Forks: The Triple Bottom Line of 21st Century Business
3	Gunnar Skirbekk	2019	Epistemic Challenges in a Modern World
4	Manfred Max-Neef	2005	Ecological Economics
5	Ove Jakobsen	2019	Økologisk Økonomi, Ett perspektiv fra fremtiden
6	European Commission	Retrieved 2023	The Just Transition Mechanism (JTM) An official website of the European Union

Table 1: Main theoretical frameworks of the thesis

Secondary data

The initial selection was based on major reports mentioned in the discourse. The most cited reports, the UN (UNECE, 2022) and EU (European commissioning, 2023), respectively provided us with a comprehensive start to get an overview of the topic, while also having a reasonable degree of reliability.

Based on feedback from the interviews we saw the need to revisit certain statements provided by the informants. We opted to look through documentation made available by governing bodies regarding nuclear energy, and organizations aggregating data from mentioned organizations. Additionally, we also supplemented with the reports mentioned by informants during the interviews. We checked all references and reports mentioned by our informants during the interviews to validate them and to see if they could bring more valid input to the thesis.

Furthermore, we needed a reference to the most often proposed SMR in the media, the GE Hitachi BWRX-300 (GE Hitachi, 2019), to verify statements made by the informants. This documentation was available from the supplier directly.

This provided us with the following list of secondary data sources:

#	Authors	Published	Title
1	GE Hitachi	2019	Status Report – BWRX-300 (GE Hitachi and Hitachi GE Nuclear Energy)
2	Abousahl, S., et.al.	2021	Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation')
3	Nuclear Energy Agency and the International Atomic Energy Agency	2020	Uranium 2020: Resources, Production and Demand
4	World Nuclear Association	2023	World-nuclear.org
5	UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE	2022	Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources

Table 2: Secondary data sources

Due to the number of topics in the discourse, we've opted to present the secondary data in a separate chapter before presenting our primary findings.

Research design

Exploratory design

We selected the explorative design method as it allowed us to explore and understand nuclear energy in Norway from an environmental, economic, and societal perspective, and to see if it could be an acceptable source of energy in the green shift (Sander, 2022).

Exploratory design is a common practice in most qualitative research projects where there is limited knowledge by the involved parties of the study. And for the writers of this paper, we had little knowledge on nuclear energy before writing this thesis. Issues and sample strategy were continuously adjusted as we learned more, and as the project progressed. As we got more information and our knowledge of the subject grew, we adjusted accordingly. This proved to be valuable when selecting the proper questions for our data capture. This is something that also is described in the theory on explorative methods, where being flexible during the research process may lead to changes because new information gives new insights and perspectives (Ghauri & Grønhaug, 2005).

If all choices are made in advance and at the start of the assignment, it can pose a threat to the quality of its qualitative research. One of the great advantages of using qualitative research methods is that they can uncover new and unexpected knowledge, which in turn forms the basis for new issues and ideas (Johannessen et al., 2020, p. 23).

Qualitative methodology

We are three students with dissimilar backgrounds and experiences. At the start of this thesis, we had different opinions on applying nuclear energy in the green shift transition, where one opposed the idea, and the other two accepted the idea. This difference in opinions is an advantage because it could be applied as a “self-check” when writing this thesis. The researcher's personal life experience influences the informants and plays a major role in a study's conclusions (Johannessen et al., 2020, p. 52) and since we saw the topic differently between us, we felt that our biases gave us a benefit when covering the neutrality of the assignment.

The thesis research question was based on existing studies, literature, and theory in addition to lessons learned from existing and older nuclear plants. To gather the primary data, we performed in-depth interviews. Hence the choice of qualitative approach for this topic was the best option.

Focus areas during the process of selecting informants in qualitative research were not based on a large number of informants. Rather a smaller number of informants who possess relevant information and knowledge on the topic (Johannessen et al., 2020, p. 57). Selection of the informants was hence made carefully to reflect and explain the different opinions of relevant and influential stakeholders, as well as to give the scientific background on the various options. The selection of candidates for our study was based on "purpose sampling" (Patton, 2015) and defined a wide array of selection criteria to get the perspective of different stakeholders in politics, commercial, sustainability and technical fields. We were aware of the idea that selection strategy can affect the result and the information that we get from informants. In Michel Quins (Patton, 2015) selection strategy for candidates we have defined the "Intensity sampling" as a good selection strategy for our study.

Empiricism and theory

Choosing the right approach for performing the research was made early in the process to select the correct research design. This selection defined the relation between empiricism and theory.

In our thesis we answered our research question which was shaped as a 12^{th} chapter (naturally structured as a master's thesis) in the NOU 2020: 15 report regarding nuclear energy and its impact on rural districts. It was based on the report and supporting theory to get an idea of nuclear energy and how this could fit in as an energy source in rural Norway. We performed several interviews with several selected candidates which provided us with the primary data for the research questions and topic.

The data we acquired from the report and theory have been reviewed and compared to the primary data results (acquired by interviews).

Research design: Case design

This thesis is based on a case design approach as it is good for describing, comparing, evaluating, and understanding various aspects of a research problem. Case design as research design is described as "a process that involves designing a research problem, selection of a case, selection of informants, collection of data and criteria for analyzing and interpretating of data" (Johannessen et al., 2020, p. 211). We started out by defining our research problems and refined them several times under the writing process. We interviewed informants that fulfilled our requirements regarding three diverse backgrounds (scientists, politicians, and industry/power sector). After defining the interview questions, selecting the informants, and performing the interviews we proceeded to transcribing and collecting the relevant data as described in the three following sections of data collecting, processing, and analyzing.

We found that the simple case and holistic strategy was a suitable selection for this thesis. According to Johannessen, within-case-analysis/simple case study could be applied for unique, extreme, or critical cases that could uncover a crucial phenomenon. It allows researchers to investigate a phenomenon thoroughly and consider different sides of it (Johannessen et al., 2020, p. 211). Our research question was complex by nature, and especially in times of crises as now by pandemic and war in Europe. The research question is highly relevant under these circumstances where the demand for more (clean) energy in addition to being self-supplied with energy is of the highest importance.

Our strategy started by collecting relevant information from reports on the subject. Thereafter we gathered relevant information about the study, so we could get a better understanding of its setting and potential influences. We tried to engage with the text by reading the text multiple times, paying attention to various aspects each time. This helped us uncover layers of meanings. We also kept note of the social, political, and cultural factors that might have influenced the author's creation of the text. We also considered norms, values, and beliefs of the time and place in which the text was produced and that could have affected the writer’s angle.

We used the hermeneutic circle to move between understanding the parts and the whole (Stanford, 2020). Therefore, we explored existing interpretations of the subject of nuclear power, including scholarly articles, commentaries, and historical analyses. This helped us to consider alternative viewpoints and adjust our interpretations based on new insights and perspectives that emerged during the research process. By doing so we could take our various interpretations to create a better holistic understanding of the results, highlighting how various aspects contribute to the overall meaning. We acknowledge that interpretation is influenced by your own perspectives, biases, and context and this self-awareness is essential to understanding the limitations and possibilities of our analysis. It therefore helped that from early on we had three different opinions on nuclear power. We have in this thesis tried to explain the reasoning behind our interpretations, drawing on textual evidence and contextual analysis of the research.

Samples and selection criteria

When selecting informants, the main goal was to ensure that the expected data generated from the interviews would cover the proposed research questions. Employing Flourishing Business Canvas on the case study, the three topics we focused on was the economic feasibility, environmental impact, and societal readiness in Norway. With this in mind, our selection strategy was purposeful sampling, where we defined what topics we needed to cover, and then select informants based on this framework (Johannessen et al., 2020, p. 58). The selection strategy we chose to achieve the goal of this paper is key informant strategy, selecting highly qualified representatives for relevant institutions, while proposing slightly differentiated selection criteria for the informants expected to shed light on the three main topics (Johannessen et al., 2020, p. 69). The key informant strategy, assuming appropriate criteria are defined, yields deeper insight into our selected topics, and has also acted as a source of other informants for the thesis.

Due to the topic of nuclear energy being brought into the public media sphere regularly, the initial informant was vetted against the selection criteria based on their public presentation, credentials, and opinions on nuclear energy. The mode of recruitment was direct contact, referrals, by phone or e-mail, based on location or availability of contact information (Johannessen et al., 2020, p. 72).

After the initial round of interviews, the project relied on the snowball effect to uncover additional valuable informants for the project. This was included in the interview guide, asking the informant if they could recommend any other additional informants on the topic (Johannessen et al., 2020, p. 71).

Laying down a baseline, we first selected informants from the public sphere. Informants that had been involved in the public discourse regarding nuclear energy, adhering to the following selection criteria for the various categories:

- **Economy:** Economist and/or political spokesperson regarding energy economics of policies related to nuclear power generation.
- **Environmental:** Representatives from an environmental organization and/or physicist addressing the environmental issues and solutions regarding nuclear energy.
- **Societal readiness:** Representative from an academic entity providing courses in nuclear physics, established physicist in the field and/or political spokesperson on the topic.

The selected informants covered one or more of the three topics mentioned above, where each topic was reviewed on data saturation as we finalized each interview (Johannessen et al., 2020, p. 75). The selection process did however illuminate some of the epistemic challenges in today's scientific domains, as mentioned by Gunnar Skirbekk in his book Epistemic Challenges in a Modern World (Skirbekk, 2019). This will be further discussed under the chapter Strengths and Weaknesses.

Through the snowballing method we received several additional informants but did not have to review the original selection criteria, as the referrals fit well with our initial criteria.

The following informants provided us with data in this thesis:

#	**Selection criteria**	**Gender**	**Relevant education**	**Selection method**
1	CEO of nuclear energy startup and CEO of energy company	Male	PhD. in Geology and Geophysics	Public discourse
2	Mayor of district (centrality index 5)	Male	N/A	Referral
3	Professor at the institute of physics and technology, UiB	Male	PhD. in Nuclear Physics	Referral
4	Representative in Bergen city council	Female	N/A	Referral
5	CTO of nuclear energy start up and former nuclear decommission technician	Male	MSc Nuclear Chemistry	Public discourse
6	Mayor of district (centrality index 6)	Female	N/A	Public discourse

Table 3: Informants list

Data collection

Based on the key informant selection method, the interviews were performed one-to-one. This allowed the informants to go in depth on the presented topics and give a thorough set of data based on their expertise and viewpoints. While the topic of nuclear energy is highly opinionated, we interviewed the informants in their formal capacity as experts (Johannessen et al., 2020, p. 120).

To ensure that all topics were covered during the interviews, a semi-structured interview guide was used. This gave us the added benefit that the interviews resulted in comparable output even though different researchers performed the interview. The semi-structured guide did, however, present a challenge to the researcher performing the interview, making sure not to affect the informant in the process. The balance between structured and unstructured was weighed between the needs of covering certain topics and allowing the informant to divulge data that the project might not have been made aware of with a more structured approach. As the project matured, the interview guide was developed into a more structured form. But by the time we initiated the first interview we had a semi-structured guide that we employed unchanged for all informants. We sent out the interviewed guide before each interview, giving the candidate the benefit of pre-studying the questions.

The interview guide was based on the proposal outlined in *Forskningsmetode for økonomisk-administrative fag* (Johannessen et al., 2020, p. 111) and the final guide is found as the attachment “Interview guide” at the end of the paper. The general structure of the interview guide was done by the following order:

- **Introduction:** Presentation of researcher, project and scope, handling of personal data, the informant's rights in relation to the project and the interview outline. This was the step where the statement of consent, in accordance with NSD, Norwegian Centre for Research Data, was presented (Johannessen et al., 2020, p. 115). This is further detailed under "Ethical considerations”.
- **Factual questions**: Simple questions with simple answers which initiated the interview with the informant. We used hobbies, interests, or other themes to establish an initial report.
- **Introduction questions**: Questions that steered the interview onto given topics. Open-ended questions where the informant could give us personal observations and musings regarding the topic e.g. "What comes to mind when you hear the phrase "Nuclear power" "?
- **Segue questions**: Questions designed to segue the interview from the introduction into the key topics of the interview. As the topic of nuclear energy does carry emotional

attachments with many, the introduction question often carried directly into one of the key topics.

- **Key topics**: The aim of the interview was to get as much data on our defined key topics.
    - Economy
    - Environmental
    - Societal readiness

  Depending on which criteria the informant was selected by the order and depth of each topic varied from interview to interview.

- **Complex or sensitive follow-up questions**: If topics warranted follow-up questions that might delve into the complex or sensitive, these were saved or shelved until the end of the interview, to keep them from taking over or disrupting the interview. Although the topic is considered sensitive, this was not an option we had to use heavily.
- **Wrap-up**: The closing of the interview was announced ahead of the actual wrapping up. In the semi-structured form, we used a trigger for the announcement, as the interview was sometimes too free form for calling "the last few questions”. During the interview's final moments, the informant got the option to ask questions, clarify open ends and make final comments not covered in the interview proper.

Despite the differentiating selection criteria, the interview guide was common for all informants. Although the weighting of the topics differed between the informants, it facilitated the coding of data and provided an easier comparison of data between interviews. For all informants, the interview guide and statement were, as mentioned previously, offered beforehand (Johannessen et al., 2020, p. 123).

As the informants were to be interviewed in their formal capacity, the researchers aimed at conducting the interviews in either the informants place of work if possible, or a neutral location of the interviewee’s choosing (Johannessen et al., 2020, p. 122). While online interviews have become more common over the last few years, the goal was to meet in person, as this often leads to a more relaxed dynamic. By the end of the interview all four out of six interviews were conducted on the informant’s working location, while the remaining two were done online.

The researcher proposed documentation of the interview situation as recording of audio and the researcher notes. This was accepted by all informants. All relevant data was verbalized e.g.; the informants did not need to be observed by researchers, and all data is available in transcript on request (Johannessen et al., 2020, p. 117). No additional topics were introduced by the informant in any of the interviews, so all relevant data was generated between the introductory questions until wrap-up. No diagrams, pictures, or illustrations were offered by the interviewees, but several offered up sources on new theory or perspectives. The once applicable are available in the initial theory chapter or as secondary data.

Data processing and analysis

Collected data from the interviews, were processed and analyzed before being presented in the data chapter. This has led to a sizable amount of text based on several hours of audio recorded materials that have been transcribed. The transcription process was performed by transcription AI provided by the University of Oslo. The transcription service is hosted on the University grounds and is rated for processing sensitive research data. The output of this process was then manually reviewed and rectified for any inconsistencies compared to the source audio material. Processing work of the collected data was then performed, where reduction of data took place. This included extracting useful information from the big and unstructured data quantity (Johannessen et al., 2020, p. 155).

As we performed the qualitative analyses, we aimed to select and interpret the data acquired as to be organized according to our categories before data analyses (Silverman, 2006, referred in Johannessen et al., 2020, p. 155).

Following, we performed data analysis i.e., breaking down data to find patterns and material that could support in the discussion of the research questions. The general findings are available under the Data section of the thesis, and further employed in the discussion (Johannessen et al., 2020, p. 156).

Validity, reliability, transferability, and confirmability

Credibility in qualitative research covers the entire study and addresses to what extent we have produced results that are reliable, valid, and transferable.

Reliability includes consistency and accuracy and is tied to the survey and data collection; what data is used, how the data is collected, and how it is processed (Johannessen et al., 2020, p. 250). As mentioned by Johansen and outlined in our data collection part, the data collection is much dependent on the interviewee. In our data collection we sent out the interviewed guide before each interview, giving the candidate the benefit of pre-studying the questions. The data collection process focused on the three different areas regarding nuclear power production: economy, environmental and social readiness. But as our informants differed on proficiency, social aspects and interest, the answers per topic varied depending on the interviewee. Even though the questions were defined beforehand there were some questions that emerged during the interview to outline a specific aspect or to "dig deeper" into certain topic. One of the potential dangers that we were aware of with semi-structured interviews was that interviewers can mislead respondents. That is, even if interviewers sometimes provide information that helps respondents to produce accurate answers, interviewers may also provide information that can lead respondents astray.

Reliability was strengthened by giving the reader an in-depth description of the context and an open and detailed presentation of the procedure for the case (Johannessen et al., 2020, p. 250). So, a revision procedure to the case and data collection process was made available on request and included all aspects of the thesis during and at the end of the project. Reliability was also strengthened with a higher focus on all practical conditions concerning the research interview, such as the location of the interview or that the recording is clearly audible. And for that reason, we performed in-person interviews with high fidelity audio recordings. Location was preferably at the interviewee's work location, for the benefit of the interviewee's comfort.

Validity in qualitative research was about the extent to which the researcher's methods and findings correctly reflected the purpose of the study and represented reality (Johannessen et al., 2020, p. 250). We had a high focus on selecting the correct candidates for our study as the selection would have an impact on the quality of the study at large. We feel that having a wide range of candidates and representative selections from economics, politicians and the public increases the quality of the study, as we approach from different angles and highlight the transdisciplinary of the topic. The importance of being selective in our data collection based on pre-set criteria to get the right data and opinions for nuclear power was essential.

How the interviews were performed also matters to validity of the study. Lincoln and Guba (1985) refer to two techniques that increase the probability that research produces credible results: continuous observation and triangulation (the use of multiple different methods in fieldwork, e.g., both observation and interview). For triangulation to work successfully, the research question must be clearly defined, something we feel has been obtained. There is also a need to be able to spend enough time to get to know the field of study. The students involved in this thesis have a personal interest in the field of nuclear power as an energy source and were dedicated to go through the subject in dept by the time of the interview. By being up to date with the necessary knowledge, the researchers could make relevant and sophisticated research questions and distinguish between relevant and non-relevant data. Having the knowledge in the field of study they were also able to use multiple methods during the study, like observation in addition to interview to determine the interviewees level of knowledge, although this was not specifically documented in the transcripts.

For our study we allied with mentors that were considered technical experts in the field of nuclear power production that can support us in giving input of the relevance on collected data. As Johansen, Christofferson and Tufte refers to that validity can be strengthened by returning data to the informants to confirm the results, or to have competent resources analyze the data and to see if they can conclude with similar or matching results (Johannessen et al., 2020, p. 251).

The study is specific about nuclear energy in rural Norway. It has been a deep dive study, specifically on the topic. Knowledge produced by this thesis might be helpful in future research on the topic or other perspectives. Since qualitative research in most cases involves data collection from a few individuals or a group that has certain common characteristics (depth and not width), qualitative results tend to be directed towards the contextually unique, and towards the meaning or significance of those aspects of it or the social reality being studied (Johannessen et al., 2020, p. 252).

To strengthen the verifiability of a qualitative study, it is important for the researcher to present the study so that it is possible to follow a common thread throughout the process.

Reflections

Nuclear energy is a topic that despite being highly specialized, is opinionated by many. From a researcher’s perspective, this demanded extra diligence on the researcher’s part, to limit undue influence on both informants and the analysis of data. We are hoping that the differing opinions on the topic by the researchers involved counterbalances some of the personal biases that we see on the topic.

Considering the informants, we saw that there was contradictory information offered by different informants. The prevalence of factoids and references to weak and/or outdated studies in the debate makes it a challenge to reach conclusions or make a solid argument for either side of the debate.

Another challenge that we encountered was related to the complexity of the topic. Involving different elements such as economy, environment and society, besides nuclear energy, required a broad level of knowledge and research for the conclusion to be comprehensive.

Finally, the type of reactor we focused on, SMR, is a recent technology. And it has not yet been studied enough to see the full range of impacts on the environment, economy, and society. This had us relying on historical data, abstractions, and put certain limits on the level of details that were available in the discussion.

Strengths and weaknesses – design and method

This paper is subject to the inherent weaknesses for qualitative research. From a project standpoint, these can be the amount of time and resources required in both data collection and data processing. Due to the relatively small number of informants compared to a quantitative approach, the project was also more vulnerable to informants not showing up or withdrawing consent. However, the more in-depth report between researchers and informants provided the project with effective informant gathering through the snowballing strategy, providing the project with a far deeper and more precise pool of data than in a quantitative method.

From a data and findings perspective, we expected to see good in-depth perspectives on the topic, due to interviewing key informants. But due to the nature of the interviews, and the opinionated topic, the data was sometimes hard to validate. In some cases, we were provided with academic sources by the informant to support their claims. The validation of the claims and basing them on facts was important. We therefore had, if not been given solid references, searched for theory to cross examinate the claims in accordance with our theoretical framework on epistemic challenges. The data analysis was also sometimes work intensive, depending on what sorts of insights were provided by the informant(s).

Ethical considerations

As the theme of nuclear power historically has been subject to controversy in the environmental and political sphere, the ethics and privacy considerations of our informants has had even higher demand (National research ethics committees, 2022).

The ethical considerations in out methodology were based on the guidelines outlined by Nerdrum in 1998, and reiterated in the course book (Johannessen et al., 2020, p. 45) and made out the framework for out paper specific considerations:

1. The informant's right to self-determination and autonomy.
2. The researcher's duty is to respect the informant's privacy.
3. The researcher's duty is to avoid causing damage.

To ensure that the process adhered to the ethical obligations, we took several actions.

Created a project primer – what theme we are studying, backgrounds of the researchers, the scope of the paper and the context of what the received information is used for. It allowed the informants to more easily decide if they would like to give their acceptance to be interviewed for the paper etc. In the primer we also included contact information, if they at any point would like to subtract their contribution from the project. This primer is available in the attachments – "Informasjonsskriv".

The data received from the informants was handled according to satisfactory privacy standards. The nature of the method and theme made the project handle direct and indirect personal data. Data like names, sound recording, political leanings, and relations to organizations like universities, environmental was treated according to NSD (NSD, 2022) and GDPR (Datatilsynet, 2018) requirements, and stored and handled securely.

Due to the theme's nature, data and informant information was to be handled as anonymous and confidential unless specifically requested otherwise by the informant. All our informants offered to being named in citation if needed.

The information and ethical standards regarding the project were outlined in the project's statement of consent, which is based on the recommendations provided by NSD (NSD, 2022). The statement of consent is available in the attachments.

Literature review and secondary data

Moving into the findings and discussion segment of the thesis, we have opted to present our main secondary sources and data point as a primer to the primary data and discussion.

Status Report – BWRX-300 (GE Hitachi and Hitachi GE Nuclear Energy)

Due to it being mentioned as one of the most relevant reactor designs during the interviews, we have selected the GE Hitachi BWRX-300 reactor as a proxy for general SMRs in the thesis. The BWRX-300 is a Boiling Water Reactor, a proven and common reactor design based upon the existing reactor ESBWR that is in production today. The BWRX-300 is considered Generation III. The status report will provide us with indications of what specifications a modern SMR can provide.

A BWRX-300 reactor has an output to the electric grid of 270-290 MWh a year for an estimated 95% up time, including planned maintenance, for the 60-year time frame that the reactor is designed for. Maintenance is mainly associated with 2 to 4 weeks shut down every 12 – 24 months depending on maintenance schedule. The process also provides 600 MWh worth of energy in the form of clean hot water which can be employed as residential remote heating or by complementary industry. The whole site footprint, including the plant, storage and associated buildings is designed to be 26,300 m2 i.e., roughly 160 by 160 meters. A modular design, the BWRX-300 is designed to be standardized and modular to reduce cost and simplify construction and maintenance. Operations and maintenance require 75 full-time employees divided over 3 shifts which would include physicists, operators, security, and other support roles.

From a security perspective, the BWRX-300 is the 10^{th} generation BWR from Hitachi, drawing on the experience from the previous 9 generations with three layers of defense: the quality and rules regarding the plant design; the operational parameters with adjustable speeds, cooling pumps and backup power systems; and lastly, passive safety systems like redundant passive cooling systems which are claimed to be “walk away safety” safe (GE Hitachi, 2019).

Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation')

As a report commissioned by the European Union and publicized in 2021, it provides a technical assessment of nuclear energy relating to the perspective 'do no significant harm'. Due to the scope, transparency, and international collaboration of the EU we consider the report to be a fair and credible source. The report is built on the principle of lifecycle assessment, to cover the full impact from sourcing of building materials to end of life decommissioning and waste treatment (Abousahl, et.al. 2021, p 22). This will allow us to make more comprehensive statements in the discussion.

The report is sizable, and we've limited the data we will used to the following categories:

Operational lifetime covers expected lifetimes for reactors. Generation II reactors, which are the main type of reactors currently operating around the world, are usually designed for 30-40 years of operations where some can be provided with additional operational lifetime extensions (s. 123). SMRs, which is the type considered in this thesis, like the Hitachi BWRX-300 has a designed lifespan of 60 years with options for operational lifetime extension (Abousahl, et.al. 2021).

Comparison to other electric generation technologies is made relevant through nuclear fuel contributing to 25.8% of the electricity generated in the European Union. In 2017 it was made out to 56% of the low carbon energy in the energy mix (Abousahl, et.al. 2021, p. 32). The contribution to low carbon energy from nuclear in developed nations and the world is 40% and 30% respectively (Abousahl, et.al. 2021, p. 34).

Fuel will be referred to in the next reference below, Uranium 2020: Resources, Production and Demand, where we will look at expected global fuel availability for 'Open fuel cycles'. Where the fuel availability can be expanded through use of the existing but expensive 'Partially closed cycles' i.e., recycling that we have today, there are also initiatives looking at 'Fully closed cycles'. This would be repeated reprocessing of fuel and expand the global reserves to an estimate 5000 years (Abousahl, et.al. 2021, p. 103).

Safety is defined as accidents or premature deaths by a given power source per GWh produced. Regarding nuclear safety, the fundamental safety objective is to protect people and the environment from the harmful effects of ionizing radiation. (Abousahl, et.al. 2021). Historically the Generation II nuclear plants have had a safety record on par with solar and modern hydro plants when including both Three Mile Island, Chernobyl, and Fukushima.

Generation III are slated to have a safety record 2.5 orders of magnitude below that of today's solar power (Abousahl, et.al. 2021, p.172), making nuclear energy the safest, in terms of premature fatalities, of all types of energy. This is further detailed in the chapter 'Carbon Neutrality in the UNECE Region '. In terms of catastrophic accidents, defined as 30 000 casualties or more, Generation III reactors are estimated to happen with a frequency of 1 in every 10 billion reactor hours (Abousahl, et.al. 2021, p. 175).

Decommission of plants are divided into three main approaches with two separate end statuses. These are immediate dismantling after operational shut down, deferred dismantling and entombment and the end statuses are 'greenfield' i.e., they can be used with no restrictions, and 'brownfield' where an area must be closed with certain restrictions. Today immediate dismantling is favored by most decommissions, while deferred dismantling where the location is allowed to lose the most acute radiation over decades before teardown is being employed by example Germany. Chernobyl, where a reactor is permanently sealed on site, is an example of entombment (Abousahl, et.al. 2021, p. 125).

Long- and short-term waste management and disposal are divided into four main categories: Very low-level waste (VLLW), Low-level waste (LLW), Intermediate-level waste (ILW) and High-level waste (HLW). Where most countries have conventional storage facilities for VLLW and LLW, ILW and HLW require permanent storage in specialized facilities (Abousahl, et.al. 2021, p. 225). The recommended solution is deep storage in geologically stable repositories, with little to no ground water circulation. There is also a requirement for the fuel to be or not be retrievable, based on the possibility for reuse of fuel in the future (Abousahl, et.al. 2021, p. 255). Onkalo spent nuclear fuel repository in Finland is considered the first permanent storage facility of HLW and ILW nuclear waste with Sweden following closely (Abousahl, et.al. 2021, p. 258). HLWs with a high level of short-lived radionuclides and heat output, have been recommended for on-site storage on the plant for several decades. This allows for the decay of the most short-lived radiation before transport to permanent storage (Abousahl, et.al. 2021, p. 228).

Regulations are provided on a global level by IAEA (International Atomic Energy Agency) and include many important conventions regarding nuclear installation safety, maintenance, waste management and non-proliferation (Abousahl, et.al. 2021, p. 308). This in turn is the basis for the Norwegian laws and conventions regulating existing nuclear sites (Lovdata, 2023). The regulations for operating nuclear sites in Norway is based on operational licenses provided by the state. For Norway this detailed by DSA (Norwegian Radiation Protection Authority) in their report 'Veileder til de generelle konsesjonsvilkårene' (DSA, 2022).

Uranium 2020: Resources, Production and Demand

Uranium, with the U-235 isotope, is the most used nuclear fuel used in reactors today. Availability 135 years with current consumption and reasonably exploited known deposits. (NEA, 2023, p. 113). Exotic future fuels like Thorium are more abundant but will not be included in this thesis (NEA, 2023).

Waste management – worldnuclear.org

As an example of practical implementation of waste management, from an economic viewpoint, is how Sweden has dealt with the issue. They have put a unique tax on every kWh produced and sold by a nuclear plant. Per today the tax is approximately 0.67 euro cents/kWh, with 0.436 cents/kWh earmarked for future waste management. This tax revenue is held in a state governed fund until employed. (World Nuclear Association, 2023).

Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources

This report, commissioned by UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE and publicized in 2022. Originally produced as guidance for understanding of the implications and opportunities of moving to carbon neutrality in the UNECE region across the power and energy intensive industries by 2050. It provides a comprehensive overview of the potential and future environmental impacts of commonly used energy sources. We consider the UN to be a reasonably fair and a credible source. Findings in the report are presented in a comparative manner between the following energy sources per impact category:

- **Coal power**
- **Natural gas power**
- **Hydropower**
- **Nuclear power**
- **Concentrated solar power**
- **Photovoltaics**
- **Wind power**

The key categories covered in the report are the following:

Greenhouse gas emissions are CO2 equivalent emissions expected for a given energy source. This includes all activities from extraction and transport of building materials, fuel and eventually decommissioning (World Nuclear Association, 2023, p. 50). The model presents the average expected grams of CO2 equivalent per kWh produced per energy source when accounting for its total lifetime electricity productions and emissions. Nuclear has the lowest emissions of all the included energy sources (4.9 – 6.3 g CO2 eq.), due to in part low fuel transport cost and the long lifetime of an established plant.

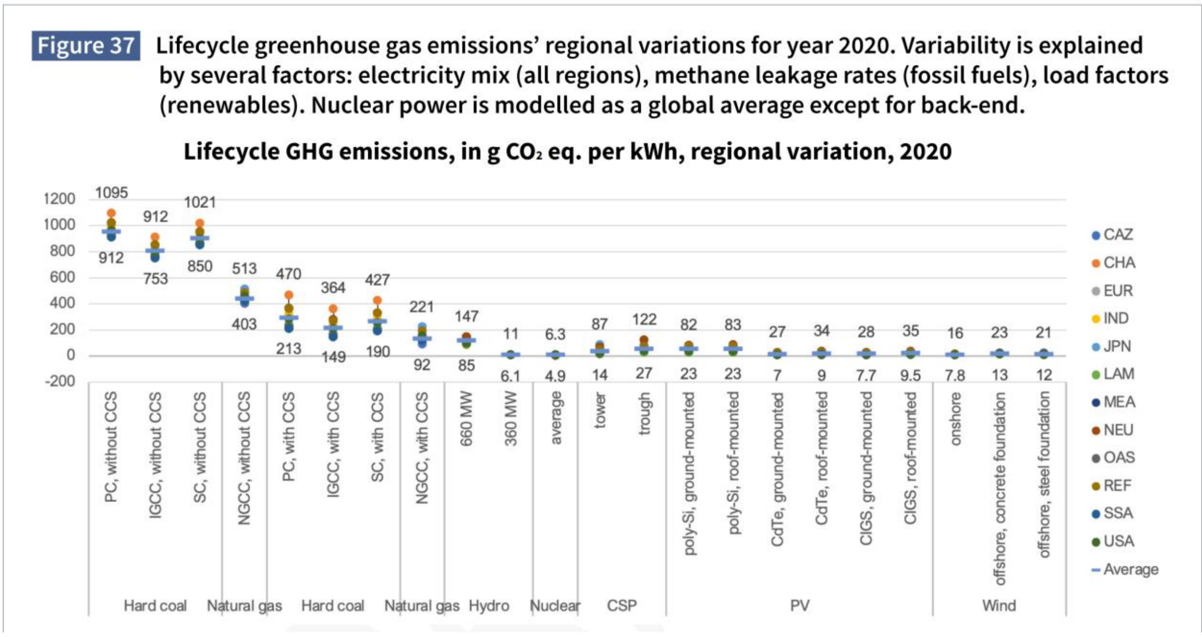

Figure 6: Lifecycle GHG emissions, in g CO2 eq. per kWh, regional variation, 2020 (UNECE, p.50, 2022)

Ionizing radiation is considered as exposure of humans to radioactivity i.e., radiation energetic enough to detach electrons from molecules. Nuclear energy contributes to 0.43 mSv a year to the public, and 4.5 mSv a year for occupational workers (World Nuclear Association, 2023, p. 7). This is mainly a byproduct of radon 222 released during uranium mining operations. Precautionary levels, as defined by the International Commission on Radiological Protection (Niu, 2011), advises against exposures over 1 mSv for the general public and 20 mSv per year for nuclear workers.

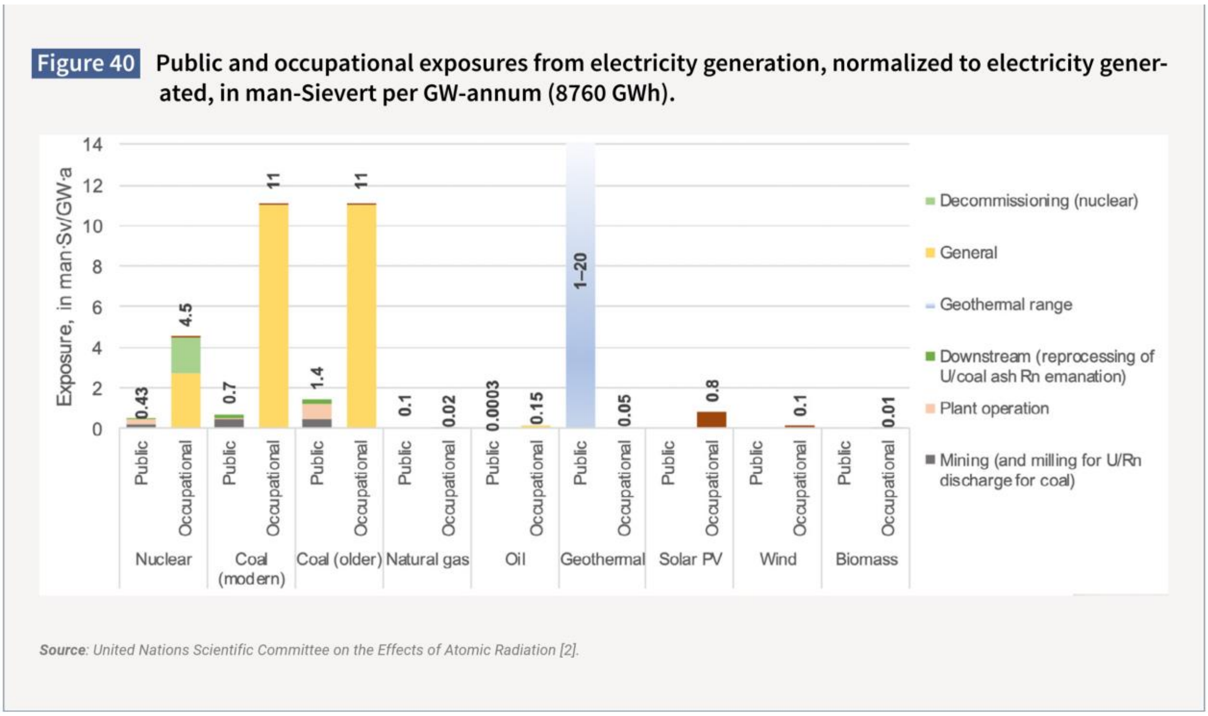

Figure 7: Public and occupational exposures from electricity generation, normalized to electricity generated, in man-Sievert per GW-annum (8760 GW) (UNECE, p.52, 2022)

Human toxicity is divided into two separate assessments, namely non-carcinogenic and carcinogenic toxicity and then summarized as human health. Nuclear energy is found to be comparable to Hydro and Wind power in terms of non-carcinogenic toxicity.

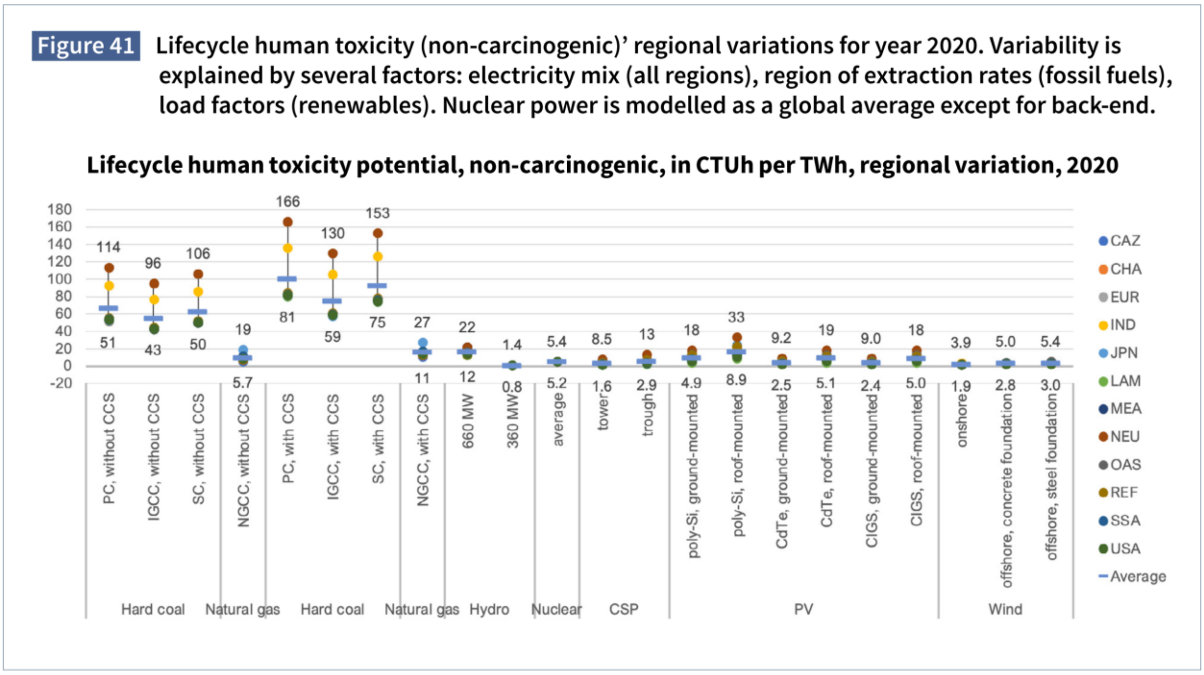

Figure 8: Lifecycle human toxicity potential, non-carcinogenic, in CTUh per TWh, regional variation, 2020 (UNECE, p.53, 2022)

Looking at carcinogenic toxicity, nuclear power is comparable only to hydro power, where both share the lowest rate of carcinogenic toxicity of all energy sources.

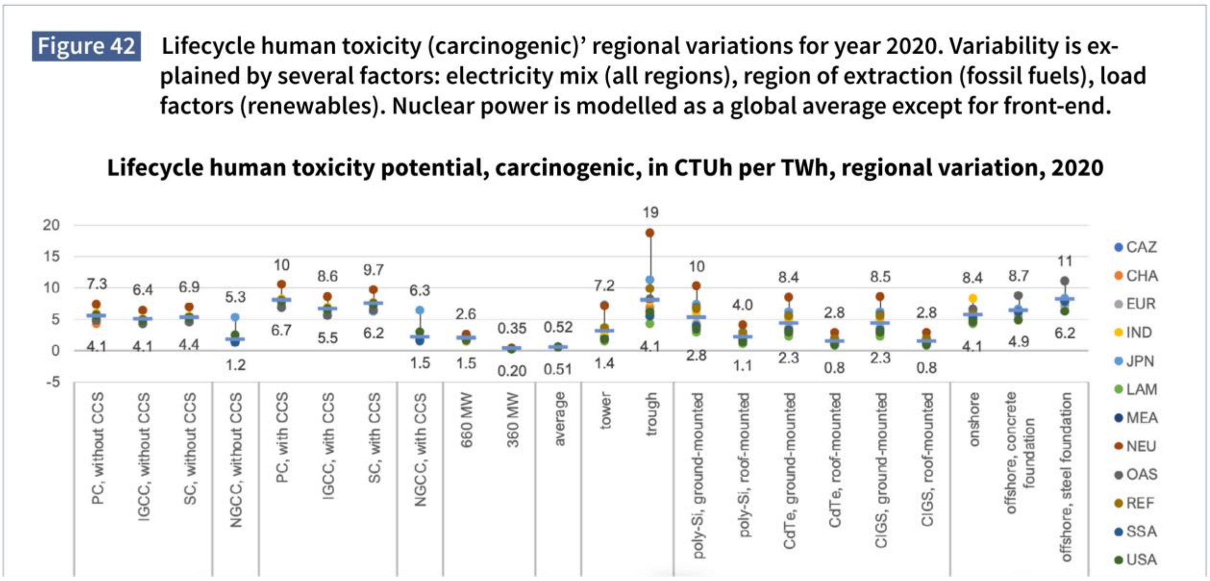

Figure 9: Lifecycle human toxicity potential, carcinogenic, in CTUh per TWh, regional variation, 2020 (UNECE, p.54, 2022)

A complete summary of impact towards human health is then presented, where nuclear is only bypassed small hydro, and selected types of photovoltaic and wind in terms of being less impactful on human health.

Figure 50 **Life cycle impacts on human health, in points, including climate change.**
Note on unit: 1 point is equivalent to the impacts (in disability-adjusted life years, DALY) of 1 person (globally) over one year.

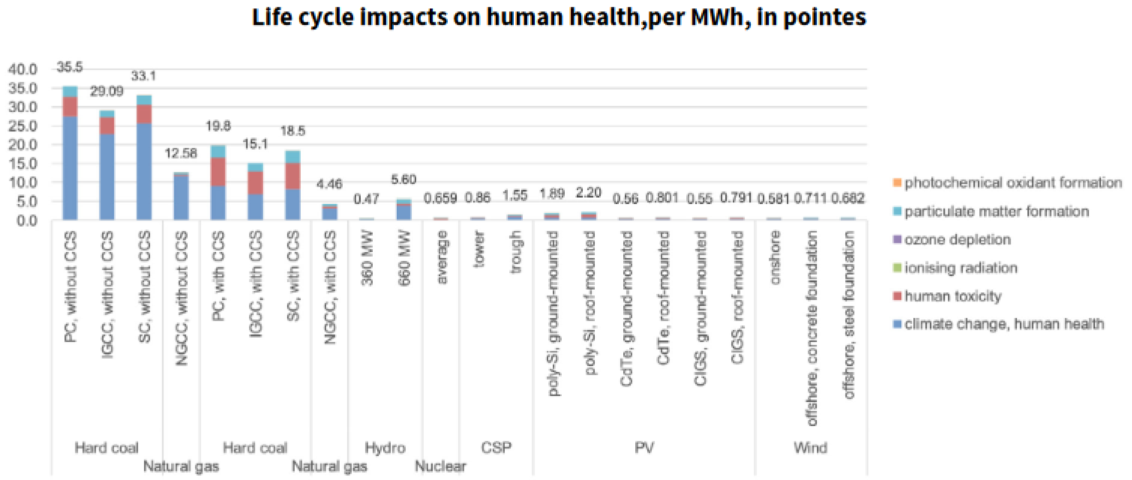

Figure 10: Life cycle impacts on human health, per MWh, in pointes (UNECE, p.58, 2022)

Land occupation includes both direct and indirect surface land use per energy source. This includes plant site and resource extraction (surface mining) in the case of fuel and mining intensive energy sources like coal and nuclear energy. Nuclear energy is here considered to be the least land intensive according to the point scale (0.05-0.07), closely followed by natural gas.

Figure 43 **Lifecycle land use regional variations for year 2020. Variability is explained by several factors: electricity mix (all regions), methane leakage rates (fossil fuels), load factors (renewables). Nuclear power is modelled as a global average except for back-end.**

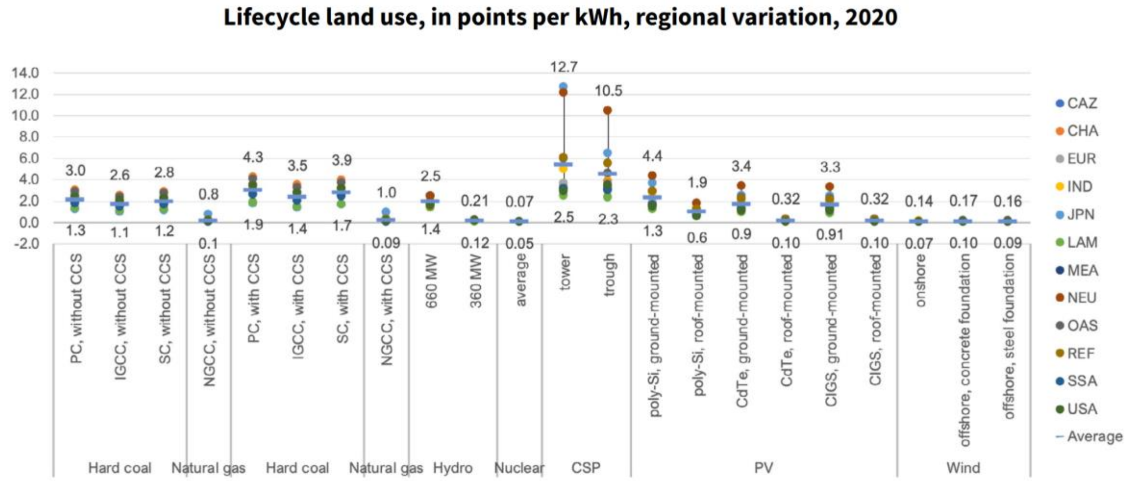

Figure 11: Lifecycle land use, in points per kWh, regional variation, 2020 (UNECE, p.54, 2022)

Water use indicates the use of water derived from the local environment. Nuclear energy has raised values of lifecycle dissipated water, comparable to other thermal power plants due to evaporation and/or the return of hot water to the environment.

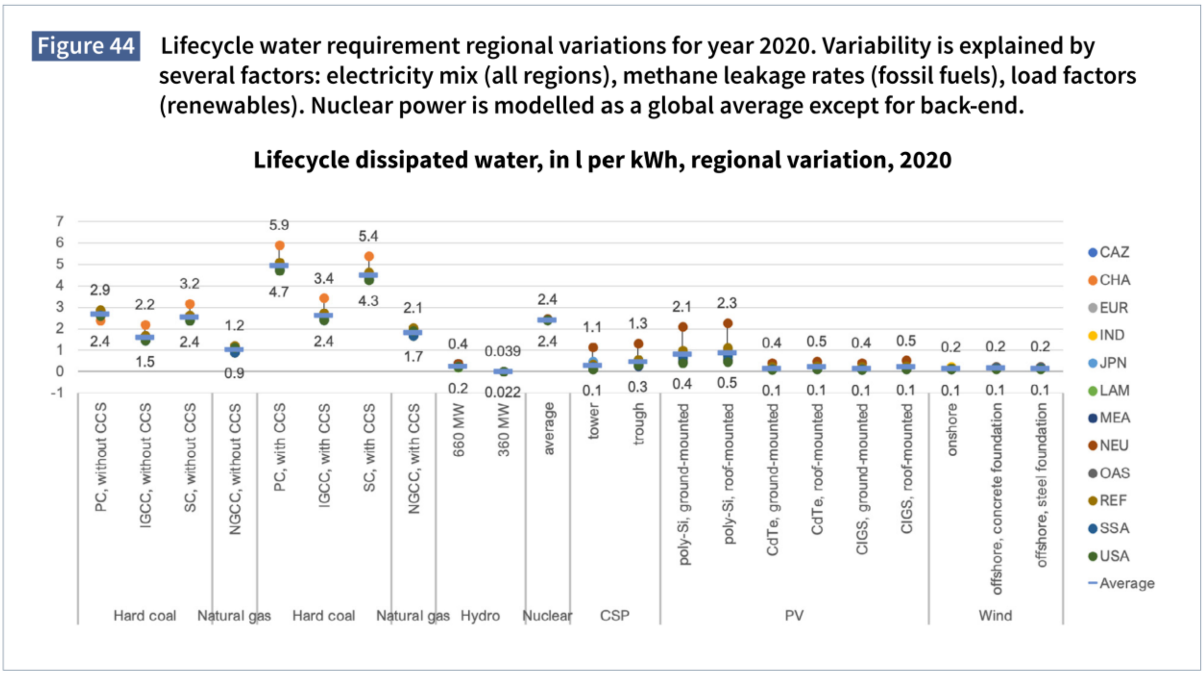

Figure 12: Lifecycle dissipated water, in l per kWh, regional variation, 2020 (UNECE, p.55, 2022)

Material resources is a calculated index based on spent material multiplied by scarcity. Strong drivers for scoring high on material sources per MWH is the need of rare earth metals and other scarce minerals.

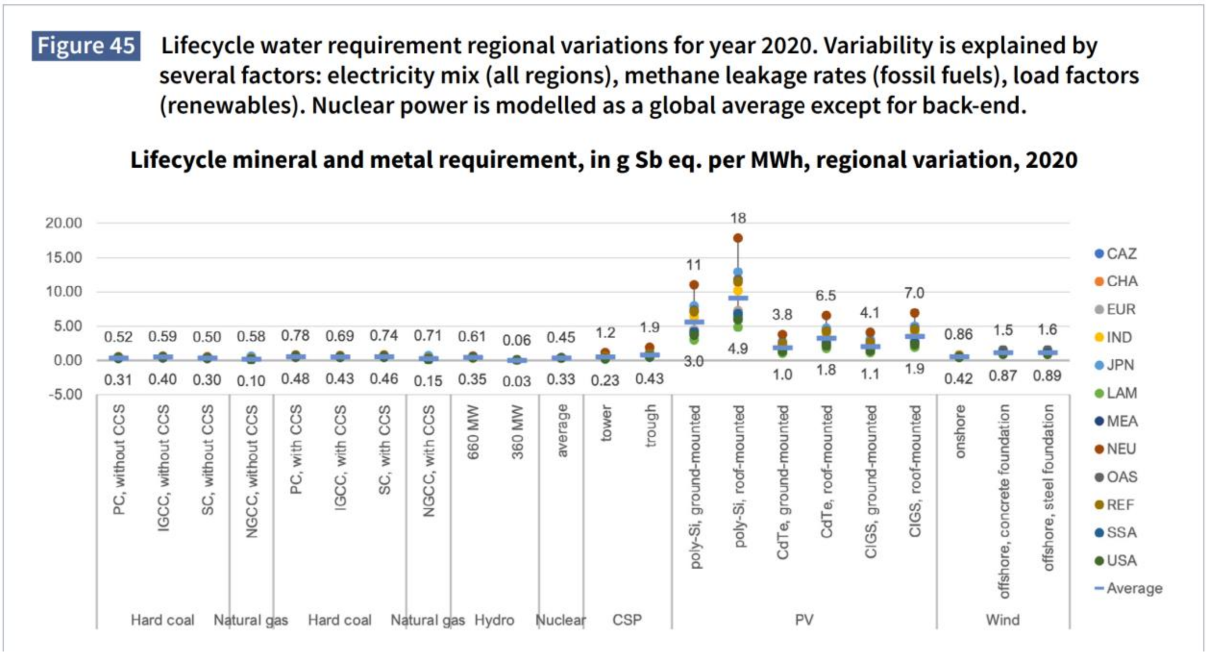

Figure 13: Lifecycle mineral and metal requirement, in g Sb eq. per MWh, regional variation, 2020 (UNECE, p.56, 2022)

The impact categories presented in the report will provide us with the data for the corresponding categories provided in the Flourishing Business Canvas Model. (UNECE, 2022).

Results – primary data

A presentation of the findings from interviews with candidates, six candidates were interviewed in total, will be introduced in this section. Accordingly, secondary data that was of great impact on the objective will also be presented. In general, it is obviously a clear distance between supporters and opponents of nuclear energy with arguments, data, findings, or questions supporting each side of the debate. Hence, two formed polars are observed during the interviews. Another observation made from interviews is that in general supporters have gradually changed their opinions into supporting side. Especially in the last years when power prices rose to record high prices and demand expectation for the coming years has grown extremely.

Questions from the interview guide were divided into four major categories: economic benefits, social readiness, environment and safety, and other thoughts or reflections.

Economic benefits

The first category represents the economic benefits. There have been many arguments for how economically beneficial it is to produce power from nuclear compared to other sources, especially offshore windmill parks and other environment friendly alternatives. One candidate refers to prices in comparison to offshore windmills and says it would be cheaper. There is also a big doubt regarding what would the exact price be. When talking about SMR plants they are supreme over other alternatives in terms of there will be a need for bigger infrastructure upgrades in cable network and stations he added. He also explains that in addition to that there would be a need for bigger investments in back-up power plants for supporting during days with no wind for instance. He mentions that besides all there must be intervention in nature for building all those mills, stations, infrastructure, back-up plants and so on.

One candidate, who had spent a lot of time on calculations of prices, explained that investments on those SMR’s construction is made for duration of (80 to 100 years) compared to windmills with expectations of approximately 20 years. The investment in windmills would be less than that for SMRs but the maintenance cost, power capacity and duration would make it much more expensive. Another point he made here is that Norway has already a great share of weather-dependent energy production which makes Norway vulnerable for weather changes if it keeps investing in weather-dependent solutions.

Waste heat generated from a 300-megawatt reactor is around 600 megawatts. This is an enormous amount of energy that could be utilized for distance heating, heating up swimming pools or water parks. The candidate explains further that "*but perhaps the most important thing is that the heat can be used to make the electrolysis process more efficient, to make hydrogen"* (translated from interview with informant 1). He explains further *"Yes, so what we see, for example, if you go out to Kollsnes, you will see that, yes, Equinor wants to build a hydrogen production plant there. Then you can make electrolysis with wind power. But if you make it with nuclear power, you can utilize the heat and make the electrolysis process more efficient. Yeah, so that's because you're using the steam, right? So that steam makes the electrolysis process more efficient by 30-40%. So, the alternative is to use electricity to make the hydrogen. But here you can use the heat, it reduces electricity consumption, it makes the process more efficient, it makes it cheaper. And so does the value of nuclear power. If you can say that it is 60 øre per kilowatt hour, then it is only the electricity. If we can use the heat for hydrogen electrolysis, the total cost will be much lower. So, what we envision is that you have a business park that needs a lot of power. And there are 37 municipalities that are in contact with us and they all have plans for business parks with energy housing. Because they're going to hire people in, right? So, one picture is that the reactor provides 75 jobs all the time. But the 2.5 terawatt hours of electricity and that heat, they will generate in industry, which will of course generate thousands of jobs. And then the International Monetary Fund has done a study where they look at this with work. What they say is that nuclear provides the best paying jobs 5% more than renewables. They provide the most jobs and they are not least local jobs. And only nuclear power provides continuous work beyond the construction phase."* (translated from interview with informant 1). So, this led to stable, high paying jobs and as one primary industry is built, the secondary, tertiary and so on industries will be created and developed around it which will be significantly contributing to the local citizens and rural districts and benefit them as told by a candidate who is mayor of one commune (translated from interview with informant 2).

On the other hand, opponents of nuclear power show their skepticism to those figures and numbers as they do not reflect the whole picture. There is one thing to build and operate a reactor and another to safely run it, guard it and get rid of the waste. They look at those numbers with big wonders. One candidate asks, *"What price tag do you put on safeguarding the waste for the next thousand or ten thousand years?".* He further asks what will happen if they need to get it from underground and confirms that there are definitely some hidden costs there. He agrees, though, that if only operating a functional light water reactor, without looking at the initial capital investment and future safeguarding costs, then it might be cheap compared to solar or wind running costs (from interview with informant 3).

Social readiness

The second category is social readiness and by that the competence, experience and conditions required. Under this category there were bigger disputes compared to the first category. With regards to availability of the right competence and experience for building, developing, and operating such reactors, there have been great split in opinions. A couple of the candidates claim that there is a huge lack in competence in Norway in this field. One candidate says the following *"Based on that, I know that Norway does not have the competence to invest in nuclear power. So, one can import engineers. Today, France is trying to renew itself on nuclear power, which depends on Chinese engineers. Even France does not have enough engineers, do not have enough capacity, so Norway has a long way to go to invest in the skills needed"* (translated from interview with informant 4).

Another candidate points out that the last two research reactors in Norway, that were not even commercial, have been shut down. He adds *"My colleagues, the reactor physicists, almost all of them are retired by now, right. So, this expertise is gone"* (from interview with informant 3). These are two samples of candidates opposing nuclear energy. On the other side some different answers were offered from candidates that are supporters of nuclear energy. One candidate explains in detail what we have and what we need to say *"Maybe not everything is in place to get started, but we have a lot in place. And then we have expertise. After all, we have IFE in Halden. We have experience with the operation of these research reactors. Then we have the Department of Energy Engineering in Halden. After all, they now have one of the world's leading competences for operating the control centers in nuclear power plants. That's why people come from all over the world. There was a rather interesting chronicle that was written in Teknisk Ukebladet now. Someone from IFE told about how they were world leaders in knowledge about nuclear energy within the areas they researched. So, there is a fairly good solid competent environment in Norway for this. But that's the way it is, we're not supposed to have construction expertise. That is not what we are supposed to work with. There we have GE Hitachi; there we have Rolls-Royce. Rolls-Royce has everything to deliver to us turnkey. GE Hitachi wants to collaborate with local industry and provide opportunities for industrial construction there. So, it's a collaboration with Framo Engineering that we've* *had there in Western Norway and that Trond Moen aims to lead for many years. So, building competence is not so central to us. It is what others have, those who will build these reactors. After all, they build them on dedicated modules in dedicated factories outside Norway. But then we can connect it to the local delivery door industry if we want. What we need is operational expertise. And there we sit with an incredible amount of expertise from the oil industry. With the operation of advanced oil installations in valued areas. We are world leaders in this. We have the Petroleum Safety Authority, we have the Norwegian Petroleum Directorate, we have the Ministry of Petroleum and Energy. So, we have created a system that works around our oil business. We understand how to safely operate these things. And we have learned from, for example, Alexander Kielland's accident. So, what we need is operational expertise. And there we can, you don't have to be a nuclear physicist to operate a modulated nuclear power plant. So, there we can further train the engineers we have today. We can initiate programs to do so."* (translated from interview with informant 1).

Environment and safety

It has been mentioned that the newer generations of the nuclear power plants are safer and optimized in comparison to older generations. This argument was mainly used by the supporters of nuclear power while opponents didn't see big or radical changes in newer reactors compared to older ones. So as for supporters' side we find one candidate explaining about the safety of operating newer reactors saying the following *"It was commissioned by the European Commission for them to assess whether nuclear power should become part of the EU's taxonomy, i.e., considered a sustainable economic activity. So, then the European Commission commissioned the EU's scientific panel to find out if nuclear power is sustainable, focusing specifically on safety and waste management. What they concluded is, existing nuclear power plants are as safe as wind power. Existing. New nuclear power plants that are being built today, so that type, European Pressurized Reactors, EPR, it is so safe that if you replaced all the existing nuclear power plants in the world, 450 nuclear reactors, replaced them with the new, modern type that is being built today, then you could expect, as a result of major accidents, an average of one death every 315 years. So, three deaths in a thousand years. And there is no other energy source that comes close to matching it. So, they say that the modern nuclear power plants that are being built today, the safest there is".* When it comes to the question regarding handling of waste, we got the following answer from the same candidate *"Then they say that the waste can be safely handled by storing it a few* *hundred meters into the ground, as they do in Finland. And then they say that in principle there is no difference, with CO2 storage as part of the taxonomy. Because that can also leak out in the future, right? Only with future generations, we are concerned about that. So, we don't talk much about CO2 storage. But of course, it can happen. And then we may have a leak from an underground warehouse. And then they looked at this, they used Finnish studies that have been going on for tens of years, and what they say is that if there were to be a leak from such an underground warehouse in the distant future, the radiation dose in the area would be unset. Those who live there, eat their food from there, drink their water from there, the radiation dose they are exposed to will be much lower than the natural background-radiation. In fact, right down to the level of radiation you get from eating two bananas a year. So extremely low"* (translated from interview with informant 1).

On the other side we find different opinions of opponents. One candidate answers the safety question saying that this is a reactor and unforeseen things may occur, hence we have operational accidents that are unavoidable. He further explains that in Fukushima there was overheating of the fuel which led to explosions, while in Chernobyl there was a human mistake. He adds that the design could be enhanced by applying different technologies and enforcing shielding and so on to reduce the fire due to explosion, but there is no way of completely negating the risk. On the question regarding the waste, he answered that you must take care of the waste *"for at least 1,000 years before toxicity drops and stays constant for almost one million years*." He adds *"And you cannot get rid of it … because one of the long-lived isotopes is iodine, which is a fission product".* He further explains that there would be need to safeguard this waste for a long time or drill a hole and store it there at 500 meters to 1000 meters under surface. Finally adding that this is a risk that we delegate to future generations (from interview with informant 3).

Other thoughts and reflections

Among other thoughts and reflection questions it has been asked if we have the right legislations in Norway. One candidate from opponents tells *"No, Norway never had a commercial, industrial reactor site. We have, of course, Statens Strålevern ... they know how to certify and license, you know, medical accelerators ... for isotope production".* He mentions that Norway took care of the reactors and licensing, but underlines that those were not commercial reactors but research reactors, and that they had basically zero energy output. There will also be a need to prepare evacuation plans. He gives an example of a reactor on

Long Island in New York, where one reactor was stopped and ruined because it lacked an evacuation plan. *"So, Norway would have to develop, I mean, procedures and protocols for licensing such large commercial reactors"* (from interview with informant 3).

A sample from the supporter's side on the question on Norway's readiness in general for nuclear power, we have the following answer *"Yes, the first thing, how ready are we. The very first thing is laws and regulations. Do we have it in place? Yes, we have. We have the Atomic Energy Act, we have the Energy Act, we have the Radiation Protection Act. We have regulations that are exactly the same as we have in the UK. We have much of the same legislation as other countries that operate nuclear power. It is because we have had these research reactors. We have previously had a Department of Energy Engineering called the Department of Atomic Engineering. That was why it was established. So, legislation was established in Norway for these things. Maybe not everything is in place to get started, but we have a lot in place"* (translated from interview with informant 1).

On question on how ready the majority of population in Norway is for nuclear energy we got the following answer from one *candidate "There was a survey that Opinionen carried out a few weeks ago, where 51% of the population answered that they are in favor of building nuclear power in Norway. The way the debate is going now, more and more people are becoming positive. So, we believe that it will work. We have made more progress than we dared to hope for when we started just four months ago. So, we believe that it can go this way in May, when the Stortinget will vote on whether to investigate nuclear power. It can go both ways. But if you look forward to the parliamentary elections in two and a half years, I am quite optimistic"* (translated from interview with informant 5).

Regarding the opinion of people in one commune that was considering the nuclear power option, the major said the following *"in addition to the fact that we have had a round in the municipal council which is open on the website. Just go in and see. There are several people who have seen the session about nuclear power that has happened at some of the birthday times in one or two years. So obviously I have an interest. When I meet people on the street, no one has actually come up to me and said that I am the opposite. But I find that people are very happy. I was at the debate then, among other things. It was early January, so it hadn't ripened at all. After all, I almost didn't have the municipal council yet. But there was such massive support in relation to... No one came and was angry and upset. I had expected that.*

Quite powerful. I thought I was selected in the autumn, so it might be a bit broken here" (translated from interview with informant 6).

This was a sample of selected answers to some questions from interviews where different candidates offered different opinions reflecting in general their own standpoints. It is clearly a reflection upon the side they were in terms of supporting or against nuclear energy.

Flourishing Business Canvas

Preparing for the discussion, we've employed the Flourishing Business Canvas to structure the findings according to the business contexts. Full sized canvas is available as Appendix 5: Flourishing Business Canvas.

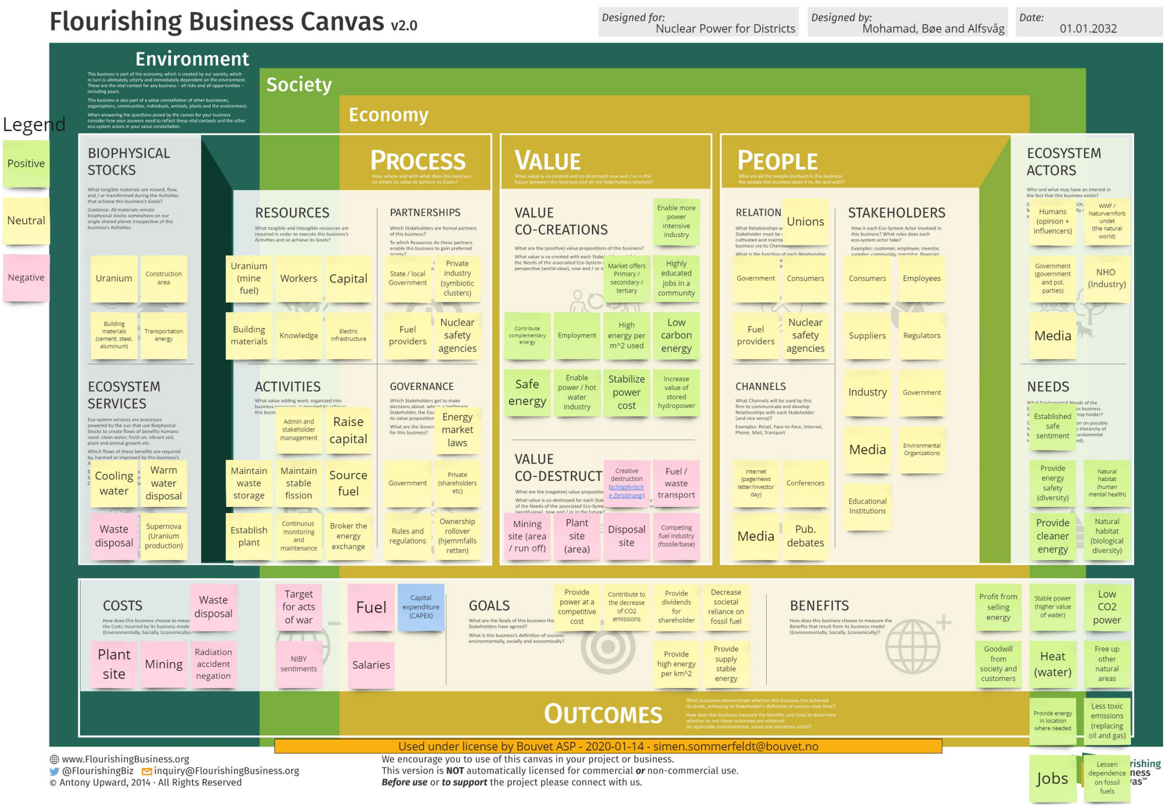

Figure 14: Flourishing Business Canvas

Discussion

In this discussion, we explore the complexities of nuclear energy within the context of rural Norway. In accordance with the theory of epistemic challenges, we recognize the need to address certain national level topics due to their broad impact like output of energy, primary fuel, transport, nuclear waste, and storage. Our exploration is also guided by a theoretical framework rooted in concepts of strong and weak sustainability, transdisciplinarity and the triple bottom line. Furthermore, the based theory is looked through the lens of the flourishing business canvas, where we navigate the complicated interplay between these facets, seeking to explore the potential, complexities, and trade-offs essential to the adoption and integration of nuclear energy technologies.

The debate surrounding nuclear energy adoption is inherently complex. Given its capacity to generate large amounts of power, coupled with its concerns regarding safety, environmental impact, and economic viability. This is especially of relevance in the rural landscapes, as it is often equipped with distinct socio-economic structures and environmental vulnerabilities, serving as both focal points for resource development and the exploration of energy needs.

Within this, it is important to evaluate not only the immediate economic gains but also the long-term sustainability and societal implications, bringing on a holistic understanding that goes beyond the disciplinary boundaries. This is also reflected in our performed interviews where we have recognized the importance in the diverse aspects of knowledge domains and stakeholder perspectives by engaging interview informants with and from diverse backgrounds. This has helped us to foster a comprehensive understanding of the complicated link between nuclear energy implementation and the broader socio-ecological challenges it brings.

Central to our analysis is the theory between strong and weak sustainability paradigms, which serve as fundamental touchstones for assessing the viability and resilience of nuclear energy initiatives in rural contexts. Here we have used the framework in assessing the impacts of nuclear energy, by incorporating the economic, environmental, and social metric. This will help us foster a holistic evaluation and enables us to appraise the trade-offs and synergies that emerge within this triple bottom-line framework (Elkington, 1998). Furthermore, this is also underscored by the UNs 17 goals where we can find the need and call for cooperation. It also provides a platform for articulating the potential avenues for mitigating adverse impacts while amplifying the positive contributions of nuclear energy to rural development securing a "just transition".

In navigating these intellectual terrains, we are acutely aware of the epistemic challenges that permeate our modern world. The exponential growth of information/disinformation and the complexities of emerging technologies necessitate a reflexive approach to knowledge creation and application. Within this context, the flourishing business canvas emerges as a valuable tool for structuring the thesis.

Then after discussing the three overarching topics, we bring it together in a final chapter where we are bringing it together into a holistic view. Through the combination of these theoretical foundations, we embark on a comprehensive discussion, seeking to understand nuclear energy role in rural Norway, and to offer insights that are both theoretically robust and practically relevant to the challenges and opportunities that may lie ahead.

And as there is a substantial overlap of topics under each of the three perspectives the economics chapter serves a double role of introducing most of the topics and terms. Topics and terms that will then be revisited in a different perspective under later research questions.

Research question 1: Economy

The establishment of a nuclear power plant represent a central change in Norway’s energy portfolio, bearing significant economic implications. This first research question endeavors to comprehensibly evaluate the economic landscape surrounding the establishment of a nuclear power plant by seeking to address the key aspects of ensuring economic viability. So before going any further we would like to reiterate the main question we would like to illuminate in this chapter:

Pros and cons with nuclear energy plants contributing economically on the national and district level?

Central to this is the discernment of the primary economic goal underpinning the decision to invest in a nuclear power plant. As seen below the informants address not only the desire for energy security and stability but also considerations for sustainable economic growth and job creation. But also, the implications and risks that may come with the establishment of a nuclear plant.

The structure used first lets the informants address the business case with goals and motivations before the challenges being addressed. Followed by their proposal of a practical setup and the economic benefit of the energy source.

Goals

The economic goals, as stated by the two representatives from the nuclear energy industry, are to provide stable competitively priced electricity to meet the estimated future energy demand. Proposed as a stable base load on the power grid, informant 1 detailed the proposal of providing continuous energy throughout the year, making up during the winter the losses projected for the summer months. Regarding the climate goals of 2030, informant 5 pointed out that the timeline for a finished plant was expected to be in the 2040s from a realistically viewpoint, contributing to the climate goals of 2050.

Benefits

From an economic viewpoint the benefits are divided between the ones for a future nuclear energy company and the communities hosting the plants. Summarized by informant 1, the benefit for a company is the expected levelized cost of electric (LCOE) NOK 0.60 per kWh over the lifetime of the first plant, trending downwards towards NOK 0.40 per kWh or lower for additional future plants. The expectation for the downward trend was due to the developing cost learning rate. The business proposal was further detailed as running the plants at full capacity all year. The higher margins during winter would make up for expected losses during summer, with the expectations of the average annual market price > LCOE per kWh. The output for the proposed BWRX-300 reactor would be expected to be 300 MWh, discounting maintenance downtime, with an additional 600 MWth of thermal energy available as heated water (GE Hitachi, 2019).

Communities would see an increase in available jobs estimated to be 75 full-time positions per plant according to the specifications provided for the BWRX-300 reactor. These positions range from specialized nuclear physicists and controllers to security and general maintenance, providing income to the district. Informant 1 provided an additional comment regarding jobs associated with nuclear power, that the International Money Fund (IMF) had found those jobs to pay 5% more than comparable jobs in renewables. The politically involved informants i.e., 2, 4 and 6, regardless of their general views on nuclear energy, found this job creation to be a positive prospect. And as mentioned in the EU report (2021), referring to the proposed lifetime of the BWRX-300, these benefits would be available for 60 years or longer accounting for optional lifetime extensions to the plants (GE Hitachi, 2019).

Value co-creations

Outside the immediate benefits for energy company shareholders and the involved community, several informants talked about the value co-creation potential found in deploying SMRs. The findings related to three broad categories: impact on the electricity market, public economic impact and complimentary industries and effects on the community.

Informant 1 summarized several assumptions on the electricity market. Having nuclear energy running at a standard baseload all year round would stabilize electricity prices. A side effect of this would be that hydro power would potentially rise in value, as hydro plants could use more of their water reserves during high electricity price periods than they can today, where they must provide the majority power to the Norwegian grid all year around. Rounding out the argument he pointed out that nuclear, water and wind play well together regarding stabilizing the grid, as they are complementary as a baseload, highly customable and periodic power source respectively.

Furthermore, this ties into the public economy which informant 1 and 5 provided more detail on. SMRs would be possible to place where power is needed, to a high degree eliminating the governmental cost of building new and expensive power infrastructure which has proved to be an issue with several competing power sources like solar and offshore wind. As a representative for district governance, informant 6 pointed out that estimating new power infrastructure was a major bottleneck in both establishing competing power sources and establishing new power consuming industries. And lastly a proposal made by both informants 1 and 5 regarding the long-term value for the district in question was that in the case of private investment. After the 25-year investment horizon, assuming a 7% discount rate and when private investors have written of the initial investment, the energy would be available for the public at a severely discounted price.

The third general category covered the value co-creation in the district. For this category informant 1, 2, 5 and 6 contributed with inputs. Initially constructing the plant would require an estimated 3 – 4000 man-years. As the plant comes online, with its 75-job requirement, tertiary jobs in the district would become available as with influx of highly skilled workers moving to the district. This would also lead to a more diverse and robust mix of expertise in the district's economy. And with the availability of 600 MWth of hot water available from the reactor, complimentary industries could become viable in the surrounding area. A few mentions were: district heating, swimming halls, salmon farming / indoor farming, hydrogen electrolysis, bio – and oil refineries and more. Any industry who requires heat below 200 degrees C.

And in the realm of potential future value, informant 3 outlined the use case of employing spent nuclear fuel as fuel in generation 4 reactors. But he was quick to point out that this was not available technology today and might never be realized in practice.

Cost

The initial construction of a nuclear power plant can be expensive due to the complexity and safety measures involved. Costs include site preparation, equipment procurement, and the overall engineering and construction process. Where the LCOE of nuclear power can be competitive compared to other technologies, establishing a nuclear plant is known for being notoriously capital intensive. According to informant 5, the selection of SMR as plant technology was in part for the capital cost was "10 billion NOK rather than 50 billion" that you might see with a traditional > 1 TWh nuclear plant design. There is still some risk related to this figure, according to informant 3, as the proposed Hitachi BWRX-300 has yet to be built and production at scale achieved (GE Hitachi, 2019). This will be an economic risk going forward that'll be mitigated as the initial prototypes are in place and the supply chains are established. The representatives from the nuclear industry, as mentioned earlier, accounted for a LCOE of 0.60 NOK for the initial for the first reactors built, then trending downwards as construction cost would decrease. Historically two thirds of the construction cost of a nuclear plant is the financing cost. This weighed in favor of selecting an SMR design, as the smaller size is expected to be finished in 3 to 4 years, compared to the median construction time of a traditional reactor that is 7 – 8 years. Learning points from recent reactors going over budget was mentioned in relation to build time. The major pitfalls were building with little experience, starting while designs were only 40 – 50% finalized, and the delays and issues with governmental licensing stemming from this. "The key is to have a finalized design already tested" according to informant 5. While informants 3 and 4 did not believe in the feasibility of establishing competitive Norwegian nuclear power, informants 1, 5 and 6 believed that this should be achievable even without subsidies received by competing technologies.

From an operating perspective two main costs were uncovered: operations cost regarding staff, and costs associated with fuel and fuel supply chains. Albeit one informant strongly suggested that due to scarcity the price of fuel would skyrocket over the next decades, there was a consensus among all interviewed that per today the operational costs were considered very competitive in the modern energy market.

Looking into the future, the cost of safe waste disposal and decommissioning was viewed as challenging. Two main proposals were given to address this issue. The first was proposed by informant 5, where he detailed the Swedish model where each kWh sold from a nuclear plant had an affixed tax earmarked for future waste handling to hinder. This was especially important in the case of private nuclear energy companies, to stop externalization of cost as has happened in the fossil fuel industry. The second was a proposal for cost sharing with neighboring countries, i.e., Sweden and Finland, whom both has permanent storage solutions under development, albeit this is currently limited by law in the two respective countries (Regjeringen 2, 2021). However, two informants viewed the challenges as practically unsurmountable, and expressed worries that private companies might try to externalize this cost – handing the responsibility over to the communities of the future.

There would also be costs associated with more miscellaneous activities, where the cost burden was not specifically defined. General analysis of operational plans, achieving licensing for energy production, and establishing and implementing evacuation plans were the ones mentioned. System integration would also have a cost, but this was agreed to be minor in comparison with other power generating technologies.

Value co-destruction

An increase of available nuclear power would also have negative impacts for certain stakeholders.

Due to the large capital investment, much of the funding would be held up in building plants. This could alternatively be used towards activities like energy saving measures, energy effectivization and reduction of electricity consumption. On a general note, informant 4 proposed that reduction of energy usage should always be prioritized before energy production. This was extended to prioritizing what Norway already have, and spend the money on refurbishing hydro, and installing solar and wind.

In reference to the increase in value of hydro power, as mentioned earlier in value co-creation, nuclear would be likely to affect the earning potential of intermittent renewable energy sources (IRES) like wind and solar. By nuclear providing base load to the electricity grid, there would be less price fluctuations for IRES to benefit from, as the output from IRES cannot be managed in the same way as hydro, gas, and similar technologies.

Activities

Informant 5 referred to the IAEA Milestone Approach (IAEA, 2023) as the international standard for activities needed to be taken to establish nuclear power in a country. The economic activities before a nuclear power plant would be established were according to informant 1 and 5 the following. The first step would be raising an approximate of 10 billion NOK for the initial capital investment. Then there would be concurrent investment intensive activities: build the plant, hire, and train personnel, and establish the infrastructure for transporting fuel and waste before the project would finally start to turn a profit.

Resources

Accomplishing the proposed activities encompasses large amounts and a breadth of material and immaterial resources, which in large part are mentioned as cost. Informants 1 and 2 provided the most in-depth summary of resources needed.

First and foremost a project would need initial funding. For the construction phase there would be a high demand for construction, safety, and nuclear domain knowledge. The bulk of construction would be on site, using large amounts of concrete and high-quality steel in addition to standard construction materials. During the installation stage the pre-constructed modules of the SMR reactor, turbine and surrounding systems will be needed. Immaterial resources would then have to be in place before production could occur: evacuation plans, licensing, and approval, as mentioned by informant 3.

Operations would see the need for staff: nuclear physicists, operational personnel, security, and janitorial services. Production of energy would see a continuous need for water as coolant, and a need for refueling of enriched uranium-235 on a semi-annual schedule with the associated supply chains.

Tying this together, the remaining major resource is access to the electricity infrastructure and power market, but with limited overhead, according to informant 5, as the plant is expected to be placed where infrastructure is already present.

Governance

With the capital and operational expenditures covered, the issue of governance was introduced to our informants. This would be the decision structure for a future nuclear plant and is at first glance divided on the public to private axis. Due to the nature of nuclear energy, and the level of regulations and licensing that it entails, we decided to also include the governmental oversight in this chapter. And we found that all the informants were unified in that they wanted a highly involved government. However, as details emerged, we found that what the informants meant by highly involved government varied greatly.

Everyone agreed that the government would have the overarching mandate regarding governing nuclear plants through rules, regulations, and licensing. Informant 1 pointed out that this governing framework was already in place (Lovdata, 2023), due to the operation of Norway's research reactors based on standards from IAEA as detailed in 'Veileder til de generelle konsesjonsvilkårene' (DSA, 2022). Informant 3 did point out that the licensing frameworks were still lacking regarding running commercial reactors, where informant 5 proposed that Norway should use the licensing frameworks already developed in countries like Canada and Sweden. Informant 3 furthermore pointed out that before any operations could begin there were additional plans that needed government approval, like evacuation plans and waste treatment.

From an ownership perspective we saw a larger divide between our interviewees. On one end of the scale, informant 6 assumed that the only way forward was via private companies. And she was ready to give a go ahead to companies that could present a good business case that did not need subsidies to be realized. The representatives from the nuclear industry provided a more centred view, where they proposed private ownership of nuclear plants, but invited both governmental and local ownership into the mix. They both stated that it would be preferable with local involvement, so districts were encouraged too co-own. Informant 5 also proposed escheat on plants after a certain number of years, modelling Norwegian hydro power, handing the plant over to the district after private investors had received return on their investments. On the other end of the axis informants 3 and 4 held that all nuclear operations have to be state owned, mentioning Swedish Vattenfall as an example of a state-owned nuclear energy company.

With the substantial time horizon of waste management all informants viewed it as a separate entity regarding governance, and all were in favour of governmental or international ownership of the process.

Stakeholders

Outside the governance of the lifecycle activities, there are many additional stakeholders relevant to the production of nuclear power. Regarding the public at large, informant 1 described how interest had exploded in the public sphere in the last year. Underscoring his point, the same influx of interest was also one of the reasons that we chose this topic for the thesis. And, why there were many available informants to contact in the public discourse at large. Even as an opponent of nuclear power, this increase of public interest was what led informant 4 to seek out more information regarding the topic earlier this year.

From this there are several stakeholders that pertain to the economy of a plant. Two out of the three public officials interviewed stated an interest on behalf of their districts, with informant 5 summarizing the potential districts as *"most districts in Norway need 300 MWh rather than 1 500 MWh."* At the time of the interview the representatives from the nuclear industry could inform us that they had been contacted by 37 districts with a request for information. One of the district majors considered it good politics to have available power in districts, as this attracted industry. Promoting a more robust economic mix, it could provide both nuclear plant jobs, industrial jobs, and service jobs in the greater area. Even the retractors of the technology in general agreed with this statement.

On a national level the stakeholders were found inhabiting several different roles. Construction and the operations of a plant could involve a breadth of economic factors. GE Hitachi / Rolls-Royce and local industrial construction companies would have an interest in the construction of plants. From an operation standpoint local Universities, providing educated resources, and operational engineers would be relevant. The representatives from the nuclear industry mentioned retraining controllers from the oil industry as a route to staffing plants, indirectly supporting the intention of EUs 'Just Transition' (European Commission, 2023). However, this was strongly disputed by informant 3 and 4, stating that *"all relevant expertise is gone and retired."* Further detailing the statement, they both said that the real stakeholders would be foreign nuclear physicists, chemists, and engineers, as we would have to bring them in from abroad. For the public at large the access to additional electricity also affects the national sphere. And the public would have a vested interest in the prevention and handling of a possible contamination event, as mentioned by informant 4. And as mentioned earlier by informants 3 and 4, and to a lesser degree the remaining informants, the government could have a stake in the form of ownership. This would also apply to the storing and potential need for securing future waste. In this informant 3 and 4 also emphasized that the future generations had a stake in the generation and storing of waste. But as offered by informant 1, contrary to earlier versions of nuclear plants, run by what is nuclear powers today, the national defense would only have a defensive stake in nuclear energy. Whereas earlier they would also have an offensive role in that the wanted weapons grade plutonium.

And lastly, by the nature of the energy production process, there would be international actors. In addition to the construction stakeholders mentioned above, and foreign nuclear energy companies, the fuel value chain would be a substantial part of the stakeholder matrix. This would encompass Australia, Kazakhstan, Canada, Russia, and China, with more as listed by informant 5.

Partnerships and Relationships

Partnerships and relationships summarize which stakeholders are active in business activities and value co-creation/co-destruction respectively.

While both perspectives are covered above, informant 5 especially pointed out partnering with the existing teams at Kjeller and Halden when starting up production of energy.

And from a relationship perspective, both district majors wanted to point out that in the case of establishing a nuclear plant, they would like to see cooperation with the neighbouring districts.

Channels

Lastly, the channels er defined as the forms of communication proposed to establish and maintain relationships between the relevant stakeholders.

All the informants requested more information form research communities, but it varied greatly what type of information. On a high-level informant 1, 2, 5 and 6 all wanted to see existing information and data about newer generations of reach the public to a greater degree. Informant 3 and 4 on the other hand were more sceptical to new findings and statements, and wanted new research to come forth, in both the scientific and public sphere, especially regarding safety. In all instances it was mainly mentioned that media and the internet had the role to play in disseminating information to the public.

The discourse highlighted strongly the challenges outlined by Skirbekk regarding the modern discourse (Skirbekk, 2019), and we will revisit this as we dive into the research questions about Environment and Societal readiness further below.

Summary

The economic benefits of implementing SMRs in Norwegian districts was viewed as a potentially positive business case by a unanimous group of informants. However, one informant worried about future fuel prices, and another about that the capital expenditure rather being used for energy saving initiatives or alternative sustainable energy sources. This included both the access to a stable source of electricity, the low infrastructure costs incurred by the government and the interplay with existing power sources. Value co-creation for the district in question was undisputed in terms of additional jobs, attracting industry and the generation of tertiary services to support the influx of industry. The capital cost however was seen as substantial, and a major hurdle for getting projects off the ground. The operational costs, as of today, were considered negligible by all informants. The future cost of waste management was also a source of contention, where one proposed solution was to fund future waste management through an earmarked fund.

Identifying the governmental structure, and by association the role of the public in the investment and operation of the plant, was another source of disagreement. With relevant stakeholders ranging from local districts all the way up to international states, informants presented a whole spectrum of governing structure: from wholly private to completely state owned and everything in between.

From a simply economic standpoint, SMRs seem to present a net positive result from both a private and a public perspective, with the two biggest hurdles to the economic bottom-line being the capital cost and waste management. We will now look at the environmental impact, to get a better view of the costs and benefits not readily apparent from looking at nuclear energy in a purely economic perspective.

Research question 2: Environment

As the global community grapples with the imperative to reduce greenhouse gas emissions and mitigate climate change, nuclear energy has emerged as a significant contender to other sustainable energy solutions. However, this transition raises pertinent questions regarding its environmental implications. In the context of Norway's commitment to sustainable energy solutions, the prospect of establishing a nuclear powerplant in a rural setting carries significant implications for both energy security and environmental stewardship. For this chapter the guiding question is the following,

Pros and cons with nuclear energy plants impacting the environment on national and district level?

The research question number 2 endeavors to conduct a comprehensive evaluation of the impact associated with the establishment of a nuclear powerplant in the rural landscapes of Norway, and the associated stakeholders on a national and international level where relevant. By scrutinizing various facets such as emission, land usage, water resources, and the preservation of local ecosystems, this research question aims to provide the essential insight for navigating the intricate balance between meeting energy demands and safeguarding the ecological integrity of rural communities in Norway. As for the previously covered research question, we will also here start out with the needs and benefits of nuclear power, before diving into the challenges and objections.

Needs

The needs in the FBC model stem from the environment, and as an extension, society as a subset of the environment at large. To provide a comprehensive overview of the needs, we will provide the needs of society first, which is energy, as that is the driver for many if not all the subsequent environmental challenges we now see.

Illustrating the needs of the Norwegian society, informant 1 explains that Norway has a total energy consumption of close to 320 TWh each year. And that approximately 50% of this figure comes from fossil fuel sources with most of the remaining being electricity. This is also something that is mentioned by informant 5. In addition, informant 1 points out that Det Norske Veritas (DNV) in their newest report "Energy Transition Outlook 2023" has estimated an increase of 30-40 TWh in Norway by 2050. This led into two major needs presented by the informants regarding energy on top of what was presented by DNV. There was a consensus among all participants that in a future energy outlook, fossil fuels are needed to be phased out in general with its effect on pollution and climate, and the fact that it is rapidly diminishing. Informant 5 formalized it as being a need for new green energy sources to reach our climate goals. Additionally, informant 4 proposed the need to reduce the overall consumption and challenged the premise of all new power plants by asking if we would end up enabling more energy consumption than we should and that this can lead to a higher consumption. With a bid for less consumption, this is supporting a stronger sustainability vs weak. None of the other informants envisioned higher consumption led by more energy production. Outside the realm of energy output, there were also a call for minimizing human impact in general, and informant 6 specified that degradation of nature needed to be minimized, and informant 3 summarized the general sentiment of all the interviewees with "a climate and energy crisis is on the horizon".

Looking past the need for energy, we look at the environmental needs and if they correspond with the Nine Planetary Boundaries as they are defined in the latest publication of 2023 (Stockholm Resilience Centre, 2023).

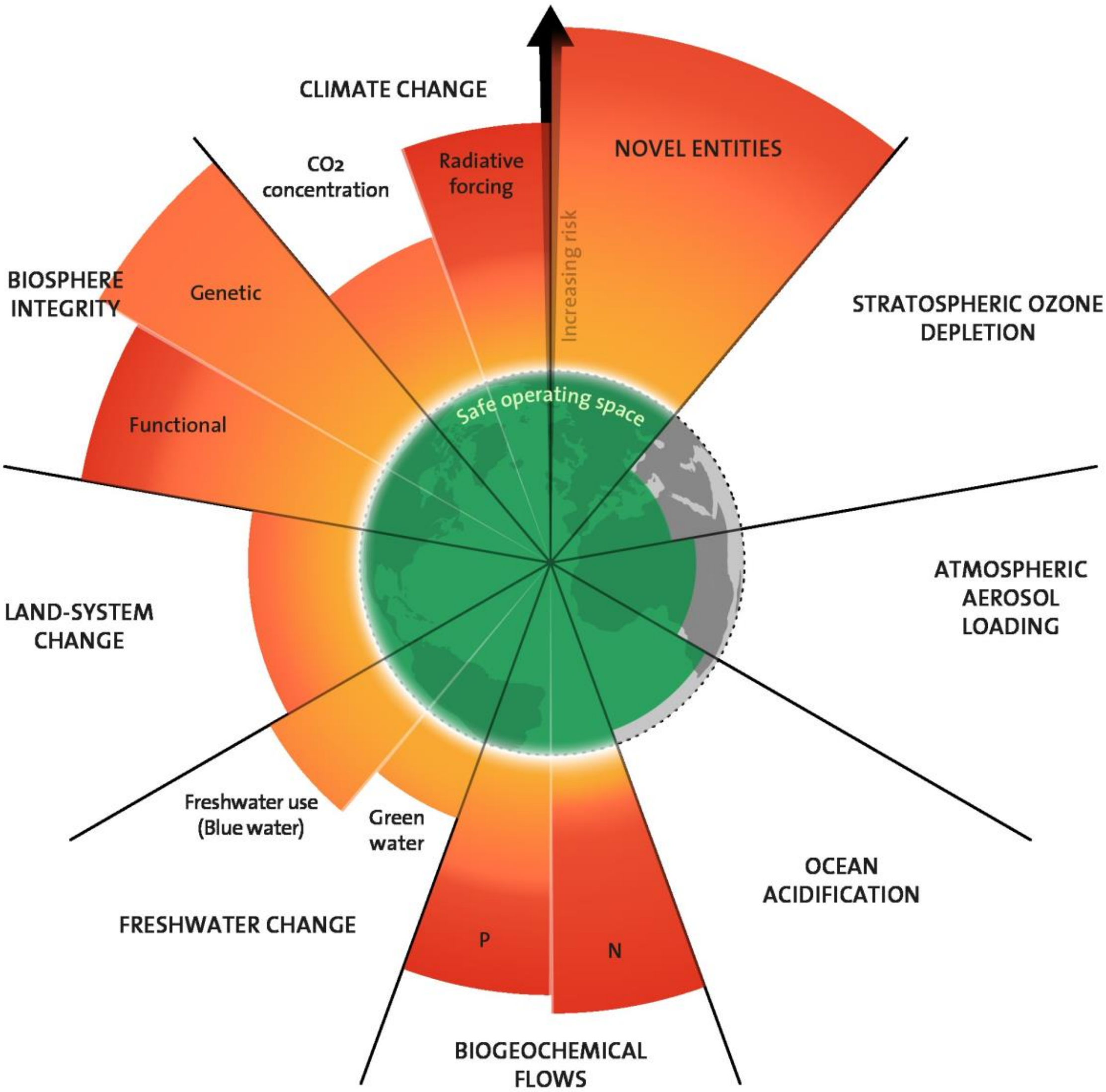

Figure 15: The Nine Planetary Boundaries (Stockholm Resilience Centre, 2023)

We find that several boundaries are relevant to the needs mentioned and warrant urgency. Of the mentioned needs, the degradation of nature and the minimizing of human impact corresponds greatly to Biosphere Integrity and Land-System Change which are both already outside the safe operating space of the planet, by a good margin (Stockholm Resilience Centre, 2023). The need for de-carbonating our energy sources and the phase out of fossil fuels are also directly corresponding to the boundary; Climate Change which is also outside the borders of safe operating space. Not mentioned directly by the informants as natural needs, the boundaries of Freshwater Change and Novel Entities will also be mentioned as they are integral to the environmental cost of nuclear energy. Although freshwater access is not a current issue in Norway as of 2023, the boundary is still over the global operating limit, so bears mentioning as the need for freshwater is increasing. Novel Entities on the other hand is highly relevant. The boundary, quantified for the first time in the 2023 paper, is considered the hardest exploited of all the 9 planetary boundaries. Including the emissions of toxic and novel substances, metals and radioisotopes, Novel Entities is together with Biosphere Integrity, Land-System Change and Freshwater Change the boundaries that would be affected in the event of a catastrophic accident in a nuclear reactor, which would directly affect the general need for a liveable environment.

And with the needs defined we look closer at what goals and benefits nuclear energy can provide to accommodate these needs.

Goals

The environmental goal of nuclear energy is also seen in the light of the societies need for cleaner, stable, and affordable energy. This corresponds well with our previous claim as a weak sustainability view of environmentalism. Except for informant 3, all the informants saw the potential of nuclear power contributing in some way or another. Although informant 4 specified that she could not close the door on nuclear, she felt that there are still too many challenges overweighing the benefit of introducing it as a viable option of energy production in Norway.

Aggregating the inputs provided by the informants, the definition of a success for implementing nuclear power ended up as being the creation of a substantial amounts of stable power with minimal area and climate impact. And by extension providing parts of the solution to the issue of climate change, especially regarding the climate goals i.e., provide energy that can phase out fossil energy production. Informant 5 did however detail that this would at the earliest be affecting the 2040 levels of CO_2, while aiming to reach the climate goals of 2050.

Activities

The actual number of activities related to the implementation, operational and decommissioning of nuclear power and with a potential environmental impact was held to a general consensus among the informants. Albeit with varying details, all the informants provided the same general overview of the processes involved. On the environmental risks and impacts of these activities, however, there was substantial disagreement.

The environmentally impactful activities in the building phase were laid out mainly by the informants from Norsk Kjernekraft. 3 to 4 thousand man-years over 3 - 4 years will be on the building site will have an impact on the immediate area, including the transport and application of building materials in the period.

Informants 3 and 5 then laid out the details of the operations activities required to generate power. The fission process, being the most central activity, was also one of the most contentious subjects. Where informant 1 described the reaction in the proposed generation 3 reactors as passively safe or *"walk away safe"* where you had to actively had to input energy to sustain the reaction, informant 3 meant this was misleading as there could always be unexpected mishaps in the processes. Informant 3 also listed actions like refueling, discharging the reactor and the handling of waste as all points of potential failure regardless of safety measures. Furthermore, there will be the use and release of cooling water.

Supporting the operations, the global supply chain of fuel was also outlined as a contributor to global impact. With the mining, refining and transport at the front, and the intermittent storage, transport, and permanent storage of different levels of radioactive waste at the back end.

But with the general agreement on the activities at large, the costs and benefits coming up next, was shown to be far more contentious topics.

Benefits

The environmental benefit of nuclear power is laid out as one of the main selling points for employing technology. Incidentally, the potential environmental cost is also one of the largest objections against the technology, and these will be covered in the next chapter. Several benefits were proposed by the informants to meet the goals outlined in the chapter above. And as the UNECE life-cycle assessments report on electricity sources cover many of the same characteristics as mentioned by our informants the information can quantified to a degree.

The major benefit that was brought up was nuclear powers feature of being able to produce substantial amounts of energy with minimal to no carbon emissions. This was mentioned by all but one informant and acknowledged even by one of the opponents to nuclear energy.

Having a low fuel transport cost and virtually carbon free production compared to the comparatively long lifetime of a plant with > 60 years, nuclear energy may achieve a very low level of greenhouse gas emissions. Looking at the data from the UNECE rapport, and accounting for the mining of fuel, building and decommissioning a plant, and the storage of waste, nuclear energy comes out with the lowest life-cycle greenhouse emissions of all reviewed energy sources. At 4.9 - 6.3 grams CO_2 equivalent per kWh produced, the second least emissive energy source is small hydro plants with 6.1 – 11 grams per kWh respectively (UNECE, 2022, p. 50).

From a land use perspective there were two main points that came up during the interviews. The first one was presented by informant 1, 5 and 6, where they pointed out that the plans for SMRs they had seen required minimal area for plant and plant infrastructure. From the GE Hitachi BWRX-300 status report the plant area, including all the infrastructure is defined as a 160-meter by 160-meter area (UNECE, 2022). The same informants then went on to mention that since Norway in general had what was stated as close to ideal location for nuclear plants, the plants could also be placed close to the consumer and where the need was greatest, reducing the need for a complex electrical grid infrastructure. This was compared to ocean wind, land wind and hydro which were all very location dependent and what would lead to great environmental impacts as they all required large amounts of nature built down due to powerlines. This is supported by the UNECE report, where nuclear energy came out as the least invasive energy source for lifecycle land use per kWh (UNECE, 2022, p. 53), when also accounting for mining and storage.

All but informants 4 and 6 went on to talk about the low aggregated lethality provided by nuclear energy. They all pointed out that the perception of nuclear lethality had changed, and the topic had become more commonly known. UNECE reports on this through three different metrics but is summarized under the life cycle impact on human health. Comparing to other energy sources small hydro plants is considered marginally safer, with photovoltaic, wind and nuclear sharing the second lowest impacts on human health in terms of disability-adjusted life years (UNECE, 2022, p. 54).

As we do not have numbers relating directly to environmental lethality at large, humanities place in the environment will be used as a proxy when looking at the corresponding planetary boundaries in the end.

Costs

Albeit there are several environmental benefits related to nuclear energy, the main counterarguments for adopting nuclear come from the environmental costs. Looking at the costs mentioned by the informants, two distinct categories of argumentation emerge. First there are the costs relating to the lifecycle of the plant and fuel cycle, which will need to be realized at some point. The second category is the costs associated with operational accidents and failure of waste storage. The costs related to the lifecycle will be presented and then further detailed in the Resources and Biophysical Stocks sub-chapters in the Environment chapter. Costs related to the accidents and failure will be detailed in this chapter.

Looking at the first category, one of the initial topics brought up was the location of the actual plant and the associated infrastructure integration. The representatives from Norsk Kerner referred to the area used by a SMR of the type BWRX-300 to equate approximately one football field. There would also be the integration cost for connecting a plant to the electricity infrastructure which proudly translates into area have to be converted into powerlines and transformers. Both informants did, however, underscore that there was a business case for connecting an SMR directly to an industry with high power demands which would effectively eliminate this cost. On a national level, this was the most talked about topic of all the interviews. The storage of nuclear waste and the location of permanent storage was important for all 6 informants, where both informant 3 and 4 cited that such an area would be exposed for an unacceptable risk. Globally, there is also an area cost that was acknowledged regarding mining. Informant 3 pointed out that around the world there are huge mining operations, and the most easily exploitable deposits are already extracted. With an indication that there will be need to further expand mining activities in the future. Also incurring, will be the amount of building materials. All informants were acknowledged nuclear plants requirements for the large amount of concrete and steel needed for safety and radiation shielding. And this was known by all to be one of the key drivers of capital costs incurred in an economic perspective.

Shifting the perspective towards the other category of cost, the potential costs that could be incurred in the case of accidents or disasters. On an operational level, informant 4 brought up that there would be a general increase health related cases and especially those of cancer in the vicinity of the plant. The topic was also brought up by informant 5 referring to the Norwegian regulatory laws allowing maximum 0,25 millisievert of radiation from a nuclear plant. This would equate to 5% of the radiation we are exposed to each year and be less than the radiation a human gets from food each year. The real emissions from a plant would in addition be far below the legal maximum stated making the operational levels of radiation negligible to all life outside the reactor core. This view was challenged by informant 3 who saw no way to completely illuminate the risk, stating; *"I mean, unforeseen incidents and accidents and human mistake and a combination of this, I mean, will lead to a disaster. And you cannot avoid this."* Following up, he outlined that there would always be inherent risk to even standard operations in running a plant: discharging the reactor of gas and/or liquids, transporting fuel/ waste etc. with the possibility of radiation leaks, loss of cooling or criticality accidents. And these risks would be present during the whole life cycle of the plant. According to informant 5 Norsk Kjernekraft did not receive that many questions regarding these kinds of any accidents anymore, attributing this to the increased security of the new generation reactors and increased knowledge in the populace. He did however concede that the public still had many questions regarding the waste containment and the risk associated with nuclear waste in general.

Waste storage, and in particular the storage spent on fuel disposal was the topic that covered most thoroughly by all informants. The site of a future depot was mentioned by all, but risk of containment failure of spent fuel was talked about in detail by informant 3 and 4. Separating the waste value chain into 3 steps, they spoke of the intermittent storing on the plant grounds, the transport of fuel and waste, and the final long-term storage of spent fuel. For all three legs of the value chain informant 3 also addended the risk of threat actors, be it foreign nations or terrorists, as possible ways there could be radiation leaks into nature. Outside of natural disasters also affecting all three steps, the transport was also presented as a potential risk for radiation leaks, especially due to the geography of Norway. Long winding transport routes throughout the country was viewed as a higher risk than for example rail transport in France. And lastly the potential cost of mismanagement of high-level waste, stating the leakage of radioactive materials into the ground water at the disposal site. With high-level waste remaining highly radioactive for thousands of years, this was viewed as passing the risk down to future generations. Informant 1, 5 and 6 pointed out that permanent storage, was close to be operationalized by both our neighbouring countries according to guidelines agreed upon by the UN (Abousahl, et.al. 2021). But with the consequences stated as 'incalculable' by informant 3, the risk analysis of permanent storage would never be acceptable for the opponents of nuclear power, with informant 4 summing the perspective up with *"it's better safe than sorry"*.

Resources

With the benefits and costs covered, this chapter will dive further into what material resources will be needed to establish a nuclear plant and operate energy generation. This was summarized by all 3 informants from the industry of nuclear and physics fields.

The core of nuclear energy is the U-235 isotope of uranium that is fissile i.e., it can readily be split into other elements generating heat in the process. Being a less prevalent isotope in uranium ore, the U-235 is enriched in refineries, making the final fuel between 5 – 20% U-235. This isotope uranium is exceptionally energy dense, releasing millions of times more energy than burning an equivalent amount of coal. The process needs large amounts of cooling, and in the case of the GE BWRX-300 reactor this is access to large amounts of cold water. Additionally, there is the building materials and technologically advanced components like reactor, generators and cooling systems needed for the initial building phase. Together with the area needed for mining, refining, operations, storage of waste, and transport between these, this summarizes the main resource demands made by a nuclear power plant regarding the environment. And this reflects once more the high capital cost and more modest operational costs seen in earlier chapters.

With the resources needed defined, the next two chapters will dive deeper into what impacts this has on our planet and our ecosystem services and biophysical stocks.

Ecosystem services

With ecosystem services defined as the natural processes that operations rely on, nuclear energy relies solely on the natural water cycle with its need for continuous cooling (World nuclear association, 2020). Informant 1, 3 and 5 all lay out the need for light water reactors to have access to cold water at all times during operations. In practical terms that means that a given plant will take in cold water from the environment, and release the water spent for cooling as steam and hot water back into the environment. This means that a nuclear reactor must have access to a river or a fjord for its cooling needs – and informant 1 and 5 points out that this is one of the requirements that make Norway into one of the ideal candidates for nuclear energy. According to the UNECE rapport, the lifecycle dissipation of water is one of the metrics where nuclear come out unfavorable compared to for example solar and wind, placing on par with other thermal power plants like natural gas and coal (UNECE, 2022, p. 55). And while informant 5 informs that newer plants need less cooling than older plants, referring to nuclear plants in the US desert running on a nearby towns wastewater, informant 3 reminds that there have recently been exceptions to water access by existing plants abroad. Nuclear plants along the Rhine were close to having to close during the summer of 2022 when the river was close to dry all the way up. And a similar scenario was also seen after the destruction of the Zaporizhzhia dam in Ukraine in 2023. A plant situated by the ocean front would not have the same vulnerabilities but could on the other hand be susceptible to high water like what was seen in Fukushima in 2011.

And as loss of cooling can lead to critical meltdown accidents, a plant would be vulnerable to changes in weather patterns in the future, especially if reliant on river systems.

Biophysical stocks

The effect on nuclear energy on the planet's biophysical stocks, together with its ecosystem services, is what gives the strongest indications on what concrete impact will be seen in the natural world. With the activities and resources defined, we look closer at what is moved, changed, and transformed as part of building and operating a SMR.

Through the building process there will, as mentioned in earlier chapters, be used substantial amounts of concrete and steel. In contrast to the huge upfront costs, the amount of material used adjusted for rarity and lifecycle output greatly favours nuclear compared to other up and coming power sources like wind and solar according to informant 1 and 5. This is also supported by UNECEs rapport where nuclear has the most favourable mineral and metal footprint per MWh of all power sources but small hydro plants (UNECE, 2022, p. 56).

The site used for the build of a nuclear plant will be heavily industrialized and therefore also see the impacts as a biophysical stock. Selecting a site is considered one of the most crucial steps in planning a nuclear plant, and our informants presented a wide range of criteria that should be met before a plant could be considered feasible. As mentioned in the previous chapter, a nuclear plant needs to have continuous access to water, preferably a river or a large body of water like a lake or the ocean. Furthermore, informants 3 and 5 list up additional criteria for a selected area: must be stable, away from any sort of flooding, not exposed to extreme weather, have minimal earthquake risk and must not be in a natural protected area. On this note both informant 1 and 5 brings up the claim that Norway is among the most ideal locations in the world for nuclear energy, with stable bedrock, low seismic activity, and abundant access to water (McEwen, 2000). Informant 5 illustrates this further by mentioning that there could be ideal sites for both a plant and permanent storage in almost every district in Norway, except for maybe Oslo proper and a handful of outlier districts. Informant 4 added that in the case of a plant being built, it should be placed on a 'grey area' i.e., a site that has previously been used for industry to limit its footprint. The site itself for a GE BWRX-300 would be 160 by 160 meters, as mentioned in the benefits chapter. With the amount of power available for generation over the lifetime of the plant, this places nuclear power as the energy type with the least land use impact per kWh of all mentioned in the UNECE rapport, followed by natural gas that come in with a factor of 10 higher on the land use metrics (UNECE, 2022, p. 53). These numbers also include surface mining operations, which will be detailed further down in the chapter. Considering infrastructure, informant 3 pointed to that a location would need to have easy access to transport infrastructure like good roads, train lines or harbors. The two majors in the interviewee pool both spoke about the importance for selecting districts that already had the required infrastructure in place to avoid unnecessary down building of nature, while also promoting their respective districts as ready for more industry. With the option of placing nuclear plants in a wide range of locations, informant 1, 5 and 6 pointed out that this could give us large savings in establishing the plants close to the industry and residential areas where power was needed. Which in turn would save the environment by limiting the need for large power infrastructure from the place of generation and place of consumption. Considering the decommissioning of a plant after its lifetime, the EU rapport operates with two statuses and three approaches: greenfield, where an area can be used with no restrictions, and brownfield where and area can only be used with restrictions (European Commission, 2023, p. 125). Where Chernobyl uses the approach of entombment, leaving a brownfield, Germany has opted for a deferred dismantling, leaving the site to lose radiation before returning the site to greenfield. The final approach is immediate dismantling, which is recommended by the EU, and aims to return an area to greenfield status as quickly as possible. While referring to the UNECE report and the new power sources that must be located on specific locations like wind power, informant 1 said that *"we would rather build-down nature than acknowledge the reports saying that nuclear energy is part of the solution for a carbon free future".*

The impact of the near environment is a contentious topic in the public discourse. While informant 4 had worries that the presence of a nuclear plant would lead to an increase of cancer in the districts, both informants 3 and 5 told that the radiation from a plant would be negligible, even compared to the natural background radiation. However, informant 3 added that this was under normal operations, once again stating that the risk with nuclear power was related to abnormal actions in production and handling of radioactive waste. According to UNECE nuclear power exposes the public to 0.43 man-Sievert per GW/year, followed by coal with 0.7 - 1.4 man-Sivert and geothermal with 1 – 20 man-Sievert, where the majority of radiation is from released radon-222 gas during mining operations (UNECE, 2022 p. 52). Adding to this, informant 1 said that the radiation emissions from mining were comparable to any other mining operations, and not unique to uranium. Including the risk of radiation leakage and critical accidents, we need to consider the effects on nature and human health in both an acute and long-term perspective. All informants referenced major accidents like Chernobyl, Three Island and Fukushima – illustrating both human, technical, and environmental causes of error respectively. The three representatives from the nuclear field all spoke about how the 3rd generation of light-water reactors, which includes BWRX-300, came up with new designs that prevented the types of accidents associated with the old designs in Chernobyl. The BWRX-300 also incorporates passive security, where you must input energy to sustain the reaction, but as mentioned earlier, informant 3 would not use the term “walk away safe” used by informant 1 and 5. Considering the fallout of Chernobyl, there is the real possibility of large areas getting negatively affected by an accident. Informant 3 illustrated this by pointing out the raised radiation levels that can be still found in vegetation and mushrooms from Belarus to Norway and quoting premature deaths from various causes related to the Chernobyl accident to be between 20 000 and 50 000 mainly due to cancer. One big advantage with the light-water design is that it would most likely not be able to catch fire as happened in Chernobyl, even in the event of a critical failure. Considering this up against the UNECE rapport looking at non carcinogenic toxicity in humans per TWh, and by proxy animals, nuclear power comes in with the lowest instance of human toxicity shared with a small hydro plant and wind energy (UNECE, 2022, p. 53). Looking at the carcinogenic toxicity, nuclear energy comes in with the lowest prevalence of all energy sources together with small hydro plants (UNECE, 2022, p. 54). On complete lifecycle impact to human health the rapport has nuclear power almost on par with the two safest sources of power which is reported to be small hydro and specific types of photovoltaic and wind (UNECE, 2022, p. 56). With the numbers presented corresponding to the operation of generation 2 reactors all over the world, including Chernobyl, Three Mile Island and Fukushima,, the EU is estimates that the lethality of the generation 3 reactors will be safer by another 2.6 order of magnitude going forward (European Commission, 2023, p. 172)), and the chance of another disaster like Chernobyl would be 1 in 10 billion reactor hours (European Commission, 2023, p. 175).

The numbers presented above by UNECE also included the impact on human health during mining, transport, decommissioning, and storage of waste. Permanent storage of low-level nuclear waste already exists in most developed countries, including Norway, and this was not something viewed as contentious. But as mentioned earlier, the permanent storage of spent fuel was the most highly discussed topic during our interviews. The view on permanent storage was split on views between informants 1 and 5 claiming that the issue with permanent storage already had satisfactory solutions, to informants 3 and 4 believing that no currently proposed approach could ever be safe enough. Informants 2 and 6 fell between the two viewpoints, but displayed remarkable technology optimism with informant 2 saying "*With a 100-year horizon to figure out the waste issues, they'd be 99% sure to have an even better solution than today"*. Based on the interviews, only deposition of the fuel in bedrock was proposed as a probable solution. As told by informant 5 earlier, there are a high number of eligible sites in Norway considering the criteria mentioned earlier. However, biophysical stocks will be impacted by the deposing of spent nuclear fuel and other radioactive waste. And several challenges and worries were presented by the informants. While the first permanent no maintenance storage has yet to open in Sweden and Finland, Norsk Kjernekraft operated under the assumption that this was the model that would be relevant for Norway, either by itself or in cooperation with either Sweden or Finland. This approach would see the spent fuel deposited 500 meters underground in non-porous bedrock with low seismic activity, adhering to the standards recommended by the EU in 2020 (European Commission, 2023, p. 255). Informant 1 specifically challenged anyone objecting to address the rapport directly. While informant 4 argued that it was peculiar that there had not been possible to establish permanent storage before, informant 5 countered the argument by explaining that spent fuel had a planned 40-year period where it's stored on site before being moved. During the first 40 years, 99.9% of the radioactivity would disappear, making the spent fuel both easier to transport and deposit (European Commission, 2023, p. 228). By that account meant that the bulk of spent fuel from the reactors in the 80s were now getting ready for storage. Furthermore, he went on to illustrate that over the following 100 000 to 250 000 years, the spent fuel would return to the level of radioactivity that it was originally when it was extracted from the earth then staying at that level due to uranium's natural radioactivity. Informant 3 and 4 still viewed this as a too risky venture, with basically passing huge environmental risks down to our future generations, as unacceptable. According to informant 1 simulations done in Finland on containment breaches of fuel canisters would lead to the equivalent to the additional radiation of eating two extra bananas a year, for the residents drinking that particulate groundwater in the far future. Informant 5 elaborated that the school of thought that the waste is deadly for hundreds of thousand years was a misconception. And he went on to point out that Norway deposits thousands of tons of other environmental toxins each year and spent fuel would be one of the few types of waste that diminished itself over time. Claiming that nuclear energy was held to a completely different standard to other comparable industries, he requested that the public debate could do with taking the issues into perspective. And worrying that opponents could sometimes seem to fall into the zero-risk bias fallacy, where in the chase for zero-risk solutions end up doing harm in the process.

Lifting the view to a global level the value chain also has international impact with mining operations, refinement of fuel and the transport in between. Informant 3 talked about how the mining of uranium-235 required huge mining operations across the world, with the associated impacts of all mining operations. But still be considered the least invasive in terms of land occupation by UNECE, as mentioned earlier in the chapter (UNECE, 2022, p. 53). With the World Nuclear Association citing that there are approximately 135 years' worth of uranium-235 available with the current 'open cycle' consumption (NEA, 2023, p. 113), informant 3 pointed out that as the more easily accessible ore is being depleted, more invasive mining operations would need to commence. Informants 1 and 5 did however mention future technologies like 'partially' and 'fully closed' fuel cycles that could recycle and extend the available fuel for up to 5000 years (European Commission, 2023 p. 103). However, this together with filtering out uranium from sea water, was seen as unproven or downright impractical altogether by informant 3.

Finally, looking at the CO2 impact of a nuclear energy plant, the sources are almost exclusively from the building phase, mining, and transport. And this was unanimously agreed among all informants, and supported by the UNECE report, where nuclear came out as the power source with the lowest emission of CO2 equivalent per MWh with only half the emissions of the second which was small hydro. This had informant 6 stressing *"That although nuclear was not renewable, it was emissions free. Which is what is needed now."*

The chapter indicates that the practical steps of creating nuclear energy does not contain many disagreements, but as informant 3 pointed out, even in the field of physicists they are divided in their view of nuclear energy. But with informant 5 saying *"I often get questions on how to make nuclear power safer. There are probably ways, but it is already the safest type of power we have."*, it all falls down to people's beliefs and interpretation of risk.

Seeing the spread in viewpoints on the topic, there is informant 1 and 5 accepting the proposed near future solutions leaning on the rapports from the UN and EU. While the more neutral 2 and 6 showing technology optimism. And for the two sceptical informants, informant 3 summarized his final view on the environmental challenges as following: "*Maybe in an ideal society, nuclear energy could be doable, right? If we would have a stable society, peaceful, no terrorists, no religious insane people. Yes, and then maybe, maybe you could convince me*".

Ecosystem actors

With potential environmental impacts truly on the global scale, there is hardly a single ecosystem actor with no vested interest in nuclear energy one way or another. And with the FBS defining ecosystem actors as a human organization needed to speak for each stakeholder, we've divided the stakeholders that came up during the interviews into the representatives for humanity and the representative for the natural world.

From a societal level the informants brought up humanity as a general entity due to the potential impacts. And as stated by informant 3, establishing nuclear power was not a decision left to a single district or the people living in the vicinity of a planned reactor. Such a decision would involve both governments, meta-governments like EU and the UN, international value-chains and international regulatory bodies like IAEA and others. Nationally one would see entities like national defense, industry (NHO) and media taking an interest.

And speaking for the ones without a voice, organizations like Bellona, Greenpeace and Naturvernforbundet would be involved. And lastly, added by informant 4, someone will speak for future generations.

Summary

The environmental impact of SMRs has been shown to be contentious among the interviewees for our study, accurately reflecting the public debate that initiated this thesis.

Apart from informant 4 all informants seemed to agree that under normal conditions nuclear power can be considered a good source of energy on general terms, and more specifically in the Norwegian geography. There were however huge discrepancies regarding if the potential risks and consequences are acceptable, with both informant 3 and 4 stating that there is no place for nuclear energy anywhere in Norway as there is no way to reduce risks to zero.

Considering impact, all forms of energy must be considered weak sustainability, as even with renewables there is an impact through the mining, production, and area use. Referring to the environmental needs of the planet and the nine planetary boundaries defined by Steffen et.al. at Stockholm University (Stockholm Resilience Centre, 2023) we see that nuclear energy scores very favourably on all axes of crossed boundaries. With minimal impact on both land-system change, climate change and biosphere integrity, with little to no negative contribution to freshwater change and biochemical flows according to UNECE (UNECE, 2022). Land-system change is particularly relevant when considering the local impact for a selected district. However, catastrophic instances can possibly affect novel entities' boundaries negatively, as highlighted by few but highly impactful accidents throughout history. This still causes scepticism in the public.

So, from an environmental impact perspective, considering the strengths and weaknesses of the Norwegian geography, there is an argument that nuclear power could be a positive for both global and local environmental pressure – under the assumption that society will continue to demand more power. It could contribute positively to both the districts and national triple bottom-line. But will come with inherent risks, that may never be acceptable to some.

Research question 3: Societal readiness

The establishment of a nuclear power plant transcends technical and economic considerations, deeply embedding itself within the social fabric of communities. Understanding the social implications of such a venture becomes paramount. For our third research question we are therefore addressing the social aspects of the implementing nuclear power in Norway:

Pros and cons with Norwegian society regarding implementing of nuclear energy into its energy mix?

This research question embarks on a comprehensive evaluation of the socio-cultural impact associated with the establishment of a nuclear power plant. And with this we still see several of the earlier mentioned topics being reviewed again in a different perspective, reflecting the transdisciplinary approach selected for the thesis.

Needs

With the needs of the environment being the overarching concern in the FBC model, the needs of society are more often than not the strongest driver in a business analysis, which was the reason for FBC being established in the first place. The most basic of societies needs regarding nuclear power is societies need for accessible energy. And the increased energy consumption expected going into the future. And informant 1 underlined the above priorities with *"there is this this tripartite, faith, hope, and love. We want to save the climate and nature; we want low energy prices, and we want energy security. In the end, energy security always ends up as the highest priority"*. Informant 5 worried that society didn't really acknowledge the importance of energy considering how our society is set up today, with informant 2 pointing out energy access is one parameter in keeping a society stable. Both district majors requested more energy, stating that energy in by extension, industry was needed to maintain district communities. Not all informants agreed that we would need more energy in the future, with informant 4 proposing that society should rather try to lower its energy consumption as an alternative. This was the only argument for strong sustainability that was voiced in the interview process. But informant 4 conceded that *"but society might need more energy before we start scaling back again, as it's hard to tell"*.

An on a more general level informant 5 defined the need for a predictable way to migrate away from fossil fuel, stating that *"as a society we need to reach our climate goals."*

Stakeholders

As stated earlier, most if not all have a stake in the establishing of nuclear power in a country and a given district. Looking back at what has been covered in the economic, environmental, and now the societal chapter, there are some stakeholders that are more pertinent than others. And which have varying degrees of support for forwarding nuclear energy in general or on a national level.

Involving a significant number of actors, nuclear power in a Norwegian district still find that it has stakeholders on a global scale. Especially as Norway and the world is together working together towards the global climate goals, as mentioned by informant 5. According to informant 1 the Intergovernmental Panel on Climate Change says that the world needs to multiply the amount of nuclear output in the future, while the International Energy Agency wants to see it doubled. The international community has a regulator function through the agency IAEA. Associated with IAEA there are all the existing and potential national actors in the fuel value chain – ranging from the USA, Canada and the UK to Kazakhstan, China, and Russia. Informant 5 did however point out that considering current events, there were initiatives working on creating value chains non-reliant on China and Russia. On a more general level both the EU and the UN have published their reports on nuclear energy and comparative energy sources respectively, both making out nuclear energy in a positive light. From a scientist's point of view, informant 3 wanted the reports read with a grain of salt, due to them being written by bureaucrats. From a neighboring country perspective Finland, Sweden and to a degree Poland has been said to be potential cooperative partners. And with the UK and European power market connected to the Scandinavian energy market, the whole continent has a vested interest as described by informant 1.

Politically inside Norway's borders the topic of nuclear power is contentious, but apparently changing. Informant 1 tells that most Norwegian political parties now acknowledges that we need nuclear power in the world. And even points out that MDG (The Green Party) is in favor of nuclear energy, but with the caveat that it's not placed in Norway. Informant 4 provides more information, saying that the topic seems to have reached increased interest lately. Seeing Frp (The Progressive Party) voting for, and Høyre (Conservative) wanting to explore the topic. Even her own party, SV (Social Liberal Party) has removed their statement of 'no nuclear energy' from their program. However, they have added it to the country charter of Vestland instead, showing the division in opinions also inside political parties. In contrast, informant 2 informs that his party (Center Party) does not have a stance nationally, but they recently voted in favor in the Vestland county elections. He goes on to explain that he's under the impression that the interest in nuclear is rising as the popular opinion of the land wind is waning and people are looking for an alternative. And in his district, there is also skepticism towards offshore wind, as there might be unforeseen impacts on the fisheries that are a staple industry in the region. Informant 1 underscores this by pointing to the recent Fosen conflict. This was also the same mechanism that led to nuclear being considered in informant 6s district, where an overwhelming 70% voted against land wind in 2019, mainly due to land use. She goes on to say that it looks like it might be a trend, as the early 2023 Opinion census showed that 51% of the Norwegian public were now positive towards nuclear powers in Norway. Informant 1 saw this trend reflected in that Norsk Kjernekraft was contacted by 37 districts for more information by the spring of 2023. But as informant 6 concedes, many will most likely still have a mental barrier towards nuclear energy for many years to come due to historical high-profile accidents. Informant 4 summarizes: *«it does not seem like Norway has yet made up its mind”.*

Outside the political sphere, there are also a high number of stakeholders found in each district. The majors both describe a strong local interest for more energy, referring to both households, existing and potential industry. And as informant 2 emphasizes, the secondary and tertiary industries in the district and neighboring districts. Informant 1 specifies that in aggregate this also involves NHO and their membership organizations as access to energy will affect more than just the immediate electricity zone. And existing industries in the energy sector, especially oil, can have a role as either as a direct competitor or as a partner depending on how the industry chose to react referencing the complimentary industries mentioned in the economy chapter. And the possibility for a just transition will be discussed further down in resources. But on a general level nuclear would pose a threat to the oil industry, as it’s proposed as part of the solution to de-fossilizing society.

Looking at organizations supporting or opposing nuclear, several categories were mentioned. Nuclear power operators like Norsk Kjernekraft and potentially the government, SMR providers like Rolls-Royce and GE Hitachi and up and coming future technologies providers like Copenhagen Atomics and Seaborg Technologies working on generation 3+ reactors out of Scandinavia as mentioned by informant 1 and 6. If a building phase materializes, the construction phase would involve either thousands of foreign experts or foreign experts contributing together with local contractors under large construction contracts. However, as informant 4 puts it, one would need to be wary of the motivations of private actors. Operators in other countries should then also be consulted according to informant 3, and briefly mentioning ABB and Vattenfall in Sweden, Simens in Germany, and Areva in France. Other organizations that will also be part of the process are nature organizations like Naturvernforbundet and Bellona as mentioned by informant 3 and 4. And with informant 4 pointing out that nuclear plants will be additional targets in a national defense plan, informant 1 underlines that none of the scenarios and reactor designs proposed for Norway lend well to a nuclear weapons program.

From a societal perspective educational institutions and existing nuclear expertise, like Halden and Kjeller will also have a defining interest in how society can mature towards nuclear energy. But as informant 3 mentions, even the experts in Norway disagree, often with the older generation opposing and the younger generation supporting nuclear.

Lastly informant 5 explains that there are many myths in the discourse regarding nuclear power. And on the behalf of all stakeholders involved, the two majors interviewed both hoped for a future discourse with updated, correct, and believable information, with a steady perspective weighing pros and cons up against each other.

Benefits

Benefits have been thoroughly covered from the economic and environmental perspective. With many previously mentioned benefits also having an impact on society, nuclear plants in the districts also provide society specific benefits as mentioned by some of our informants.

The main benefit provided by a nuclear plant would be providing large amounts of relatively cheap electricity for up to a century, after the initial capital costs. And both representatives from Norsk Kjernekraft mentioned that after the capital investment was paid down over the first 25 years the following 40 - 60 years would provide very cheap power. If the right of repatriation is implemented, in the same way as was done for Norwegian Hydro, this could be a very valuable proposition for the public. With the prospect of having a nuclear plant in place for a century informant 2 detailed how it could revitalize and bring people back to a district. Both in terms of new jobs, but also secondary and tertiary jobs appearing to support the new plant. This was agreed about all but informant 4 that didn't see many benefits with nuclear power at all. Informant 1 also offered the possibility for existing oil rig operators to be offered a new career path in nuclear, in accordance to just transition, as Norway is one of the best in the world on operations knowledge and you didn't need to be a nuclear physicist to operate an SMR.

As covered in the environmental chapter, the plant would have a low area impact both regarding the plant and associated infrastructure. And as infrastructure is a public expenditure, it saves the public on having to develop the additional infrastructure. When informant 6's district considered windmills, it was the area impact and infrastructure that felled the proposal and opened the consideration for nuclear energy.

And lastly there is the possibility of nuclear contributing to Norway's green shift, with the reservations considered in the environmental chapter above.

Costs

The costs on a societal level have on many levels corresponding points in economics and environment. But we also see that there are additional components in play, for example new stakeholders involved and the general outlook from involved stakeholders.

First there is the integration cost of a new plant, which was discussed earlier, which will fall to the public to fund. While both informants 1, 5 and 6 point out that these are lower than other up and coming energy sources, it’s still present. Society will also be challenged with the cost model of a new plant, where the capital expenditure is almost completely located at the beginning of the plant lifecycle. This puts pressure on potential investors and companies, be them public or private. All informants view this as one of the major hurdles of nuclear energy, with some viewing it as a challenge and others seeing it as neigh unsurmountable.

From a general public’s perspective there are also major political decisions that society need to decide on several continuous topics. As discussed earlier, there will be general approval of nuclear as a power source, the placement of reactors and the final repository of spent fuel. As a consequence of the decisions, there would also be a lot of public work to get all licensing, regulatory and contingency frameworks in place. Both district majors highlighted that any decisions made on district level would have to be done in concert with the neighboring districts as well. Some of these discussions would also lead to operational consequences, like establishing the actual industry handling waste. And according to informant 3, this should only be handled by a public entity. Furthermore, the establishment of new value-chains for fuel access would leave the national government with higher complexity in foreign affairs, where there are many national actors involved from mining to reactor ready fuel.

On an individual level there is also a cost regarding psychological pressure. Informant 6 describes this as ‘the mental barrier of accidents that has happened’, and informant 2 tells that Chernobyl and Fukushima often comes to mind when discussing the topic. Depending on the risk assessment of the individual this could be on a range of topics like a plant being a terror target, an additional military target in a conflict, general accidents or just a feeling of distrust of the day-to-day operational safety as mentioned by informant 4. Informant 1 said the industry was very familiar with the *“not in my backyard”* sentiment. But meeting this societal cost, informant 5 pointed out that the general fear of nuclear was in many cases rooted in myths. And with operational nuclear plants in place, more people would have access to correct information.

With a shift in the energy industry society would also have to acknowledge a shift in the required knowledge and skills in the populace. Colleges and universities would have to undergo changes in what courses they would provide, especially seen in light of moving away from the fossil fuel industry, as referred to by all informants.

While both representatives from Norsk Kjernekraft had announced the ambition of building and delivering nuclear power without governmental subsidies, informants 3 and 4 did not believe this to be realistic and assumed that the public would end up shouldering unforeseen costs in the process. Informant 6 acknowledged the same potential scenario, but pointed out that the recent building of offshore wind did receive significant subsidies in both building and operations, and indirectly by the public covering very large integration costs.

Concluding, both informant 3 and 4 underlined several times that whatever cost incurred by implementing nuclear energy, much of it would also have to be handled by the future generations.

Resources

The recourse chapter for society will look at the readiness of human resources needed for establishing nuclear energy. As the more standardized human resources like security and general facility maintenance was covered in the economic chapter, this chapter will focus on the specialized knowledge needed for the building and operations of a reactor.

Considering the specialized positions mentioned, the informants mentioned especially operators, and nuclear physicists, chemists, and engineers. Detailing the requirements for both the building and operational phases, informant 1, 3 and 5 all offered much information for the technical expertise needed. Listing the following: welders, mechanical-, electrical-, and nuclear engineers, nuclear chemists, nuclear physicists, and operational controllers in addition to security and facility maintenance. Informant 3 held a general view that ”*we have zero, almost zero expertise in nuclear in Norway”*, supported by informant 4 who reiterated the views of Naturvernforbundet that we do not have enough nuclear physicists in Norway. Pointing to the decommissioning of the reactors at Kjeller and Halden, informant 3 held that all but every relevant reactor physicist had retired and there were just a handful of relevant experts left, which were connected to NTNU and UiO. And no nuclear engineers at all. This was disputed by informant 1, 5 and 6 on two counts: that there would be one to two decades to build up expertise, and the actual amount expertise present in Norway already today.

Informant 1 and 5 both said that with political support in place, and plants scheduled for the late 2030s or early 2040s, universities would have ample time to create more and more specialized educational programs for the nuclear disciplines. Regarding general engineering disciplines and operational capacity, informant 1 pointed towards how the Polish governmental energy company PGNiG aimed to solve a similar challenge as they're planning to open 79 SMRs in Poland by 2040. With a highly skilled workforce available from the oil sector, they were looking at establishing programs for engineers and oil platform controllers to transition to nuclear energy. With Norway being world leading in platform controllers, informant 1 proposed this as a strong contribution to a just transition from our fossil fuel extraction industry. And considering that Poland has only had 1 research reactor, in contrast to Norway's 4, he considered this a highly feasible approach. With the claim that from an operational perspective, there was only a limited need for nuclear physicists to run a SMR i.e., 2-3, this showed that Norway was well suited with the needed knowledge. Regarding the existing competencies in the country, informant 5 insisted that the nuclear domain was larger than most considered. Listing approximately 200 associated with Institutt for Energiteknikk in Halden and Kjeller, 120 in the directorate for radiation- and nuclear safety, and 30 with the decommissioning of the research reactors, he held that the base for establishing commercial expertise was in place.

In the building phase there were two main approaches presented by informant 1, provided by Rolls-Royce and GE Hitachi respectively. Rolls-Royces SMR would be built and handed over "key-ready" for the operational stage by a dedicated Rolls-Royce team. GE Hitachi would provide technical expertise in the building phase but cooperate with local industry during construction. All design and module production would happen at remote factories for both providers. This would limit the need for local expertise with building the plants. Informant 4 did however point out that France, an established nuclear nation, still required the assistance of Chinese engineers as they now were renewing parts of their nuclear capacity.

Lastly regarding handling of waste, informant 5 said that Norway was very well suited with expertise handling low and medium level radioactive waste, referring to the decommissioning crews working at Halden and Kjeller. Of which he was part of before starting at Norsk Kjernekraft.

As the state of Norwegian expertise seem to still need to mature, the base knowledge seems to be available in a capacity. But there also seems that there will be a need for foreign expertise in the building phase for all proposed approaches. Informant 6 wanted to underline that historically Norway used to be one of the leading countries in Europe when it came to nuclear, before we discovered oil. Summarizing what she thought of the discourse like this: *"I get annoyed when I hear politicians and ministers go out and claim that we have no experience with this"*.

Activities

Having the benefits, costs and needed resources defined, there are many steps that need to be fulfilled before nuclear energy is viable. In the process of getting a district ready for nuclear energy, and by extension the whole Norwegian society, there are several activities that was brought forth by our informants. In discussing the activities, we will see how large the gap is between today's status and how it needs to be for nuclear power to become operational.

The first step would be to get political support on the issue of nuclear being accepted if it's done in accordance with established terms and regulations. According to informant 1 and 5 this was the main hurdle that kept the first projects from being initiated. Informant 5 detailed further that Norsk Kjernekrafts roadmap had the first operational SMR in place in a Norwegian district by 2040, including the political process of getting licensed. But if political approval arrived shortly, they should be able to have the first plant in place already in the 2030s. As part of this process the legislation and regulatory framework would have to be established or fitted for commercial Norwegian nuclear power. All informants referenced the research reactors at Halden and Kjeller, and informant 5 informed that having these in place has led to most of the legislation already being in place. Furthermore, he details that this has led to the signing of the major international conventions on nuclear safety, maintenance, waste management and non-proliferation. From this we have the Norwegian Atomenergiloven (Lovdata, 2023) and other associated regulations in place. This is further detailed in 'Veileder til de generelle konsesjonsvilkårene' for nuclear energy (DSA, 2022). There are however still adaptations that must be made in the existing legal framework to allow for commercial reactors in Norway. Informant 5 continues with proposing that this could be solved practically by looking at other comparable nations that has implemented nuclear power and adapt the laws and licensing requirements for Norwegian conditions. As Norway has neighboring nuclear nations, national emergency plans are already in place for reacting to a nuclear disaster. Considering this, informant 6 felt that it was wrong of Norway to join Sweden and

Finland in exploring nuclear power *"because we're afraid of handling spent fuel or not happy with today's solutions"*. From studying Norway's licensing and regulatory readiness compared against IAEAs milestone for establishing a nuclear program in a country, informant 5 hold that Norway is *"exceptionally well suited".* But, as informant 4 put it, this will still have to be put into practice, with additional funding to the governmental bodies to have them able to perform their new licensing and regulatory functions. And from this the first nuclear actors would have to apply, qualify for, and then have granted operational licensing to carry on with the build process.

With the national approval in place together with rules and regulations, suitable sites need to be selected. Contrasting the "*not in my backyard*" sentiment mentioned earlier, informant 1 said that 37 districts had been in contact at the time of interview (2023), requesting more information about the proposed SMRs. But informant 3 requested that this was part of a larger national discussion, as the potential impact is larger than just the district in question. The most important thing in the process was, however, that the public had to be kept informed as stated by informant 2.

Having a site will then lead to the building phase where one might see 3-4 thousand man-years over 3-4 years as discussed earlier. For the district in question this can be a strain on existing infrastructure. And with the high likelihood need for foreign specialists, as mentioned by informant 3 and 4, this would also impact immigration if they were coming from outside Schengen. Following this > 75 employees per reactor would need to be sourced and established in the district and supported for the lifecycle of the plant as per the BWRX-300 requirements (GE Hitachi, 2019). Part of this would be establishing the educational programs required to have controllers and operators from other industries ready and licensed for nuclear operations. With an influx of needed knowledge of nuclear power, this would also ultimately impact local and national educational institutions, seeing more nuclear physicists, chemists, and engineers into the 2030s and 2040s.

Lastly there would be the need to establish a storage site for nuclear waste. As told by informant 5, there are good existing routines in Norway already regarding low and medium level radioactive waste. But considering that the first permanent deposit of spent nuclear fuel is soon to open in Finland, there is no good solution in place in Norway. Although the practical application of storage would not be needed before > 40 years after the first plant went operational, the process could be expected to be lengthy. First, selecting a site, as it proved to be the most contentious issue of the interviews, and secondly that the proposed depth for passive storing would require making a storage facility 500 meters deep. And as an initial part of the process informant 1, 3 and 5 all proposed to establish an electricity tax on nuclear power earmarked to future handling of spent fuel well before the first plant goes online.

There is a large amount of work to be done before nuclear power can be a reality in Norway. Both legislatively and socially there are many hurdles that need to be cleared before it's feasible and it would have the support of the public. But as shown, much of the groundwork has been done due to Norway having part in several international agreements and having run several experimental reactors earlier.

Summary

As shown above, there is an enormous number of stakeholders involved in considering nuclear power in a Norwegian district. Although most activity is now seen coming from the districts, the biggest hurdle presented is to get political support on a national level. There seems to have been a shift, where conflicts related to formerly popular green energy alternatives like land wind has led to the public looking into alternative routes to climate positive energy.

In a societal readiness perspective Norway seems to be well suited to meet the challenges related to establishing nuclear in one to two decades if there is political will to follow through with education and licensing. Educational institutions would need to implement new and relevant courses and there would have to be programs for existing oil engineers and controllers to enter into nuclear energy operations. On a law and regulatory basis, informant 5 concludes that Norway has a very solid foundation, with the relevant laws already place and all relevant international agreements signed. The one thing missing is to implement the additional regulations and licensing regarding the commercial operation of a nuclear reactor. This readiness perspective is however contended by two informants on a more general level as being unfeasible.

Referring to the economy chapter, and considering the findings in this chapter, there are indications that implementing nuclear power would also contribute positively to the society section of the triple bottom-line. Firstly, for districts, with an increase in high value jobs and industry; and secondly for the region and the nation, with increased energy safety.

Going forward, there is a general request from informants 1, 2, 5 and 6 for more and more precise information in the public discourse, with informants 3 and 4 requesting a thorough evaluation of the risks by everyone involved.

Conclusion

The aim of this thesis was to examine the potential of nuclear energy in rural Norway and if it could play a pivotal role in advancing the green shift in the districts of Norway, focusing on the economic, environmental, and societal-readiness perspectives. As a result of this research, it is evident that the potential implementation of nuclear energy in Norway is a multifaceted endeavor that demands careful consideration of various environmental, societal, and regulatory factors.

On a global level, nuclear energy has been used for over six decades as a source of power, and its contribution to the global energy sector cannot be overlooked. Despite the apparent advantages that nuclear energy has, it has remained a contentious issue in many countries. The social, environmental, and economic impacts of nuclear energy have been the subject of numerus studies and debates. Effectively addressing the epistemic challenges surrounding nuclear energy requires a collaborative effort that spans scientific, social, and political domains. This thesis had the aim to explore how nuclear energy can be part of the energy transition by employing a multidisciplinary approach, drawing on key theoretical frameworks to provide a comprehensive evaluation using the Flourishing business canvas. Additionally, it incorporates valuable insights from experts' interviews spanning politics, technical expertise, and economic perspectives.

From an economic standpoint, the integration of nuclear energy offers a promising pathway towards stability and prosperity for rural Norway, with capital costs and waste management identified as the primary challenges. The analysis reveals that despite the substantial initial capital investment required for nuclear infrastructure, the subsequent operational phase yields long-term benefits. With the right policy frameworks, this investment can be amortized over decades, rendering nuclear energy a cost-effective option for providing large quantities of affordable electricity. The potential for repatriation, as successfully demonstrated in other sectors, underscores the economic resilience that can be achieved through nuclear energy.

Environmental considerations loom large in the transition to sustainable energy systems. Nuclear energy emerges as a low-carbon alternative, with a minimal carbon footprint compared to conventional fossil fuels. However, it is crucial to acknowledge the challenges associated with the management of radioactive waste and the potential risks in case of accidents. The low area impact of nuclear energy plants, both in terms of the facility itself and associated infrastructure, addresses concerns related to land use and conservation. None the less, together with all the other sources of energy we've reviewed, nuclear power only qualifies as weak sustainability. Although with a comparably low impact, there is a fundamental substitution of natural capital to human capital. But ultimately, the capacity of nuclear energy to function as a linchpin in reducing greenhouse gas emissions aligns with Norway's commitment to meeting climate targets.

Societal readiness emerges as a pivotal aspect, with political support, regulatory frameworks, and public acceptance playing instrumental roles. The implementation of nuclear energy transcends technical and economic considerations, embedding itself within the social fabric of rural communities. Acknowledging that the local societies seek climate and nature measures, affordable energy and energy security is paramount. Addressing concerns related to safety, security, and long-term waste management will thus be foremost for gaining public trust. The establishment of a nuclear power plant necessitates careful planning, thorough risk assessments, and transparent communication with stakeholders at all levels, in rural Norway as well as nationwide. By recognizing the pivotal role of energy access in maintaining societal stability, stakeholders emphasize the imperative of a predictable transition away from fossil fuels. However, concerns persist, rooted in historical accidents and myths, necessitating comprehensive public engagement and accurate information spreading.

The synergy of economic viability, environmental sustainability, and societal readiness elucidates the transformative potential of nuclear energy in rural Norway. The economic benefits, coupled with a low environmental impact, position nuclear energy as a key player in the green shift. Engendering societal readiness necessitates strategic communication and a collaborative approach to alleviate concerns and harness the collective will towards a sustainable energy future.

Our findings also show the need for aligning nuclear energy implementation with the broader goals of the nation. Balancing the need for accessible, reliable energy against environmental and social considerations is a central challenge. Additionally, the cost implications, both in terms of initial investment and long-term operational expenses, highlight the need for a robust economic framework.

To fully realize the potential of nuclear energy in rural Norway, it is imperative to embark on a multifaceted approach. This includes:

1. Political Consensus and Regulatory Frameworks: Fostering political consensus and enacting robust regulatory frameworks are pivotal prerequisites for the successful integration of nuclear energy.
2. Public Engagement and Education: Comprehensive public engagement programs, coupled with accurate and accessible information dissemination, are essential in dispelling myths and addressing concerns surrounding nuclear energy.
3. Investment in Human Resources and Education: Investing in education and training programs to build a skilled workforce specialized in nuclear technology is crucial for successful implementation.
4. Continual Evaluation and Adaptation: Regular evaluation of the economic, environmental, and societal impacts of nuclear energy implementation is necessary to adapt strategies and policies in alignment with evolving needs and circumstances.

While the prospects of nuclear energy present promising opportunities for rural Norway as well as the nationwide energy landscape, it is imperative to approach this transition with caution, diligence, and a comprehensive understanding of its implications. By harnessing its economic viability, environmental sustainability, and societal readiness, Norway can pave the way towards a sustainable, low-carbon future, ensuring energy security and contributing significantly to global efforts in combating climate change. This demands a well-informed and collaborative effort, encompassing all relevant stakeholders, that will be instrumental in shaping a sustainable and responsible nuclear energy sector for Norway. This thesis offers a foundation for future discussions and actions in this critical area of energy policy.

References / Literature

Abousahl, S., Carbol, P., Farrar, B., Gerbelova, H., Konings, R., Lubomirova, K., Martin Ramos, M., Matuzas, V., Nilsson, K., Peerani, P., Peinador Veira, M., Rondinella, V., Van Kalleveen, A., Van Winckel, S., Vegh, J. and Wastin, F.,. European Commission, 2021, Technical assessment of nuclear energy with respect to the 'do no significant harm' criteria of Regulation (EU) 2020/852 ('Taxonomy Regulation'). https://publications.jrc.ec.europa.eu/repository/handle/JRC125953.

Datatilsynet, 2018, Om personopplysningsloven med forordning og når den gjelder. https://www.datatilsynet.no/regelverk-og-verktoy/lover-og-regler/om-personopplysningsloven-og-nar-den-gjelder/

DNV, Retrieved April 23, 2023. Five challenges we need to overcome to move the energy transition forward in 2023. https://www.dnv.com/article/five-challenges-we-need-to-overcome-to-move-the-energy-transition-forward-in-2023-236989

DSA, 2022, Veileder til de generelle konsesjonsvilkårene. https://dsa.no/publikasjoner/_/attachment/inline/8551203a-8bc9-4263-9ab9-0c301d9d6c7c:060bc4c2c1c32673e35c220ce031e89495572fed/DSA-hefte%205%20Veileder%20til%20de%20generelle%20konsesjonsvilk%C3%A5rene.pdf

DSA, 2023. Norway's Report to the joint 8th and 9th Review Meeting of the Convention on Nuclear Safety. https://dsa.no/publikasjoner/_/attachment/inline/6ba0ee0c-1fde-4638-9c4b-7f934a2b606b:333dd9cca3e5ea11fdffc6f04ab454d181e08ec6/DSA-rapport%2003-2023%20Norway%E2%80%99s%20Report%20to%20the%20joint%208th%20and%209th%20Review%20Meeting%20of%20the%20Convention%20on%20Nuclear%20Safety.pdf

Elkington, J., 1998. Cannibals with Forks: The Triple Bottom Line of 21st Century Business. Capstone Publishing Ltd

Elements, 2022. Who Is Building Nuclear Reactors? (1) https://elements.visualcapitalist.com/nuclear-reactors-under-construction/

Elements, 2022. Visualizing Nuclear Power Production by Country (2) https://elements.visualcapitalist.com/visualizing-nuclear-power-production-by-country/

European Commission, Retrieved September 14, 2023, The Just Transition Mechanism: making sure no one is left behind. https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en

Flourishing Business, Retrieved April 13, 2023, Background & History. https://flourishingbusiness.org/background-history

GE Hitachi, 2019, Status Report – BWRX-300 GE Hitachi and Hitachi GE Nuclear Energy. https://aris.iaea.org/PDF/BWRX-300_2020.pdf

Ghauri, P. N., Grønhaug, K., 2005. Research methods in business studies: a practical guide. 3rd edition, Pearson education limited.

IAEA, 2015, Climate Change and Nuclear Power 2015. https://www-pub.iaea.org/mtcd/publications/pdf/ccanp2015web-78834554.pdf

IAEA, Retrieved September 14, 2023. Milestones Approach. https://www.iaea.org/topics/infrastructure-development/milestones-approach

Jakobsen, O, 2019. Økologisk økonomi Et perspektiv fra fremtiden (1. utg.). Flux forlag

Johannessen, A., Christoffersen, L. & Tufte, P., 2020. Forskningsmetode for økonomiskadministrative fag. 4th. ed. Abstrakt forlag.

Kolmes, E. F., 2018. Context-Based Design – A Business Model Architecture for an Innovation Centre in the Energy Transition. Researchgate.
DOI: 10.13140/RG.2.2.17418.90565

Lincoln, Y. S. & Gubba, E. G., 1985. Naturalistic inquiry. Beverly Hills, Calif.: Sage Publications.

Lovdata, 2023. Lov om atomenergivirksomhet [atomenergiloven]. https://lovdata.no/dokument/NL/lov/1972-05-12-28/KAPITTEL_4#%C2%A753

Manfred, A. M., 2005. Foundations of transdisciplinarity, 53 (5-16). https://doi.org/10.1016/j.ecolecon.2005.01.014

McEwen, T., 2000. The site selection process for a spent fuel repository in Finland - Summary report. Timo Aikas, Posiva Oy

National geographics. 2019. What is nuclear energy and is it a viable resource? https://www.nationalgeographic.com/environment/article/nuclear-energy

National research ethics committees, Retrieved October 10, 2022, Guidelines, https://www.forskningsetikk.no/retningslinjer/

Naturvernforbundet, Retrieved April 23, 2023. Atomkraft. https://naturvernforbundet.no/energi/atomkraft/

NEA, 2023, Uranium 2020: Resources, Production and Demand. https://www.oecd-nea.org/jcms/pl_52718/uranium-2020-resources-production-and-demand?details=true.

Nikel, D., 2021. The Story of Nuclear Power in Norway. Life in Norway. https://www.lifeinnorway.net/nuclear-power/

Niu, S., 2011. Radiation protection of workers. International Labour Organization. https://www.ilo.org/wcmsp5/groups/public/@ed_protect/@protrav/@safework/documents/publication/wcms_154238.pdf

Norges offentlige utredninger (NOU: 15), 2020. Det handler om Norge — Utredning om konsekvenser av demografiutfordringer i distriktene. https://www.regjeringen.no/no/dokumenter/nou-2020-15/id2788079/

Norges offentlige utredninger (NOU), 2022. Nett i tide – om utvikling av strømnettet. https://www.regjeringen.no/no/dokumenter/nou-2022-6/id2918464/

NRK, 2022. Ny klimaplan peikar på kjernekraft. https://www.nrk.no/vestland/ny-klimaplan-peikar-pa-kjernekraft-1.16180596

NSD, Retrieved 2022. Lag en datahåndteringsplan. https://www.nsd.no/lag-en-datahandteringsplan

Nystad, Ø., Jaminon, J., Jakobsen, O., 2008. Er målsetningen om økonomisk vekst forenlig med kravet om bærekraftig utvikling? https://nordopen.nord.no/nord-xmlui/bitstream/handle/11250/294315/Nystad.pdf?sequence=3

Osterwalder, A., Pigneur, Y., 2010. Business model generation: a handbook for visionaries, game changers, and challengers. 1st. edition. John Wiley & Sons P&T.

Patton, M. Q., 2015. Qualitative Research & Evaluation Methods: Integrating Theory and Practice, 4th Edition. In (Vol. 2). Beaverton: Beaverton: Ringgold, Inc.

Regjeringen 1, 2021. Norway's oil history in 5 minutes. https://www.regjeringen.no/en/topics/energy/oil-and-gas/ norways-oil-history-in-5-minutes/id440538/

Regjeringen 2, 2021. Om nukleære anlegg i Norge. https://www.regjeringen.no/no/tema/naringsliv/forskning-og-innovasjon/Norsk-atomavfall-og-atomanlegg/om-nukleare-anlegg-i-norge/id2484230/

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., … and Rockstrom, J., 2023. Earth beyond six of nine planetary boundaries. SCIENCE ADVANCES, 9 DOI: 10.1126/sciadv.adh2458

Rockström, J., Steffen, W., Noone, K., Persson, A., … and Foley, J., 2019. Planetary Boundaries: Exploring the Safe Operating Space for Humanity. Ecology and Society, 14. http://www.ecologyandsociety.org/vol14/iss2/art32/

Sander, K., 2022. Kausalt design. Retrieved from https://estudie.no/kausalt-design/

Skirbekk, G., 2019. Epistemic Challenges in a Modern World.
https://gunnarskirbekk.no/b%C3%B8ker/epistemic.pdf

SSB, 2020, Sentralitetsindeksen. https://www.ssb.no/befolkning/artikler-og-publikasjoner/sentralitetsindeksen.oppdatering-med-2020-kommuner.

Stanford, 2020, Hermeneutics. https://plato.stanford.edu/entries/hermeneutics/# Continuations.

Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., … SÖRLIN, S., 2015. Planetary boundaries: Guiding human development on a changing planet. Science 347 (6223), 1259855. DOI: 10.1126/science.1259855

Stockholm Resilience Center 2016, Retrieved May 2023, SUSTAINABLE DEVELOPMENT GOALS - The SDGs wedding cake. https://www.stockholmresilience.org/research/research-news/2016-06-14-the-sdgs-wedding-cake.html

Stockholm Resilience Centre, Retrieved May 2023, Planetary boundaries,
Licenced under CC BY-NC-ND 3.0 Credit: Azote for, Stockholm University.
https://www.stockholmresilience.org/research/planetary-boundaries.html

Strømme, S H., 2021. MDGs landsmøte vedtok lørdag at partiet skal støtte moderne kjernekraft som teknologi. Det har skapt reaksjoner innad i partiet.
https://www.nrk.no/norge/mdgs-vedtak-om-stotte-til-atomkraft-skaper-reaksjoner-1.15436579

UNECE, 2022. Carbon Neutrality in the UNECE Region: Integrated Life-cycle Assessment of Electricity Sources. LCA_3_FINAL March 2022.pdf (unece.org).

United Nations, 2022, Secretary-General's remarks to High-Level opening of COP27.
https://www.un.org/sg/en/content/sg/speeches/2022-11-07/secretary-generals-remarks-high-level-opening-of-cop27

United Nations, General Assembly, Economic and Social Council, 2023. Progress towards the Sustainable Development Goals: Towards a Rescue Plan for People and Planet (1). https://sdgs.un.org/sites/default/files/2023-04/SDG_Progress_Report_Special_Edition_2023_ADVANCE_UNEDITED_VERSION.pdf

United Nations, Retrieved 2023. Department of Economic and Social Affairs Sustainable Development. The 17 Goals (2). https://sdgs.un.org/goals

United Nations, Retrieved June 11, 2023. Renewable energy – powering a safer future (3). https://www.un.org/en/climatechange/raising-ambition/renewable-energy

United Nations, 2015. Department of Economic and Social Affairs Sustainable Developmen. Retrieved November 18th 2023, Brief for GSDR 2015; Weak Sustainability versus Strong Sustainability (4) https://sustainabledevelopment.un.org/content/documents/6569122-Pelenc-Weak%20Sustainability%20versus%20Strong%20Sustainability.pdf

Upward, A., Jones, P., 2015, An Ontology for Strongly Sustainable Business Models: Defining an Enterprise Framework Compatible With Natural and Social Science. https://doi.org/10.1177/1086026615592

Wikipedia, 2023. Nuclear and radiation accidents and incidents. https://en.wikipedia.org/wiki/Nuclear_and_radiation_accidents_and_incidents

World Nuclear Association, 2020. Cooling Power Plants. https://world-nuclear.org/information-library/current-and-future-generation/cooling-power-plants.aspx

World Nuclear Association, 2023. Nuclear Power in Sweden. https://world-nuclear.org/information-library/country-profiles/countries-o-s/sweden.aspx

Zadek, S., 2001. The Civil Corporation: The New Economy of Corporate Citizenship, Earthscan, London, Taylor & Francis.

Appendix

Appendix 1: Informasjonsskriv

Vil du delta i forskningsprosjektet

" The green shift and nuclear energy – an environmental, economic, and societal-readiness perspective for rural districts in Norway"?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å *se på atomkraft i lys av Norske forhold og særlig muligheter vedrørende distrikts Norge*. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Formålet med intervjuet er å innhente innsikt og kunnskap for vår masteroppgave;" The green shift and nuclear energy – an environmental, economic, and societal-readiness perspective for rural districts in Norway".

Oppgaven tar for seg å se nærmere på atomkraft i Norge, igjennom perspektivene miljø, økonomi og samfunnsmodenhet. Dette vil legge grunnlaget for oppgavens primærproblemstilling; har eller har ikke atomkraft en rolle å spille for å revitalisere utkantsamfunn og distrikter i Norge.

Oppgaven vil bygge på kvalitative intervju og litteratursøk på både Norske og internasjonale funn.

Lydopptak og resulterende transkribering skal ikke brukes til noen formål utover masteroppgaven.

Hvem er ansvarlig for forskningsprosjektet?

Hussein Mohamad Ali, Mohamad; Svendsen, Thomas Bøe; Alfsvåg, Lasse Instefjord, under veiledning av professor Ove D. Jacobsen ved Nord Universitet, er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?

Du er valgt basert på våre utvalgskriterier som forsker / politiker / miljøforkjemper eller representant fra industri/virksomhet, som har utmerket deg igjennom å delta i det offentlige ordskiftet som gjelder atomkraft.

Hva innebærer det for deg å delta?

- *Hvis du velger å delta i prosjektet, vil vi utføre et intervju sammen med deg, fortrinnsvis ansikt til ansikt*
- *Vi tar lydopptak og notater under intervjuet.*
- *Intervjuet har spørsmål vedrørende atomkraft, miljø og samfunn.*
- *Vi vil spørre om navn, utdanning / yrke og rolle tilknyttet temaet atomkraft.*
- *Intervjuet vil ta ca. 45-60 minutter.*
- *Dine svar fra intervjuet blir registrert elektronisk.*
- *For oppgaven vil vi også innhente informasjon fra andre kilder: faglitteratur, journaler og andre respondenter*

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Hvis du velger å delta, kan du når som helst trekke samtykket tilbake uten å oppgi noen grunn. Alle dine personopplysninger vil da bli slettet. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller senere velger å trekke deg.

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger

Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

- *Prosjektgruppe og veileder vil ha tilgang til opplysninger under prosjektperioden*
- *Datagrunnlag som inneholder personopplysninger vil lagres på tilgangsbegrenset dokumentområde i prosjektperioden, fram til det anonymiseres i henhold til kapitel under.*

Vi ønsker gjerne å bruke personopplysninger som navn, yrke/tittel og tilknytting til institusjon/bedrift i masteroppgaven. Om du ønsker å delta i undersøkelsen, men allikevel reservere deg mot bruk av personopplysninger i oppgaven, så er dette mulig.

Hva skjer med personopplysningene dine når forskningsprosjektet avsluttes?

Prosjektet vil etter planen avsluttes mai 2023, alternativt november 2023 ved utsatt innlevering. Etter prosjektslutt vil datamaterialet med dine personopplysninger anonymiseres. Det innebærer følgende:

- Lydopptak vil slettes
- Transkribert tekst vil anonymiseres ved at navn, yrke/rolle og organisasjonstilknyting slettes. Foreligger det andre typer personlig informasjon utover dette vil vi også slette disse.
- Unntak fra sletting vil være informasjon eller sitater i oppgaveteksten som er publisert i henhold til avtale.

Personopplysninger og datamateriale vil ikke brukes til senere forskningsprosjekter.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler opplysninger om deg basert på ditt samtykke.

På oppdrag fra Nord universitet har Sikt – Kunnskapssektorens tjenesteleverandør vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter

Så lenge du kan identifiseres i datamaterialet, har du rett til:

- innsyn i hvilke opplysninger vi behandler om deg, og å få utlevert en kopi av opplysningene
- å få rettet opplysninger om deg som er feil eller misvisende
- å få slettet personopplysninger om deg
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger

Hvis du har spørsmål til studien, eller ønsker å vite mer om eller benytte deg av dine rettigheter, ta kontakt med:

- Prosjektgruppe: Mohamad Hussein Mohamad Ali (mohamad.h.m.ali@gmail.com);
  Thomas Bøe Svendsen (thomas.boe.svendsen@gmail.com);
  Lasse Instefjord Alfsvåg Lasse Instefjord (lassealfsvag@gmail.com)
- Veileder ved Nord universitet: Ove D. Jakobsen (ove.d.jakobsen@nord.no)
- Vårt personvernombud: Toril Irene Kringen (personvernombud@nord.no)

Hvis du har spørsmål knyttet til vurderingen som er gjort av personverntjenestene fra Sikt, kan du ta kontakt via:

- Epost: personverntjenester@sikt.no eller telefon: 73 98 40 40.

Med vennlig hilsen

Prosjektansvarlig
Ove D. Jakobsen

Studenter
Mohamad Hussein Mohamad Ali, Thomas Bøe Svendsen og Lasse Instefjord Alfsvåg

Appendix 2: Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *"The green shift and nuclear energy – an environmental, economic, and societal-readiness perspective for rural districts in Norway"*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- ☐ å delta i intervju
- ☐ at opplysninger om meg publiseres slik at jeg kan gjenkjennes i endelig masteroppgave

Jeg samtykker til at mine opplysninger behandles frem til prosjektet er avsluttet

----

(Signert av prosjektdeltaker, dato)

Appendix 3: Interview guide

#	Interview guide: semi - structured

1.0.0	Introduction
-	Presentation of researcher, project and scope, handling of personal data, the rights of the informant in relation to the project and the outline of the interview itself. This would be the step where the statement of consent, in accordance with NSD, Norwegian Centre for Research Data, will be presented.
1.0.1	Presentation of researcher
1.0.2	Present project and scope
1.0.3	Explain the handling of personal data, the rights of the informant in relation to the project and the outline of the interview itself
-	Present statement of consent.
1.1.0	Factual questions
	Simple questions with simple answers to initiate the interview with the informant.
1.1.1	Informant introduction:
1.1.2	- Name
1.1.3	- Position (in relation to the topic)
1.1.4	- Motivation for the topic etc. (to establish report)
1.1.5	- Informal questions for warm-up: hobbies, interests etc.
1.2.0	Introduction questions

Headers
Sub-headers
Additional information
Main questions
- support questions
Action

-	Questions to steer the interview onto topics. Open ended questions where the informant can come with personal observations and musings regarding the topic. Might lead directly into the key topics.
1.2.1	When you think about the term "nuclear energy", what is the first that comes to mind?
1.3.0	Segue questions
-	Questions designed to segue the interview from the introduction into the key topics of the interview. As the topic of nuclear energy does carry emotional attachments with many, the introduction question may likely carry directly into one of the key topics. First question under each key topic is shaped as a segue and highlighted in **bold:** **- Nuclear energy** **- Environmental** **- Economy** **- Societal readiness** **- SMRs in in rural communities**
-	
2.0.0	Key topics
2.1.0	Nuclear energy
-	The production and sale of energy based on state of the art and near-future fission reactors, and what options have been proposed for Norwegian conditions.
2.1.1	What is an advanced nuclear reactor? Are there different types of reactors?
2.1.2	How do future nuclear energy fit into the existing energy mix in Norway and what pros/cons does it bring with it?
2.2.0	Environmental

-	The impact of nuclear energy on the environment. This paper will look at nuclear energy considering safety record, pollution, greenhouse gas emissions and waste disposal, as these are the common caveats in the nuclear discourse.
2.2.1	**Environmental**: The most common criticism of nuclear energy is the safety aspect. What do you see as the 3 most important factors and what can / cannot be done to mitigate the worries people have of these?
2.2.2	Is using nuclear power the way to achieve clean environmentally friendly energy? And how does it fit with Norway's climate goals (2030, 2050)?
2.2.3	- In what ways is nuclear energy a better alternative than other energy sources?
2.2.4	- Can nuclear energy be qualified as low carbon? And would you say that its looked as a sustainable way of producing energy?
2.2.5	- How does nuclear energy impact the environment?
2.2.6	- Can extraction of ore be made safe and sustainable?
2.2.7	Could you tell me something about safety? From community to workers?
2.2.8	- Is it safe to live near an advanced nuclear plant?
2.2.9	- Can nuclear power production be kept safe from natural disasters?
2.2.10	- How likely is it that accidents like those in Chernobyl, Three Mile Island, and Fukushima will happen again?
2.2.11	What is the service life of a nuclear power plant? How long can you extend its service life?
2.2.12	- Why and how do you dismantle a nuclear power plant?
2.2.13	- What do we do with nuclear waste? How is it treated?
2.2.14	- How long will the radioactive waste be hazardous?
2.2.15	- How are we going to transport the waste?
2.3.0	Economy

-	How competitive is nuclear power per kw/h in comparison to other sources of energy in todays interconnected electricity market.
2.3.1	**Economy:** A common criticism of nuclear energy is that it is not competitive, especially in Norway, regarding cost. What are your thoughts regarding this?
2.3.2	How do the levelized cost of energy from nuclear compare to competing /complementing energy sources?
2.3.3	Private or governmental ownerships?
2.3.4	- State support of operation and/or construction?
2.3.5	How much energy does a nuclear reactor generate? What is the efficiency?
2.3.6	- What kind of resources does nuclear energy require? Is it worth the effort and the investment to acquire nuclear energy?
2.3.7	- How much is available of the raw material in the earth crust and how long will the supplies last?
2.4.0	Societal readiness
-	Does Norway have the academic and engineering expertise available to initiate a nuclear energy project.
2.4.1	**Societal readiness:** Apart from our previous four research reactors at Halden and Kjeller the nuclear energy traditions in Norway are not particularly pronounced. What is the state of Norway's nuclear reactor readiness from your point of view?
2.4.2	How do you think the Norwegian public look at nuclear power?
2.4.3	Where do opinions of the Norwegian politicians stand on the discussion of nuclear power?
2.4.4	What are the most contentious issues surrounding nuclear energy?
2.4.5	What do you think are the common misconceptions about nuclear?
2.4.6	What are the major challenges to the expanded use of nuclear energy? And how is it addressed?
2.4.7	Does Norway have a large skilled enough work force to support a number of reactors?

2.4.8	How does the Norwegian stance on nuclear energy compare with other countries?
2.4.9	What legislation would you like to see regarding nuclear power and nuclear waste in the near future?
2.4.10	What are your thoughts on the timeframes for nuclear power development? Politics and Economy.
2.5.0	SMRs in in rural communities
-	The transition from the current state of society, where resource, area and greenhouse gas emissions are in overshot, to a more sustainable and climate friendly society - in this paper proposed as rural sites in Norway.
2.5.1	**SMRs in in rural communities**: Considering the topics we've covered; this article is looking at potential SMRs role in strengthening rural areas in Norway. How do you see SMRs as a key piece in this regard?
2.5.2	Can nuclear power be installed anywhere in Norway?
2.5.3	How many jobs can be created by implementing a new power plant
2.5.4	How about local communities, what are your perception of the views of having a nuclear power plant in the nearby communities?
2.5.5	Are there any ideal locations in Norway regarding the power network, expertise, stability etc.
2.5.6	Are there communities that have shown interest in hosting reactors?
-	
3.0.0	Complex or sensitive follow-up questions
-	If topics warrant follow-up questions that might delve into the complex or sensitive, these can be saved or shelved until the end of the interview, to keep them from taking over or disrupting the interview.
3.0.1	Is there any kind of new research or currently underway that can change peoples opinion on Nuclear power?
3.0.2	How would you summarize your personal stance on nuclear energy?
3.0.3	How would you summarize the stance on nuclear energy of the organization that you represent?
-	

4.0.0	Wrap-up
-	The closing of the interview should be announced ahead of the actual wrapping up. In the semi-structured form, a timer should trigger the announcement, as the interview may be too free form for calling "the last few questions". During the final moments of the interview, the informant will get the option to ask questions, clarify open ends and make final comments that was not covered in the interview proper.
4.0.1	Are there any more things you would like to say before we end the interview?
4.0.2	May I contact you if further questions should arise?
4.0.3	Thank you for your time.

Appendix 4: Vurdering NSD

Sikt

Meldeskjema / The green shift and nuclear energy – an environmental, economic, and… / Vurdering

Vurdering av behandling av personopplysninger

Referansenummer	Vurderingstype	Dato
543782	Automatisk	28.02.2023

Prosjekttittel

The green shift and nuclear energy – an environmental, economic, and societal-readiness perspective for rural districts in Norway

Behandlingsansvarlig institusjon

Nord Universitet / Fakultet for samfunnsvitenskap / Ledelse og innovasjon

Prosjektansvarlig

Ove D. Jakobsen

Student

Mohamad Ali

Prosjektperiode

01.04.2023 - 30.11.2023

Kategorier personopplysninger

Alminnelige

Lovlig grunnlag

Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Behandlingen av personopplysningene er lovlig så fremt den gjennomføres som oppgitt i meldeskjemaet. Det lovlige grunnlaget gjelder til 30.11.2023.

Meldeskjema

Grunnlag for automatisk vurdering

Meldeskjemaet har fått en automatisk vurdering. Det vil si at vurderingen er foretatt maskinelt, basert på informasjonen som er fylt inn i meldeskjemaet. Kun behandling av personopplysninger med lav personvernulempe og risiko får automatisk vurdering. Sentrale kriterier er:

- De registrerte er over 15 år
- Behandlingen omfatter ikke særlige kategorier personopplysninger;
    - Rasemessig eller etnisk opprinnelse
    - Politisk, religiøs eller filosofisk overbevisning
    - Fagforeningsmedlemskap
    - Genetiske data
    - Biometriske data for å entydig identifisere et individ
    - Helseopplysninger
    - Seksuelle forhold eller seksuell orientering
- Behandlingen omfatter ikke opplysninger om straffedommer og lovovertredelser
- Personopplysningene skal ikke behandles utenfor EU/EØS-området, og ingen som befinner seg utenfor EU/EØS skal ha tilgang til personopplysningene
- De registrerte mottar informasjon på forhånd om behandlingen av personopplysningene.

Informasjon til de registrerte (utvalgene) om behandlingen må inneholde

- Kontaktopplysninger til personvernombudet (hvis relevant)

- Formålet med behandlingen av personopplysningene
- Det vitenskapelige formålet (formålet med studien)
- Det lovlige grunnlaget for behandlingen av personopplysningene
- Hvilke personopplysninger som vil bli behandlet, og hvordan de samles inn, eller hvor de hentes fra
- Hvem som vil få tilgang til personopplysningene (kategorier mottakere)
- Hvor lenge personopplysningene vil bli behandlet
- Retten til å trekke samtykket tilbake og øvrige rettigheter

Vi anbefaler å bruke vår mal til informasjonsskriv.

Informasjonssikkerhet

Du må behandle personopplysningene i tråd med retningslinjene for informasjonssikkerhet og lagringsguider ved behandlingsansvarlig institusjon. Institusjonen er ansvarlig for at vilkårene for personvernforordningen artikkel 5.1. d) riktighet, 5. 1. f) integritet og konfidensialitet, og 32 sikkerhet er oppfylt.

Appendix 5: Flourishing Business Canvas