Climate Change and the Expansion of Arctic Shipping

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

The potential economic benefits from increased Arctic shipping are enormous. As well as changing the logistics of global trade, Arctic shipping routes have the potential to generate inward investment flows benefiting the Northern and Indigenous communities, supporting regional development, and enhancing economic and social sustainability. At the same time, however, unregulated economic expansion carries a significant risk. In such a fragile region the ecological consequences might be severe and potentially irreversible. Likewise, the social, economic, and cultural consequences of such ecological damage would likely cause serious disruptions, affecting life across the region, as well as having global impacts in terms of climate change. For this reason, during this early, preparatory period, well before any largescale commercial exploitation, it is imperative that the community of nations and other stakeholders establish a clear and effective set of standards along with an effective governance regime to regulate Arctic shipping to ensure contributions to long-lasting wellbeing. In the case of the largely pristine Arctic environment, it is crucially important that we understand the ecological and biophysical limits of increased exploitation to avoid irreversible impacts whereby disruption and crisis will out-weigh stability and development.

This research seeks to understand the potential expansion of commercial Arctic shipping in the wake of the anticipated decline of Arctic sea ice. In the first phase of a longer-term doctoral project, my goal has been a preliminary review and synthesis of the literature relating to medium- and long-term costs and benefits with respect to sustainable development in the region. This scoping project has been designed as the first step toward the development of a Sustainable Arctic Shipping Standard (SASS). The research centers on the analysis of literature from a diverse range of scientific fields to create a comprehensive picture of the potential threats arising from increased Arctic sea shipping.

This research shows that anticipating the overall impact of arctic shipping on regional sustainability is extremely complex. While the environmental impact might be more negative, there are some serious economic advantages, that are often opposed to the environmental losses. The effects on local communities are also ambiguous and further research is needed to have a more defined conclusion. Nevertheless, the key areas of concern and opportunity are usefully identified.

Acknowledgements

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AC – Arctic Council

ACAP – Arctic Contaminants Action Program

AEC – Arctic Economic Council

BC – Black carbon

CAFF – Conservation of Arctic Flora & Fauna

CDP – Carbon Disclosure Project

CEPA – Canadian Environmental Protection Act

ECAs – Emission Control Areas

GHG – Greenhouse gas

HFO – Heavy Fuel Oil

IMO – International Maritime Organization

LNG – Liquid Natural Gas

NEP – Northeast Passage

NGO – non-governmental organization

NIS – Non-indigenous species

NSR – Northern Sea Route

NWP – Northwest Passage

NZ – Net zero

TCFD - Task Force on Climate-related Financial Disclosures

TTS – Temporary Threshold Shift

SASS – Sustainable Arctic Shipping Standard

SDGs – Sustainable Development Goals

SEEMP – Ship Energy Efficiency Management Plan

SSI – Sustainable Shipping Initiative

SRTI – Ship Recycling Transparency Initiative

Chapter 1 Introduction. Research goals, objectives and framework

1.1 Research Purpose and Objectives

This research seeks to understand the potential expansion of commercial Arctic shipping in the wake of the anticipated decline of Arctic sea ice. My goal has been a preliminary exploration of medium- and long-term costs and benefits with respect to sustainable development in the region. In order to navigate the abundance of the information across multiple domains, and to help define and prioritize the key sustainability topics, this research requires a clear analytical framework.

The overarching goal of the project is to provide a conceptual foundation for the development of a Sustainable Arctic Shipping Standard (SASS). Such a standard would ensure that, even as retreating Arctic ice allows an enormous increase in the volume of shipping, the integrity and sustainability of the Arctic region would be protected. This might be represented as the set of actions consistent with maintaining and enhancing the existing level of sustainability while also preventing any further deterioration and engendering a more sustainable pattern of commercial activity in the region. Right now, commercial shipping through the Arctic is only under development (Arctic Economic Council, 2017). Given the rate of sea ice contraction, it is likely that full-scale shipping will become possible only by around 2050 (Melia et al., 2016). This means that some time is available for establishing a scientific basis for a sustainable shipping regime. However, the establishment of such a regime is a highly complicated and time-intensive process. Such a SASS would modify existing norms, enhancing regional sustainability, and future-proofing the integrity of the region against the trend of increasing anthropogenic activity (Campins Eritja, 2021a). Lastly, while standards now are usually focused on mitigating adverse effects rather than enhancing positive ones, it is important to approach the development of such future standards with the priority on the latter.

The research centres on the analysis of the literature from a diverse range of scientific fields to create a comprehensive picture of the potential threats arising from increased Arctic sea shipping. This research aspires to identify positive opportunities from a sustainability perspective. This baseline study will prepare the ground for later research involving a series of interviews with corporations, non-governmental organization (NGOs), scientific institutions, and government bodies. Future steps of this research will be necessary to define (a) current impacts, (b) existing patterns of governance and regulation, (c) opportunities for improvements the understanding of shipping sustainability and impact as well as economic, social, and technical innovations, and (d) possible barriers impeding the development and implementation of a new regulatory regime. Based on this information, the project will eventually allow the delineation of a clear set of actions for the development of the universal SASS.

Both climate and the geopolitical landscape are changing profoundly (Thomas et al., 2021). Obvious dangers notwithstanding, such changes engender new opportunities. In the case of the largely pristine Arctic environment, it is crucially important that we understand the ecological and biophysical limits (Young, 2021) of increased exploitation so as to avoid irreversible adverse impacts whereby disruption and crisis will out-weigh stability and development.

Among other effects, climate change is causing a rapid melting of the Arctic Sea ice, thereby opening up new possibilities for commercial navigation and greatly shortened shipping routes through the Arctic (Faury & Lasserre, 2019). There is still no consensus among either circumpolar nations or international scientific bodies as to whether or not to take advantage of this emerging opportunity. But uncertainty notwithstanding, some companies are already starting to develop long-term action plans with a view to exploiting commercial opportunities (Joseph et al., 2021). The potential economic benefits from Arctic navigation are enormous (Ryan et al., 2020). As well as changing the logistical pattern of global trade, there is the possibility of massive financial inflows benefiting the Northern and Indigenous communities, supporting regional development and enhancing economic and social sustainability (Christensen et al., 2019). At the same time, numerous potential threats would accompany the unregulated overexploitation of the region. In such a fragile region, the ecological consequences might be severe and potentially irreversible and the social, economic and other human consequences of that ecological damage could cause serious disruption that would affect the life of the region as well as that would have a global effect. For this reason, during this early, preparatory period, well-before any largescale commercial exploitation, it is imperative that the community of nations and other stakeholders establish a clear and effective standard and governance regime to regulate Arctic shipping to ensure the long-lasting wellbeing (Zhang et al., 2020a).

Many companies that are intending to develop Arctic shipping opportunities are in the process of creating their own internal sustainability plans. Though a good start, such action plans primarily reflect the interests of those corporate stakeholders and may be oriented primarily to public consumption and image management. Clearly such corporate interests are not necessarily aligned with the regulatory regime that would be required for long term sustainability. A classic problem is that ad hoc arrangements for managing common property resources can engender a regulatory 'race to the bottom' (Ostrom, 1990). For this reason, it is important to make sure that an overarching SASS is well-informed, developed transparently and applied on the basis of international agreements and governed by international law (Molenaar et al., 2010).

Any such standard and governance regime would have to account for the complexity of the region (Lasserre, 2018). In addition to those countries with direct territorial claims – Russia, Canada, the USA, Denmark, Norway, Sweden, Finland – there is a longer list of countries (even countries such as the UAE had an interest in possible development of the Arctic sea routes) that, although having no direct access to the region, do have a clearly articulated economic interest in Arctic shipping that is driven by economical motives and the involvement of those counties in the global trade. (Solli et al., 2013). With this in mind, it is very important to find a way to create a standard that would be recognized and applied by all the parties involved.

The research presented here has been designed as a preliminary scoping project and the first step towards defining the core components of a future SASS. The review covers a wide scope of topics that are affected by the shipping industry, including environment, community development, regional economy and global trade. Establishing baseline data and summarising existing research across multiple disciplines is an important precondition for the future development of a SASS.

The key questions that guided the research are:

1. The influence of Arctic shipping on global sustainability. What are the environmental impacts of Arctic shipping? To what extent does Arctic shipping contribute to climate change? How does it affect local communities and the local economy?
2. How do corporate stakeholders view the situation and viability of the Arctic shipping?
3. What knowledge and research are needed to guide the development of sustainable shipping standards?

The goals of this research are:

1. To scope the full range of parameters and considerations germane to the discussion of sustainable development and shipping in the Arctic and establish how the well-recognized

broad considerations for progress towards sustainability should be specified to apply in the particular context of Arctic shipping.

2. To define the key sustainability-based parameters that would be material and can be used as the starting point for further analysis of costs, benefits, opportunities and risks in relation to the development of Arctic shipping with possible application for SASS development.
3. Finally, based on the gaps and uncertainties identified, to define the next steps for this research – to establish a clear foundation for the subsequent development of an evidence-based SASS that would be sufficiently robust to direct the industry onto a sustainable trajectory.

This research is conducted with the support of the Canadian Standards Association and while the development of the SASS was not the objective of this work, it will be one of the major objectives of the next stage of research. Standards development is a complicated process that among other things must be scientifically grounded and also should include the analysis of the applicability and feasibility of the proposed regime and its enforcement. While these topics are outside the scope of this work, it is important to acknowledge the complexity of this process on the preliminary stages of the research.

1.2 Research framework and thesis structure

Given the complexity of Arctic shipping from the perspective of sustainability, it is important to approach the review of the issue holistically and to ensure the absence of significant gaps in the analysis. In the future, the findings from the analysis has potential application for the development of standards, international law, and corporate best practices. Although these future practical applications are outside of the scope of this stage of the research it is important to acknowledge the potential use of the research findings for these purposes in the early stages of the research to set the context for this paper.

Approaching the development of SASS holistically is crucially important for the sustainability of region in the long-term perspective. Aside from an outright ban on Arctic shipping, the development of SASS along with a robust governance and enforcement is the only possible trajectory for a sustainable shipping regime. With this in mind, this project is limited in scope and has aimed simply to define the scope of issues identifies anticipated positive and adverse effects, whilst outlining the scientific foundation for the future development of a SASS.

After reviewing the key topics, the analytical framework structure of the research was developed so as to account for both general sustainability metrics and very context specific problems.

The generic problem of sustainability attends to issues of socio-ecological system viability, justice, equality and long-lasting wellbeing.

For this work sustainability was defined in relation to 4 generic sustainability perspectives: environmental, social, economic and governance – all with attention to intergenerational consequences:

1. Environmental integrity

This perspective depicts matters related to the ecological dimensions of long-lasting wellbeing. By clearly outlining the direction of an environmentally progressive future, this consideration would be embedded into all decision-making strategy and planning for any given activity. The alignment with Sustainable Development Goals (SDGs) #13[1], 14[2] and 15[3] can be seen as the aspirational outcome. This entails creation of positive transition towards a desirable future where the approach to doing business is re-thought and re-defined in a way that ensures protection of the life on land and below water is in peace and harmony with human activity. Moreover, this consideration should emphasize climate action, which is essential for creation of the viable and desirable future for many generations ahead.

2. Social justice, resilience and cohesion

This dimension relates to long-lasting and fairly distributed social wellbeing. Oriented by SDGs #3[4] and #10[5], research should aspire to incentivize actions that would increase social health and well-being and reduce the inequality gap. At the same time, in line with SDG#11[6] this consideration foregrounds the importance of sustainable community development. One way to mitigate adverse impacts is to include community development explicitly in the modelling of strong and robust positive interactions between various components of the system.

[1] SDG#13 Take urgent action to combat climate change and its impacts.
[2] SDG#14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
[3] SDG#15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
[4] SDG#3 Ensure healthy lives and promote well-being for all at all ages.
[5] SDG#10 Reduce inequality within and among countries.
[6] SDG#11 Make cities and human settlements inclusive, safe, resilient and sustainable.

3. Economic viability

Putting aside absolute biophysical limits and the case for degrowth (Quilley, 2013) and assuming a framework of sustainable development, economic viability is a central consideration of any framework, both in terms of returns on any government investment and corporate profitability and in terms of fairly distributed and lasting contributions to the economic foundations for livelihoods and other social opportunities, environmental protection, and other aspects of wellbeing . Attention to economic viability for government and corporate purposes necessitates an explicit engagement with SDG#9[7] which embraces innovation, industry and infrastructure. This is one of the objectives for the study, namely, to find ways to integrate appropriate sustainability considerations with the timing and scale of innovation and infrastructure development. However, the economic dimension of wellbeing cannot be discussed without the review of the existing practices, with a view to eliminating destructive patterns and enhancing those that may facilitate genuinely sustainable forms of development. But disruptive innovation should always be linked to the problem of just transitions and just distribution of benefits/opportunities and damages/risks, recognizing that the most disadvantaged people and places are usually the ones most vulnerable to the negative impacts. These considerations entail engagement with SDGs #8[8] and 16[9].

4. Governance (geopolitics, sustainability enforcement and regulatory mechanism)

Governance relates to both monitoring and regulation of any eventual SASS as well as external enforcement. By exploring the responsiveness of the proposed development to international regulations, norms and standards, and by looking at the internal practices that are already in place or that can be adopted by the industry, we can evaluate how it can be governed and guided towards a more desirable future. Even more importantly it is important to identify regulatory and monitoring failures in the past and aspects of the governance regime that need changing.

[7] SDG#9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

[8] SDG#8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all

[9] SDG#16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels

While this might be outside of the scope of this stage of the research, it is important to acknowledge the importance of this problem from the outset.

At the same time, it is also important to recognize the extreme level of the complexity and uncertainty of the research system associated with the novelty of the issue and how this is affects the environmental, social and economic parameters outlined above.

We also have to acknowledge the particular characteristics, conditions, trajectories, risks and opportunities associated with the expansion of Arctic shipping. Beyond generic sustainability assessment criteria (Gibson, 2006), the list of such context specific parameters includes:

- Climate change
    - The climate dependent timeline of the opening of the Arctic Ocean
    - The contribution of commercial shipping to climate change
    - The prospective but problematic transition to alternative fuels
- The impact of the shipping on the environment
    - The fragility and complexity of the Arctic ecosystem
    - Chemical pollution ($CO2$, nitrogen and sulphur, black carbon, used water, oil spills, shipwrecks and other forms of chemical pollution)
    - Noise pollution
    - Natural resource conservation (habitat destruction, biodiversity and invasive species)
    - Mechanical sea ice destruction
- Navigational Safety
    - Risks to shipping crews
    - Dependence on icebreakers
    - The remoteness of the region
    - Underdevelopment and lack of essential maintenance and search and rescue infrastructure
- Economic viability
    - Potential economic benefits due to the time reductions vs. net cost increase due to increased risks and required investments
    - Shifting global trade patterns

    - Shipping infrastructure development
    - Transformation of the shipping industry with alignment to Net Zero pathways
    - Connection with the industrial development of the Arctic like mining and oil and gas extraction
    - Potential overexploitation of the region and its resources leading to growing inequality, misalignment with just transition approach and uneven distribution of gained benefits between Arctic community economies and transnational corporations.
- Community impact
    - Natural resource availability for indigenous communities
    - Livelihood opportunities (especially lasting ones) creation in the northern communities
    - Increased human turn-over in and the risk of cultural erosion for Indigenous communities
    - Vital infrastructure development (for food access, medicine, etc.)
- Governance
    - Geopolitical interests of different countries in the Arctic region
    - Regulatory mechanisms to enforce sustainable Arctic navigation
    - Shipping standards

All these topics are tightly interconnected one with another; hence, it would be almost impossible and probably pointless to try to address them separately. At the same time, given the strict time-limit for this research, it would be too ambitious to attempt to study all these issues in sufficient depth. Finally, while some issues have been studied intensively others are remain under-researched and are less tractable to analysis. With all of this in mind, the following reporting structure was developed to guide the research.

- <u>Chapter 2 – Defining the context for Arctic shipping.</u>
    - A review of the shipping industry in a global context and its contribution to climate change.

- A review of developments in maritime law from its fundamentals to the development of policies and regulations focusing on the mitigation and reduction of adverse environmental impacts of shipping.
- A case specific review of the existing shipping conditions in the Arctic Ocean and the timeline for the Arctic shipping. This study was involved synthesis of climatic projections relating to the retreat of Arctic sea ice decrease and a summary of trends in declining sea ice coverage and thus probabilities with regard to the duration of the navigation season in the region.
- Finally, this chapter reviews recent changes in the shipping activity in the region complementing future projections with historic data.

- <u>Chapter 3 - Environmental factors.</u>
  - This chapter reviews existing research on the anticipated environmental impacts of expanded Arctic shipping.
  - The chapter also reviews possible benefits and opportunities that might be associated with the development of the Arctic shipping including possible emission reductions due to the shortening of the sea route. The chapter establishes a framework for the analysis of the total net environmental effect from transitioning from traditional to Arctic routes.
- <u>Chapter 4 - Economic factors.</u>
  - Chapter 4 starts with a review of the safety and feasibility risks and limitations of the Arctic shipping. These include hard climatic conditions, geographical remoteness, infrastructure underdevelopment and generally high levels of unpredictability associated with the Arctic operating environment.
  - The chapter goes on to review the economic advantages of the Arctic shipping: the feasibility of Arctic shipping in comparison with traditional trade routes; the possible boom in infrastructure development that in combination with growing presence of mining and oil and gas industries, might bring benefits to the local economies.
- <u>Chapter 5 - Social, community and cultural impacts.</u>
  - The key objective for this part of the research is to review of the community impact of the Arctic shipping. Arctic shipping might well incentivise the economic development

of the regional economy, but the impact on the local communities is neither clear nor predictable. This chapter reviews changes in the availability of natural resources for Indigenous communities, labour market, infrastructure development and availability while also looking on the practices that can be implemented to mitigate those risks.

- Chapter 6 – Governance.
    - Since governance was not the main focus of this study some of crucially important issues pertaining to geopolitics and regulation are not addressed. This was partly a function of time and resources available for the project but also the enormous geopolitical uncertainties in relation to Russia's presence on the world stage and the war in Ukraine. Any commentary in this area was likely to be quickly overtaken by events. However, this chapter does provide an overview of the existing regulations governing the industry's sustainability transition. This chapter reviews existing protocols regulating the shipping industry, and the existing Net Zero incentive structure. Additionally, this chapter reviews the literature on alternative fuel solutions since this would be one of the tangible ways to reduce the negative environmental footprint.
    - Finally, this chapter reviews the evolving regime of internal sustainability protocols and best practice that are emerging from within companies. A high-level overview of the corporate landscape delineates three significant groups of corporate players: i.e. (1) convinced advocates, (2) skeptics and (3) those who are undecided as to the potential of Arctic shipping. The analysis links general corporate approaches to sustainability and the 'environmental bottom line' on the one hand, and company positions on the Arctic shipping, on the other
- Chapter 7 – Identification of gaps and next steps for the research.
    - Chapter seven identifies a number of major gaps between desirable outcomes and the existing trajectory, and locates these in terms of future research needs.

While this research attempts to provide an overview of some scenarios to understand the current trajectory of the development of Arctic shipping and evaluate its strength and limitations as well as positive and adverse effects, I have purposely excluded some topics from the scope of the study:

- While governance and regulatory mechanisms are important to enforce sustainable shipping their review was not in the scope of this work and only a high-level overview is provided
- Geopolitics is another topic that would have a tremendous impact on the future of Arctic shipping. While such countries as the US, Canada, China and Russia have access to the Arctic region other counties also stated their interest in the region. However, after the beginning of the Russian invasion in Ukraine the international political climate changed significantly and some possibilities for the international collaboration on the issue became unavailable. Moreover, the geopolitical tension rocketed. Given the high level of uncertainty and short timeframe to make reasonable predictions geopolitical aspect was not studied under this research as the findings might be outdated fairly shortly.
- The contribution of the Arctic shipping to climate change can be both negative and positive. On one hand, potentially shorter routes might lead to reduced fuel consumption and consequently reduced GHG emissions. On the other hand, navigation through the Arctic would only increase the rate of the Arctic ice through the more intense mechanical ice destruction and accumulation of black carbon on snow and ice that would increase the accumulation of the solar radiation and lead to increased melting rates. Net impact on climate change is another topic that was touched upon, but not studied in-depth. While the general environmental impacts of shipping are extensively studied and can be transported and applied with a certain degree of confidence to the Arctic shipping, the effect on the climate change is still undergoing a serious discussion and yet no clear position is defined.

All things considered, this research is not an attempt to provide a final say on the sustainability assessment of Arctic shipping, it is just an initial study that is aiming to define the scope the potential impact and set the foundation for the future research.

In summary, the proposed steps of the study are:

1. Review the current state of the industry in general and understand the context for Arctic shipping.
2. Review the environmental implications of increased Arctic shipping from both positive and negative perspective.

3. Understand the economic component of increased Arctic shipping (viability, risks, opportunities and impact on the industry).
4. Study the possible positive and negative impacts of increased Arctic shipping on the communities.
5. Review the role of exiting regulatory bodies and international regulations guiding the industry towards sustainability.
6. Study the corporate perspective on the Arctic shipping and define different groups of stakeholders based on their position.
7. Provide conclusions and possible next steps for this research.

1.3 Research methods

Based on the proposed reporting structure I have completed a comprehensive literature review including a review of the peer-reviewed literature on the exiting state of the shipping industry and the probability and feasibility of the development of commercial Arctic shipping; risks and uncertainties associated with Arctic shipping; positive and negative environmental outcomes; contribution to climate change; economic considerations; industry transition towards suitability. A set of relevant key-words was developed to limit the scope of literature to ensure the use of the most relevant sources.

Content analysis of non-peer-reviewed articles and 'gray literature' about existing corporate trajectories and the possibility of commercial Arctic shipping has been used to harness insights with regard to the most significant authorities and stakeholders in the emerging market landscape. This was useful in elucidating cases both for and against the development of Arctic shipping as well as various options in between. This information was obtained from the professional communities and media sources.

Although the proposed review of the secondary data on corporate perspectives proved to be a valuable source of information providing a high-level overview, first-hand data collection is also important to get the deeper understanding of the issue.

One obvious option for data collection would have been primary interviews with stakeholders. Although I did explore this option and wrote over 150 letters with a view to securing access to respondents, the result was uniformly disappointing. It’s unclear whether this was a function of the post-covid situation, and senior executives working from home and being less willing to find time for interviews. However, in the time constraints of a Masters project became an insuperable obstacle and no interviews were conducted. While many of the requests were unanswered, those few potential interviewees who replied did not agree to an interview and referred to a limited knowledge and inability to draw any conclusions at this stage. Low response rate can also be related to the timing of the research – it was conducted in the period when covid was still in place and this probably had an effect on the overall predisposition of people to be involved in any kind of extracurricular activities. Lastly, this interview would potentially touch upon topics can be seen as sensitive and probably corporations were not interested in engaging in such discussions at this point.

In the next stage of the research, those interviews will help us get a better understanding of corporate strategy and policy making in this area. Moreover, interviews will give us a different professional insider view both on the position of those stakeholders who support and who oppose the opportunities of trans-Arctic shipping. We are dealing with a very complex matter here that not only combines multiple domains in areas such as economics, business management, social sustainability, environmental outcomes, and climate change, but is also complicated by the diversity and high number of stakeholders. Therefore, to get any kind of assessment of any actions we should not only know what is currently happening but also the context. By choosing the semi-structured approach to do the interviews and by creating open-ended questions we might get insightful and context-supported information that will not only answer to the question “what” is happening but also to the question “why” is it happening (Dodgson & Trotman, 2021).

Chapter 2 Defining the context for Arctic shipping

This chapter provides an overview of the maritime shipping and general scope of the Arctic shipping. By defining the high-level history of the shipping development, we can see how the industry developed and came to the modern state when the shipping through the Arctic become possible. It is essential to understand the context to be able to evaluate the implications of the shipping for various aspects of sustainability.

2.1 History of Navigation

This section explores the historical development of the shipping industry and its role in the modern world. A review of scientific articles in peer-reviews journals was conducted to define major technological advancements that affected the industry as well as the impact of shipping on global economy and environment.

Over its history, the shipping industry has been transformed by disruptive innovation. Advancements in astronomy made possible celestial navigation facilitating maritime travel and enabled numerous civilizations extend their power and trade connections (Peck et al., 2023). Both the Phoenicians and Ancient Egyptians used the celestial navigation as early as in 2000 – 1500 B.C. (Riley, 2021). By the late 900s, the same techniques allowed Vikings to travel to the territories of modern Canada. From the early Renaissance celestial navigation, along with advances in ship design, became an important foundation for an enormous expansion of maritime trade across Europe. Pushing European explorers to seek new routes to India, these technical and economic developments saw the discovery of the Americas, opening the 'new world' for the European colonization (Peck et al., 2023).

The second major technological advancement that moved the shipping industry significantly forward was the invention of magnetic compass that became widely available after the 13th century. The magnetic compass still plays a major role in the modern navigation providing easily accessible, fairly cheap and precise solution, not least as a back-up for the situations when modern satellite navigation can go off-line for unforeseen reasons (Lushnikov, 2015).

In the early to mid-20th century, before the advent of satellites, the invention of radio and radar technologies saw a suite of communications and locational techniques that greatly enhanced the means of both orientation and coordination available to both military and civil shipping. With regard to ship design, almost constant innovation since the 16th century has seen enormous advances in speed, safety, tonnage and freight management. From the late 18th century, the coal fired steam engines began gradually to displace sail power. First functioning steamboat was put in use in the US in 1787 (US Army Corps of Engineers, n.d.). Due to higher efficiency compared to the wind-powered vessels, steamboats quickly took over on inland and coastal routes, and by the middle of the 19th century were beginning to dominate transatlantic shipping.

In 1907 the first gyroscopic compass was presented for the maritime shipping use which allowed to point the ships in the direction of the true north pole and not the magnetic north pole (Riley, 2021). In early 1900s first radars started to appear which changed the shipping industry again. Moreover, if before the navigation industry was mainly pushed forward by exploratory ambitions and economic desire to develop trade routes, in 1900s the focus shifted to the military industry.

This was given impetus by Russia's defeat in the Russo-Japanese war signalling the emergence of Japan as an imperial naval power in the pacific and east Asia, and the 'Dreadnought' arms race between Britain and Germany – which led to similar naval escalations in other parts of the world including South America and Japan (Fairbanks, 1991).

The first simple radar was developed by Robert Watson-Watt in 1930s and it allowed operators to detect objects in a distinct location that were too far to be seen with bare eye by directing radio waves (Ilcev, 2020). Moreover, radio provided the opportunity for instant communication between land and the ship in open sea (Riley, 2021).

In 1956, a further technological advancement transformed shipping logistics and made possible major expansion of globalized manufacturing and trade in the last quarter of the 20th century. The first ever dedicated container ship left the port of Newark with 58 containers onboard (Thompson, 2018). Time and cost optimization of the loading and unloading processes was the major moving force behind this innovation. Before the introduction of the standardized cargo containers, ships could spend just as much time in ports to be loaded and unloaded as they were navigating between ports (GTC, 2019). This obviously meant that the efficiency of this process was very low and shipping companies would miss revenue (and profit) due such a long delay. Moreover, loading and unloading required a lot of manual labour which was quite expensive. After cargo containers were introduced to the shipping industry the cost of loading and unloading dropped from nearly 6 dollars to under 20 cents per ton – a 97% cost reduction (The Maritime Executive, 2021). the creator of the first cargo container (GTC, 2019), American merchant Malcolm McLean, was thus responsible for one of the most significant productivity revolutions in the history of capitalism. Unsurprisingly, the technology spread rapidly, becoming standardized in less than ten years. The first trans-ocean container ship was came into service in 1966 and already by 1968, the configuration of what has become the standard modern cargo container had been adopted (GTC, 2019). Introduction of container shipping was very important for international trade. It not only reduced shipping times and costs, but also increased the safety of the cargo from losses, theft and damage that might have occurred on every stage of the shipping process. Moreover, the optimization of the port operations in some degree enabled the growth of the shipping carrying capacity since before, due the inefficient and long loading process, it was economically unreasonable to have a very large ship because the loading process would take longer than the navigation itself and the customer demand for such slow logistical solution was quite low (PLS, n.d.). Already by 1980s container shipping took over the industry and was used for a wide variety of sectors from clothes to machinery with nearly 90% of all manufactured goods being containerized (GTC, 2019).

In the second half of the 20th century a new technology changed the face of the shipping industry one more time. With the development of space programs and the launch of satellites U.S. Department of Defense developed the Global Positioning System – the GPS (Riley, 2021). The introduction of GPS was essential for the high-definition maritime navigation as well as precise coastal and port maneuvering It is believed that one of the largest shipping related oil spills that occurred as a result of the grounding of The Exxon Valdez (Peterson, 2001) near the coast of Alaska could have been avoided if the GPS technology had been in more practical and common use (Gillow et al., 2003).

Aside from the technological advancements that were directly applied to the gadgets that were used on ships, some major changes have changed the shipping industry "from outside". One of the main ones is the creation of Suez and Panama canals that reduced the sailing time (Melia et al., 2016). This not only influenced the shipping industry but also redistributed economic flows Such counties as Egypt and Panama received an unforeseen economic inflow. It seems likely that the opening of the Arctic Sea route would be just as paradigmatic (Sheehan et al., 2021) as the opening of Suez and Panama canals were in 1869 and 1914 respectively (British Library, n.d.; US Dpt. of State, n.d.).

2.2 Maritime shipping in the modern world

The shipping industry plays a major role in global trade. Shipping is responsible for the transportation of 90 to 95% of manufactured goods every year (GTC, 2019). Right now, global trade is reliant on the tremendous fleet of ocean-going vessels worldwide – over 90 000 in 2020 (S. Elias, 2021). Over 60% of all the goods (manufactured goods, commodities, etc.) that are transported via sea – including perishables such as fruits, vegetables, greens and flowers, gadgets, and appliances –is transported in cargo containers; the rest is oil or grains for which there are specialized freight vessels (The Maritime Executive, 2021). Of course, container shipments are also a part of the rail or truck logistics. However, in most cases this occurs in the context of intermodal freight transport solutions – i.e. a shipping solution that requires the use of several modes of transport to deliver the cargo. Often it takes shape as the long-distance maritime shipping of a cargo container (for example, from Asia to a European port) and then from that port this container would be transported overland via rail or by truck. Anyhow, maritime shipping plays an essential role in global logistics. The impact of the maritime shipping industry on the global economy is large: goods estimated at over more than 4 trillion USD were transported via maritime shipping in 2017 (GTC, 2019). For scale, one container ship can transport more than 20 thousand containers, if those containers are filled with tech supplies, for instance, tablets, it would fit around 10 thousand tablets in each container and the overall shipping cost for each tablet would be around 5 cents USD on the routed from Shanghai to Hamburg. For larger daily use objects such as TVs, the shipping price might be around 2 dollars USD (GTC, 2019). As we can see, the maritime shipping cost enables the manufacturers to reduce expenses and maximize profitability. This is why maritime shipping plays such an important role in global trade.

Container cargo shipping is expected to remain the most demanded type of cargo shipping and the demand for container shipping is expected to continue to grow in future regardless of the global trade scenario (IMO, 2014). Currently around 10 billion tons of solid and liquid container bulk cargo is moved in cargo containers (Ampah et al., 2021). The amount of cargo transported by container carriers rocketed upward since 1980s and the value in early 2010s was over 10 times more than 30 years previously (The Maritime Executive, 2021). This soaring trend is inevitably associated with growing fuel consumption and consequently rising emissions. Between 2012 and 2040 fuel consumption by shipping vessels is projected to increase by 50% (Ampah et al., 2021). Although alternatives do exist, fossil fuels still dominate the industry for the simple reason that the energy density and ease of transportation and storage of liquid fuels is difficult to achieve with renewables. Heavy Fuel Oil (HFO) -- the main fuel that is used for shipping -- is not only responsible for large amounts of CO2 and black carbon, but it is also high in sulphur which creates additional threat form SOx pollution. Sulphur concentration in HFO is around 3.5% and for comparison an average size ship running on the 3.5% HFO would emit the equivalent of 210,000 trucks for the same distance Ren & Lützen, 2017). Although they are not so high in sulphur content, other fossil fuels such as marine gas oil and natural gas still produce a large amount of GHG emissions (S. Elias, 2021; S. Wan et al., 2022). Fuel consumption would vary based on the type of the ship. Oil tankers, containerships and bulk carriers are in the top of the list by the fuel demands (IMO, 2014). From the whole world fleet of large ocean and sea vessels those 3 types of ships consume around 50% of shipping fuel. At the beginning of the 21^{st} century the fuel consumption by oil tankers, containerships and bulk carriers was around 217 mega tons of fuel (Dalsøren et al., 2008). Regardless of the category, ship propulsion enabled by the work of the main engine is the main consumer of the fuel. Cargo container carriers due to their overall prevalence in the world cargo vessel fleet would have the largest absolute emissions (S. Wan et al., 2022). However, on the regional level we would see that due to the specificity of the global trade patterns, bulk cargo vessels would have the highest pollution contribution at high southern latitudes (Dalsøren et al., 2008).

Maritime shipping is an important contributor to the GHG emissions globally and accounts for 2 - 3% of global CO2 emissions (Ampah et al., 2021; IMO, 2014; Kuehne+Nagel, 2022). For comparison, if total emissions from the maritime shipping were compared to the emissions of the countries, the shipping emissions would be on the 6^{th} position of such rating list (S. Elias, 2021). Maritime shipping industry is developing quickly and its intensity is growing which leads to the increase in the CO2 emissions. It is projected that CO2 emission increase might reach from 50 to 250% by 2050 if the industry follows a business as usual model (S. Elias, 2021; S. Wan et al., 2022). Aside from CO2, maritime shipping contributes 10-15% and 4-9% of NOx and SOx emissions globally (Dalsøren et al., 2007).

A large share of emissions coming from the sea vessels originates near the shore and in the port areas. Around 70% of all the emissions from the whole trip are produced within 400 km of land

(Endresen et al., 2003). This happens partly because of the higher fuel demands (and consequently higher emissions) for the maneuvering activities when entering or leaving the port but also because most parts of the sea routes are laid in proximity to the shore. Port emissions are often associated with emissions from ship maneuvering and emissions from dock activity. The first category would include turning, braking, and accelerating. It’s important to note that most of those activities are more energy intensive than navigation in the open sea (if compared for the same distance) at a steady average speed (Saxe & Larsen, 2004). Around 5% of total fuel consumption is used in the port area (Dalsøren et al., 2008). This is very important because emissions in the port areas are likely be in close proximity to densely populated areas which poses an immediate threat to public health. Moreover, since maneuvering and all that is implied with it occurs on the fairly small area, the concentration of the emissions would be even higher since more intensive emissions would be spread on a smaller area compared to the navigation in the open sea where the emissions are less intensive and spread over the wider territory often remote from the human communities. The emissions form the docking area would be associated with the energy demands for heating and lighting of the facilities and for the crane activity for loading and unloading of the incoming sea vessels as well as air conditioning for cool storages that can be very energy-demanding (Saxe & Larsen, 2004).

2.3 Maritime Law. From Regulatory Fundamentals to Industry Standards

This section provides a review of the development of the maritime law that affected the position of sea navigation in maritime shipping. Current shipping standards and legislation are a product of the gradual development of maritime law. Even the sustainability requirements would inherit some of the elements form the history of development of maritime law and reginal regulations. The review of the historical development of maritime law might provide context for the understanding of how it has formed and how the new pieces of legislation especially those connected to the sustainability issues would be put in place. For this research only the review of Canadian maritime law history was conducted since the research was strict time limited. However, similar reviews are expected to be done for other legislative systems of the countries who are interested in Arctic shipping development. The history of Canadian maritime law is tightly connected with the British maritime law since for a long period of time Canada followed British legislation.

Since late 17th century Britain had practically full control over the colonial merchant shipping in all of its colonies. This hindered the autonomous development of a maritime law in Canada on early stages of the state formation and set a solid foundation for high reliance and tight connection to British maritime regulations that would last a couple centuries. A statute enacted in 1696 by British Parliament enforced that none of the colonial legislatures could pass if they were repugnant to any English statute. In other words, the British law was superior (McDorman, 1983). For next 2 centuries the power of the British Parliament remained fairly absolute. The major regulation that defined the rules for the UK's and its colonies' shipping was the 1854 Merchant Shipping Act. This regulation became a consolidation of British merchant shipping law. It was one of the most important pieces of maritime law for the maritime shipping during the colonial period (McDorman, 1983).

In 1865 the Colonial Laws Validity Act was passed. This act stated two major things. Firstly, it declared that colonial legislation will only be invalid in cases where the colonial legislation is contrary to the imperial statute, which applies to the colony directly or by "necessary intention". And secondly, the act makes it clear that the imperial parliament may legislate in the colonies and that imperial legislation will have supreme authority (*Colonial Laws Validity Act*, 1865). Overall, in that time the colonial legislative mechanism was still subordinated to the imperial bureaucracy and had no level of independence. Already by mid-19th century the Government of the UK was keeping track of the shipwrecks and potential losses in maritime shipping. One of such reports - Report of the Select Committee on Shipwrecks published in 1836 declared that over 900 shipwrecks were recorded, and the estimated volume of lost cargo was just under 3 million pounds (McDorman, 1983).

From the end of 19th century to the first decades of 20th century, Canada moved stepwise away from the status of the British colony to becoming a sovereign nation. This had a serious effect on the Canadian legislative system as a whole and on the maritime trade laws in specific. Already in 1911, the British parliament had granted a great deal of freedom to the Dominions of the UK – terminating the extent of the imperial regulation on the Dominions except for those cases when the Dominions a voluntarily expressed the desire to adopt the imperial regulation (McDorman, 1983). Of course, this step was not random and took a lot of effort of the policymakers.

Successful cooperation between Canada and New Zealand allowed the Dominions successfully to press for regulatory autonomy.

Such autonomy notwithstanding, the 1927 Canada Shipping Act was not substantially different from the antecedent imperial Merchant Shipping Act of 1894 (McDorman, 1983). Furthermore, under the Canada Shipping Act all vessels had to be registered in and fly the flag of the UK. So even until the end of the first quarter of 20th century, there were no "true" Canadian ships navigating through the seas. Only by 1929 Canada had explicitly started to articulate its own navigation regulations. Three major points included:

- Ships can navigate under the Canadian flag but they would be a subject to full legislative compliance with Canadian regulatory norms both intra-territorially and extra-territorially;
- All ships in the internal waters of Canada should comply with Canadian maritime law; and
- The Canadian courts were now enforced to apply Canadian law even to the ships of other countries making a part of the British Commonwealth.

In 1936 some fundamental changes occurred in the legislative structure. Previously existing Department of Marine and Fisheries was replaced by newly created Department of Transport. The first signs of emerging environmental oversight occurred in the early 1950s when the Canadian Government ratified the provisions of the 1954 International Convention for the Prevention of Pollution of the Sea by Oil. The regulation of the environmental impact of the maritime shipping industry continued and two major regulatory acts were introduced in 1970: Arctic Waters Pollution Prevention Act and the Ocean Dumping Control Act. The achievement of a full independence from the Commonwealth Sea Law regulations was only reached in late 70s when Canada introduced its own Maritime Code Act and the adaptation of the UNCTAD Liner Code –a New International Economic Order and alterations to the international trade system (Collins, 1984; McDorman, 1983).

The questions of environmental management started to gain traction pretty quickly in Canada in the late 20th century and two major regulatory acts that were enacted and had impact on many industries including shipping.

In 1963 Canada developed a Clean Air Act that was supposed to enforce air quality protection mainly via regulation of the air pollution levels. The act set a number of standards regulations emission limits for different industries. This act pushed the development and successful implementation of the air pollution prevention and control programs (Government of Canada, 1963). Both indoor and outdoor emissions were regulated by Clean Air Act with focus on GHG. The introduction of the Clean Air Act led to the setting of national air quality targets by ministers of environment and health and requested public progress reports on the targets and continuous monitoring and alignment of the goals with Clean Air Act objectives.

In 1999, the Canadian Environmental Protection Act (CEPA) replaced the Canadian Clean Air Act and expanded its scope to include other areas of environmental protection such as toxic substances and hazardous wastes. CEPA reinforced regulation and management standards of the impact of human activities on the environment. Key features of CEPA would include (Government of Canada, 1999):

- risk-based approach to define environmental issues, prioritizing the most significant risks to human health and the environment;
- prioritization of proactive pollution prevention and environmental impact reduction via reinforcement of adaptation of green technologies and sustainable practices;
- oversight and regulation of the use and disposal of chemicals;
- setting the framework for environmental emergency response, for instance, management of oil spills;
- fines, sanctions and other financial measures are one of the main instruments embedded in CEPA.

In sum, CEPA provides a comprehensive multi-level framework that regulates addressing environmental issues and incentivising both proactive and reactive measures such as pollution prevention, proper chemicals management and efficient emergency response. CEPA is now the primary law governing environmental protection in Canada.

On September 30, 1970 the Canada Water Act was developed to establish a cooperation framework for the interactions between federal and provincial governments on questions around conservation, development and use of Canadian water resources. This act incentivized and supported research, planning and promotion of a wide variety of programs to ensure the conservation and sustainable development and use of Canadian water resources. The Canada Water Act empowered the federal government with the right through the establishment of the proper regulatory framework to collect and analyze water data across the country to ensure sufficient water quality and quantity management. Moreover, local water management agencies like the Mackenzie River Basin Board were created under this act to provide targeted support for the water management in high risk and highly vulnerable areas (Government of Canada, 1970).

International regulation of the Arctic development is also not very consistent. Founded in 1996 the Arctic Council was created as an intergovernmental forum to collaborate between industries and governments and find ways to use the region sustainably. Arctic council provides support and regulatory framework to drive the industrial development in the region. It has a strong focus on the environmental problem and leads such environmental initiatives as Arctic Contaminants Action Program (ACAP) and the Conservation of Arctic Flora & Fauna (CAFF).

The Arctic Economic Council (AEC) is an organization founded in 2014 that has the ambition to provide a space for industry leaders to engage with each other and with local communities to find more sustainable way to do business in the region for the environmental, social, cultural and economic perspectives. Just like the Arctic Council, AEC has a designated Maritime Transportation Working Group focusing on the problems and opportunities of the shipping industry.

2.4 Decreasing Sea Ice

While changes in the regulatory environment are significant and might have a tangible influence on the sustainability of the shipping industry in general, climate change has affected the Arctic environment significantly and a new opportunity for the Arctic shipping is arising. Therefore, to have a comprehensive understanding of the context it is important to understand the nature of changes happening in the Arctic that are potentially leading to the possibility of commercially available Arctic shipping solutions.

A brief overview of the sea ice coverage decline drivers is provided in this section of the research. Moreover, this section reviews the findings from different projects that studied the timeline of the sea ice decrease in the Arctic ocean and discusses different predictions regarding the duration of navigation season for the Arctic sea routes in different decades over the century. Finally, the dynamics of the shipping activity from late 20th century to the current time is review in this section to see if the proposed changes in the sea ice coverage are already affecting the intensity of the navigation in the region.

As multiple factors have made it possible to start seeing the Arctic as a place with great developmental potential, the region has been brought into the strategic horizon of both corporate and state actors and little by little human presence has started to expand. . Large-scale interventions commenced with the activity of oil and mining companies in the mid-20th century but increasingly the Arctic has become a region of interest for other industries as well. The discussion around the creation of the new trade routes through the Arctic Ocean started awhile ago and became quite frequent in the second half of the last century. The existence of a Northwest Passage (NWP) was first proposed by John Cabot in 1490s and after a long period of exploration only in 1845 John Franklin's expedition established the likely existence of a NWP (ArcticArctic Council, 2009). The first complete NWP transit was made by Roald Amundsen in 1906 and the first successful one-season Northern Sea Route (NSR) transit was led by Otto Schmitt in 1932 (ArcticArctic Council, 2009). Until the beginning of 1970, Canadian national security was the main moving force for the development and use of the Arctic seaways and serious discussion of Arctic sea routes for international shipping began only in the 1980s (ArcticArctic Council, 2009). However, climatic conditions and the state of technological development didn't allow real-life actions to move from theory to practice until the 21st century because of climate change effects on temperatures and sea-ice coverage. Traditionally, the Arctic region was defined as the area encompassing the 10^{o} C July surface air temperature isotherm. By this measure by 2100 the region will have reduced in size by over 40% compared to the current value (Vavrus et al., 2012) e.

The role and position of Arctic sea routes in global maritime trade would be defined by the scope of opportunities and potential threats that Arctic shipping might bring. Moreover, the scale and significance of both benefits and threats are likely to be very dynamic and fluid over the next 50 years due to rolling regional environmental change. Moreover, the changes in the Arctic polar region are expected to be more significant along the Eurasian coast (Pan et al., 2023) and it would have a tangible outcome for the potential of the Northern Sea Route (NSR). Therefore, it this part we will discuss the timeline of those changes and how it has affected and will continue to affect the industry of Arctic shipping in future.

The major driver relates to ice coverage. The Arctic has the highest response to the climate change induced environmental changes of any region in the world. Changes are not only occurring at the highest rate but are also much more extensive, fundamental and dramatic in both scope and scale

(Lasserre, 2014) Moreover, with respect to average temperatures change in the Arctic, the ocean surface is much more likely to undergo a more significant temperature rise than the terrestrial area (Vavrus et al., 2012).

Sea ice conditions are seen as the major factor defining the economic feasibility, ship and crew safety, level of risk, predictability, duration, fuel consumption, route trajectory and other factors in Arctic shipping. Climatic changes indicate a clear trend to the increase in the duration of the ice-free season or a season with a reduced total surface ice coverage and smaller thickness (Peters et al., 2011). It is estimated that before 2030, sea ice conditions can be the major factor influencing the Arctic navigation and safety and after 2030 the duration of ice-free period would increase and the significance of the ice conditions would start to decrease gradually (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014).

The duration of the sea ice melting period in the Arctic region is steadily growing. Between 1979 and 2013 the melting season, it extended by around 5 days every decade (Rachold, 2019) e. In the last quarter of the 20th century, we have seen that the average rate of sea ice decrease in September is around 13% per decade and overall sea ice in the Arctic region decreased about 37% from 1979 to 2018 (Grosfeld et al., 2016). Total annual maximum surface covered in sea ice shrank from 6.1 million square kilometers in 1999 to 4.3 million square kilometers in 2019 (PAME, 2020).

The depth of the sea ice cover is also changing. Between the early nineties and 2018, the average thickness of the Arctic sea ice cover nearly halved, going down from over 3 meters to under 2 meters in depth (Rachold, 2019). The total area of the sea ice generation underwent a nearly 2-fold reduction in the last 70 years (Marchukova & Voskresenskaya, 2021). Given such developments and other things being equal, sea ice coverage would be largely eliminated in summer by 2050 and the trans-Polar sea shipping routes are expected to open up after 2050 (M. Bennett, 2019; Humpert & Raspotnik, 2012).

It has been predicted that changes in CO2 and other GHG concentrations would be the most visible in polar regions and the term ‘polar amplification’ was introduced to convey the full scale of uneven climatic change in the region (Dyck et al., 2010). Up to 62% of Arctic warming is associated with anthropogenic GHG and aerosol emissions (Yu et al., 2022). Polar amplification is largely influenced by local lapse-rate feedback, with ice-albedo feedback (Stuecker et al., 2018). This is why the effect is so much stronger on the Arctic compared to other regions. Overall dynamics of the factors catalyzing or impairing the change in the sea ice cover in the region is excruciatingly complex.

Two major feedback loops are often considered. The first one is leading to overall heating up of the region and this feedback loop is seen as more likely to happen with a more predictable and measurable consequences. This process looks fairly simple: the amount of high albedo (i.e. reflective) surface (snow and ice) is declining. This leads to lower amounts of solar radiation reflected and more solar radiation absorbed by the surface. This means more heating and consequently more ice loss which brings us to even more heating absorbed and even greater ice loss. Globally, albedo changes in polar regions account for up to 25% of direct warming (Marcianesi et al., 2021).

The second feedback loop is connected with the gradual cooling down of ocean currents such as Gulfstream do to the increasing inflow of the cold melted glacier water. Even according to modest estimates Greenland ice sheet might lose up to 30% of its ice volume by 2050 (Gerdes et al., 2006). In this case we consider the scenario that due to the increased melting of the ice and therefore increased volumes and intensity of the cold near-freezing waters fluxes in the northern seas (especially in the Nordic Seas and the Labrador Sea (Gerdes et al., 2006)) overall cooling of the ocean would occur. This would lead to the cooling down of the climate in region which in turn might incentivise the conditions favorable for the ice growth. However, the input from this feedback loop to overall cooling of the Arctic environment is subject to much debate without any consensus (Kashiwase et al., 2017; Sousounis, 2019). Temporary cooling down of Gulf Stream might occur and it might even lead to visible changes in European climate in the second half of the 21st century. However, this effect would not be strong enough to remain in place for a long time, although it might be followed by changes in weather conditions and growing frequency of extreme weather events with high potential to disrupt local infrastructure (Glikson, 2023).

GHG emissions have a direct impact on the density, thickness and the volume of the Arctic Sea ice cover. According to one estimate, one tonne of anthropogenic CO2 emitted is responsible for approximately 3 m^2 of the Arctic sea ice loss (Notz & Stroeve, 2016).

COVID has provided the researchers with an opportunity to see how the world act in the lower GHG emission reality world. It has been observed that due to covid restrictions a significant and quite abrupt drop in the amount of GHG emissions occurred. By some estimations the temporary reduction was over 5% of global emissions (Naderipour et al., 2020). Of course, COVID didn't have a significant impact to the fight with climate change since it was a one-off interruption with no continuous effect. It did, however, make possible some significant observations. Specifically, the growth rate of the Arctic Sea ice increased significantly in early 2020 (Chen et al., 2021). This seems to confirm the hypothesis of a direct connection between emissions and sea-ice= At the same time, it is important to mention that the extent of GHG emissions is only one of the factors influencing sea ice growth and decline. Other factors such as atmospheric circulation, ocean meridional heat transport and surface energy balance, and accumulated ice-albedo feedback also play an important role in a complex process of the seasonal sea ice dynamics in the Arctic (Chen et al., 2021).

Overall, we see a clear trend towards sea ice reduction all over the Arctic region. Continuous growth in the GHG emissions hinders the Arctic ice growth and aggravates the situation by changing the albedo balance. This occurs due to the reduction of the light sea ice surfaces which are high albedo, which leads to higher solar radiation accumulation. The most dramatic and significant changes in the sea ice coverage of the Arctic region would occur in the first half of the 21st century.

2.5 Navigation season in the Arctic

Climatic conditions and ice-free yearly periods are particularly important in defining the length of navigation season and its dynamics over the upcoming decades. The duration of the navigation season is one of the major determinants of the feasibility of the Arctic shipping as a full-scale alternative for the traditional global shipping routes. Even now an evident trend in the increase of the duration of navigation season is observed. It grows up to 7-10 days every year now and by 2030 the navigation season might increase by 2.5 months (U.S. Committee on the Marine Transportation System, 2019). Mid-century is often seen as a point of the start of active navigation through the region as the navigation time is expected to double and reach the appropriate length to be economically feasible and worthy of investment (Melia et al., 2016). In previous years, navigation through the Arctic mostly occurred with help of ice breakers. Many attempts to use the North-West Passage (NWP) by unprepared sea vessels were unsuccessful and very dangerous due to unpredictability and high level of danger coming from the sea ice conditions. However, 2007 was the first year when ice free conditions were observed along the whole NWP (S. Elias, 2021). The Canadian Arctic is expected to be completely ice-free in summer sometime between 2050 and 2100 (Brigham & Ellis, 2004). Opening of the sea ice along NSR also would happen at high rate. The navigation season is expected to nearly double up to 125 days by mid-century (Aksenov et al., 2017). By the end of the century most of the Arctic routes would be able to offer nearly all year long navigation routes. The navigation season for ships with minimal ice-strengthened modifications might 11 to 12 months of non-stop navigation (Melia et al., 2016).

Near-central Arctic routes for example the Northwest Passage, would become available for navigation close to the mid-century (Melia et al., 2016) or even as early as 2036 (M. M. Bennett et al., 2020). Navigation through the trans-polar route across the geographic north pole is another topic that is often discussed as a potential solution for the global trade through the region in a long-term perspective. Now, trans-polar route is still covered in ice and it is not available for navigation; however, the scientists predict that it could open up as early as by 2040 and yearlong navigation could occur by 2070. However, it depends heavily on the scenario and would be different if global community were to align its efforts to comply with Paris Agreement 1.5-degree targets or if GHG emissions and overall temperatures continued to rise. In the most favorable scenario where the 1.5-degree alignment by 2050 is achieved, the trans-polar sea route is expected to be open for navigation by the end of the 21st century (M. Bennett, 2019; Jahn, 2018; Notz & SIMIP, 2020; Screen, 2018; Sigmond et al., 2018; M. Wang & Overland, 2012). There is no linear connection between CO2 levels and temperature, which means that to cool the planet to the preindustrial levels a greater amount of CO2 would need to be reduced compared to the CO2 amount released during the heating process (M. M. Bennett et al., 2020; Sigmond et al., 2018). Therefore, the overall probability of the significant restoration of the sea ice polar caps in the Arctic is very unlikely in the foreseeable future.

2.6 Changes in shipping activity in the Arctic Ocean

As the Arctic climatic conditions change, we will see a tangible change in the shipping intensity and frequency over the year. Those changes started to occur by mid-century last century and have an overall growing trend. The load on current Arctic sea routes is still low; however, the demand is increasing (Sheehan et al., 2021). The total number of ships passing through the region is one of the representative characteristics reflecting the activity in the region. From 2013 to 2019 the shipping activity in the region increased by over 25%, although out of 1628 ships in 2019 over 40% were fishing vessels (PAME, 2020). If considering only bulk carriers and other ships taking part in global trade, we also see an increase in shipping activity. From 2013 to 2019, shipping intensity grew by over 160% (PAME, 2020).

It can be also helpful to track total navigated distance change. From 2013 to 2019 a 75% increase in navigation distance is observed (PAME, 2020). Coupled with the data on the shipping intensity we can see that the overall increase in the navigation distance is achieved not only by the increased number of ships traveling along the sea route, but also due to the increase in the average distance of each individual travel. Currently the majority of ships in the region would be supporting the mineral mining, oil and gas and fishing industries. This would define the proportion of ships of different kind currently sailing through the Arctic waters. The fishing industry is heavily reliant of the support of cargo ships, which includes refrigerated bulk and container vessels (S. Elias, 2021). Such cargo vessels as barges and tankers are often used by the extraction industry and they are also providing goods for the local communities (S. Elias, 2021). Outside of the cargo shipping industry we would see a high number of fishing boats, rare cruise ships mostly navigating along the southern coast of Alaska and search and rescue ships of local authorities (S. Elias, 2021).

Shipping activity along the NWP has been increasing in line with the general trend for the region. Traffic volume increased by factor of three since 1990s (Sheehan et al., 2021). In recent years traffic started to increase much more drastically. In 2015 total number of ships that passed through the NWP was 443 a figure that increased to 760 just two years late in 2017 (Silber & Adams, 2019). Over the past decade a nearly 3-fold shipping increase was observed in the Canadian Arctic waters and increasing length of the shipping seasons gives reasons to believe that the growth would be continuous – it is expected that by 2030, the Canadian part of NWP would be completely ice-free during the navigation season and the shipping intensity would peak (S. Elias, 2021).

As the sea ice declines, more and more ships are expected to pass through the Arctic sea routes. It is anticipated that in the upcoming years the majority of the ships would be supporting the development of the Arctic infrastructure or would be coming from the fishing industry. Since the changes in the Arctic climate open large deposits of different minerals and oil in the territory that was previously covered by a thick layer of ice it becomes economically feasible to extract those resources. Coupled with the absence of a regulatory mechanism (Schunz et al., 2020) overexploitation of Arctic resources is a real danger. Despite of numerous ecological and socio-economic consequences on the regional and planetary scales such a development would lead to the growing demand for the use of the Arctic sea routes inside the region. Many examples already exist where shipping turned out to be the most economically efficient way to transport oil and ore (Tranter, 2022) from the high north industrial sites. The gradual transition to low-carbon green economy is unlikely to hinder industry-related demand for shipping since most of the renewable technologies are reliant on rare-earth metals, copper and other elements which are now found in abundant deposits in the Arctic (Energy Monitor, 2021; IEA, 2021; Petkova, 2021). At the same time, the opening of the Arctic is creating new opportunities for the fishing industry. A steady increase in the frequency and quantity of the fishing boats is very likely. The fishing industry has been one of the major sources of inward investment and opportunity for the local economy (Reedy, 2020).

In sum, we can clearly see that shipping activity in the region is on the cusp of a period of rapid expansion and the intensity of activity is steadily growing. Even without considering the possibility of the transition of major global trade routes from Suez/Panama to the Arctic region, interest to the Arctic navigation would increase due to the growing internal region demand and likely active development of the extraction and fishing industries.

2.7 Complexity And Vulnerability

The high level of the complexity and vulnerability of the Arctic system is another crucially important consideration that should included when discussing the context of Arctic shipping because while the sea ice conditions would define the physical state of the system complexity and vulnerability would determine the conceptual component.

If we consider a scenario where the Arctic region is undergoing a noticeable increase in anthropogenic activity, we can break it down into several focal systems. Although in this research I am focusing on the shipping-centric system, it is important to note the significant overlap with other focal systems.

A shipping-centric system focuses on the relationship between the Arctic environment which includes biophysical, cultural, social and economic components and the shipping activity in the region. If we scale down, we would find dozens of sub-factors making part of the 4 components listed above that should be accounted in defining the processes within the system and understanding the scale and significance of the consequences. This all contributes to a high level of complexity of the system.

The complexity of the system is quite evident. From an environmental perspective, the Arctic is a vast region and home to thousands of species. All of these depend upon specific food chains and habitats. Hence, any disruption of the integrity of the natural ecosystem resulting in the disturbance for one species would, in the end, be likely also to have impacts on other interconnected and/or co-dependent species. Various research has already shown how climate change-induced changes going on contemporaneously with the increasing anthropogenic activity is leading to significant irreversible changes in the composition and behavior of several marine animals and associate biophysical systems in the Arctic region (Alabia et al., 2020). Since climate change alters the face of the region and opens new possibilities for the commercial usage of the region, we can see a big threat to the integrity of wildlife in the region as a result of overexploitation. As Elias says: "fossil fuel resources, navigational short-cuts, and previously unobtainable fish stocks… may well drive a number of marine mammals and other vertebrate species to extinction, unless strong conservation initiatives are put in place immediately" (S. Elias, 2019b).

The remoteness and severity of conditions, combined with low population density and fragile natural communities, make this region particularly hard to operate in. For instance, in case of any unintended situation, it would be hard or even impossible sometimes to resolve the problem – for instance without access to spare parts or to people with particular skills. Alternatively, if the solution can be found it might be much more resource-intensive than in other places on Earth (Campins Eritja, 2021b).

Moreover, due to its remoteness from the most populated areas, the Arctic region has often been considered to be an appropriate test site for nuclear research which is adding to the list of damages already caused to the region. Multiple testings of nuclear weapons by the Soviet Union and the US as well as the common practice to dump nuclear waste from the "Peaceful Atom" industry are additional things to consider when assessing the current level of damage to the region's integrity and creating the framework for future activity there (S. Elias, 2019a). Hence, the potential nuclear pollution can be seen as another factor adding to the high level of complexity of the region.

Besides, this region is divided among a number of different countries each of which has its own vision for the future development of the region and territorial claims. Arctic territories are of particular interest since “22% of the world's undiscovered fossil fuel resources” are situated there (Brutschin & Schubert, 2016) as well as it is abundant with other resources and provides an important advantage in the geopolitical games. Remoteness and the severity of the climate in the region now act as a natural barrier protecting the region from any kind of military actions there, but due to climate changes the ice is melting and the overall climate in the region becomes “milder,” this compelled period of inaction might end. The geopolitical interest in the Arctic territories was stated by several countries and due to the heating up of the region the conflict and tension there might form into a more acute and tense situation (Dittmer et al., 2011). Moreover, the number of countries declaring their interest in the Arctic region is not limited to those which have a geographical adjacency to the region. Some countries with no direct access to the Arctic (China, South Korea, Italy, etc.) are declaring their interest in the region justifying it for economic reasons (Dittmer et al., 2011), which undoubtedly only adds to the already existing high level of complexity.

Those above are just a few of the components of the shipping-centric system; in fact the list of important components is longer. The complexity of the system determines the possible scale of the outcomes and since complex systems are defined as multi-component systems with close to an infinite number of interactions between its components, any damage made to this system would result in affecting a lot of co-dependent systems and involved parties (Walker & Salt, 2012).

Conceptually speaking, every complex socio-economic system can be described as a “panarchy” which describes the strongly dynamic and practically infinite number of multi-level relationships among the system’s components (Holling, 2001). The issue here is that the complexity of the socio-ecological systems is determined not only by the number of interconnections between its components but also by some features of the complex systems that can only be identified and fully understood until all the co-dependent inner systems and their dynamic interactions are studied together as a whole. Otherwise, some characteristics of the complex system might remain unobvious (J. Liu et al., 2007).

Moreover, the complexity of this system is also supported by the fact that none of the Arctic communities can be considered separately and independently from each other. They are all part of a certain country which entails some limitations and developmental deviations which are adding to the complexity of the region. Various governmental strategies for the northern communities' development cause deviations in the functioning and in the community response to the same external changes which only adds to the heterogeneity and makes it even harder to reveal the proper action strategy, possible problems and solutions. Overall, we can say that the multi-connectional nature of the relationships among the components in any complex system might be one of the main barriers on the way to understanding the system's dynamics and consequently defining the strategy for the interactions with the system and resolving upcoming challenges.

Complementary to a high level of complexity we can clearly observe the high vulnerability of the region. From the biophysical side of the question, vulnerability is defined by the irreversible changes in climate causing major disturbances of the region. Melting ice causes a reduction in habitat space which is putting numerous Arctic species on the edge of extinction (Bonn, 2003a). Moreover, melting Arctic ice is also influencing migration patterns and on a greater scale might change the location or direction of sea currents which in turn will also affect the availability of sea resources for the indigenous communities. At the same time from the socio-economic perspective, this region is highly vulnerable due to the lack of economic self-sufficiency and high reliance on support from outside. In other words, this region has not enough infrastructure to claim itself as economically independent.

The vulnerability of the system lowers the system's ability to resist any tension from outside and makes the chances of collapse higher. With the low adaptability and transformability ability of the system comes its inability to be flexible enough to adjust to the changing external conditions and consequently the possibility of the existence of the system in the changed environment is questioned (Walker & Salt, 2012).

The combination of the high level of complexity tight together with the fact that the Arctic system is extremely vulnerable poses a serious limitation to the development of Arctic shipping.

2.8 Chapter summary

The shipping industry has often propelled the development of civilization. Sea shipping was used for freight transport for an extensive period of time. However, after the introduction of cargo containers the efficiency of maritime shipping increased dramatically. The annual aggregate value of sea freight is now over 4 trillion USD. In the modern world shipping plays a major role in the international trade and the intensity of the industry is expected to grow which among other things will lead to greater environmental impacts. Estimates vary, but currently maritime shipping is responsible for in the region of 2-3% of global GHG emissions, most of which comes from burning the heavy fuel oil (HFO) – main fuel for cargo ships. If current intensity rate remains unchanged, the consumption of HFO is anticipated to increase by 50% between 2012 and 2040.

Maritime legislation has been developing since the 1950s, and environmental enforcement is slowly becoming more effective. As the world is moving towards the (elusive) Net Zero economy, the work to develop clear transition pathways and regulatory mechanisms to support such transition are gathering impetus.

Climatic changes are affecting the Arctic Ocean significantly and as the sea ice keeps melting the duration of the ice-free conditions increases. This creates the opportunity for the maritime navigation along the Arctic Sea routes and the increase in shipping intensity of the regional vessels can be already observed. It has been determined that there are multiple factors that cause the intensive sea ice decline in the Arctic region. GHG concentrations in the atmosphere are considered one of the most significant factors affecting the sea ice coverage. A clear and continuous reduction of the sea ice coverage is observed. The ice-free navigation season is increasing by up to 7 days per year and expected to be over 2.5 months by 2030. The duration of the navigation season should exceed 100 days by mid-century and the year-long ice-free conditions are expected to appear along several Arctic sea routes by the end of the century. Over 40% sea ice coverage reduction is anticipated by 2100. These changes stimulate the increase in shipping intensity in the region and over 75% total distance increase is observed in the period from 2013 to 2019.

Arctic shipping is proposed to operate in a highly complex and at the same time vulnerable system. Many factors are contributing to that and to be discussed further in the next chapters of this research.

Chapter 3 Environmental factors.

As discussed before, shipping has a tremendous impact in the modern world. And while there are many positive outcomes for the society from the shipping activity, there is also a large environmental impact. When we are talking about sustainability, we have to be able to evaluate how would a certain development affect the long-lasting wellbeing. Environmental considerations need to be taken into consideration while discussing potential trans-Arctic commercial shipping. In this chapter major environmental outcomes of the Arctic shipping are discussed as well as some of the possible benefits. This discussion is built on the comprehensive literature review of peer-revied publications as outlined in the research framework.

3.1 Chemical Pollution

Commercial shipping is responsible for over 2% of CO2 emissions worldwide (Ampah et al., 2021). And it is also a significant source of other pollutants in the maritime environment many of which are coming as a result of the bunker fuel burning. For example, ship fuel is reach in sulphur and contains around 3.5% sulfur which causes serious sulphate contamination (Ren & Lützen, 2017). Moreover, marine shipping is a source excessive emission of methane, nitrogen oxides, sulphur oxides, carbon monoxide, particulate matter such as organic carbon and black carbon and ozone-depleting substances (ODS, halocarbons, e.g., HCFC in refrigerants) (S. Elias, 2021; Endresen et al., 2003).

From the pollution perspective commercial maritime shipping is undoubtably a major contributor and its impact is a serious disruption of the ecosystems. However, from the Climate Change perspective there is more of a debate. Large amounts of emitted GHG and CO2 in particular have net warming effect, meanwhile sulphur and nitrogen oxides have potentially cooling effect overall (Eyring et al., 2010). The effect of shipping emissions on climate change is very complex and is to be studied further. There is evidence of the ozone depletion induction as a result of the emissions from the shipping (Dalsøren et al., 2008). However, the balance between cooling vs. warming effect of the shipping might be shifted towards the later since new fuels are now researched with lower concentrations of SOx to reduce the negative environmental effects of pollution (J. Fuglestvedt et al., 2009).

Aside from the direct influence on climate change, CO2 emissions might be one of the reasons for a substantial influence on ocean acidification (Doney et al., 2012). This is having an impact on a wide range of maritime species. Especially vulnerable would be those who use the calcification process in their life such as molluscs, crustaceans and others, corals and others (Doney et al., 2012). Moreover, it has been found that the change rate provoked by this process is significantly higher in tropical and polar regions compared to the rest of the world (Jägerbrand et al., 2019).

3.1.1 Nitrogen and sulphur

Since hydrocarbons that form bunker fuels are rich in nitrogen and sulphur there is a significant increase in the concentration of the chemical compounds containing these elements in waters along the shipping routes. Globally ship emissions contribute 11% of nitrate-containing compounds and 4.5% to sulphur-containing compounds deposition (Dalsøren et al., 2008). For instance, in the Baltic Sea, up to 3% of total nitrogen input comes from combined air emissions and water discharges from the commercial ships (Raudsepp et al., 2019). Significantly higher SOx and NOx concentrations were documented sea northern routes that are currently in active use such as North Sea and the English Channel (Dalsøren et al., 2007).

Of course, different kinds of ships would have different contribution to the net nitrogen and sulphur emissions. This data would vary for different reasons associated with climatic conditions inducing or catalysing the accumulation and transformation of these elements. Based on the data for shipping along North America, southern and western Europe, and western Africa, container shipping bulk carriers (Dalsøren et al., 2007) relative to all other types kinds of shipping would be considered the main source of nitrogen and sulphur emissions. At the same time, in the Asian region, and especially in India, the Indochinese Peninsula and Indonesia, tanker vessels are seen as the main source of acidification (Dalsøren et al., 2007).

Sulphur and nitrogen oxides also might contribute to the acidification. This would be particularly tangible in the colder waters like Baltic Sea due to the lower buffer capacity (Dalsøren et al., 2007), which in the end leads to a more significant pH drops in the northern waters (Hunter et al., 2011; Salo et al., 2016). Acidification drops can potentially lead to the disruption of the ecosystems and cause mortality among some species. Acidification has been proven to be one of the potential biodiversity climate risks associated with the maritime shipping (Dalsøren et al., 2008). Given the vulnerability of the colder water to the acidification along with existing commercial use of such northern sea-routes such as Rotterdam-Boston and routes in the Baltic and North Sea, we already have evidence about the dynamics of acidification as it has been observed in the Northern hemisphere (Hassellöv et al., 2013). Excessive Nox might also increase the eutrophication that is negatively impacting the environment (Jägerbrand et al., 2019). It has been also found that nitrogen oxides might react with the volatile organic compounds and act as the precursors of ground-level ozone (Endresen et al., 2003).

Moreover, ships as emitters of Nox might pose threat to human health and wellbeing since NO2 is considered to be dangerous. The risk of the NO->NO2 transformation of the combustion products is quite high (Saxe & Larsen, 2004). This would be a significant issue especially in the port areas where the ships are doing the maneuvering and emitting larger amounts of Nox in a relatively static environment. Development of the large-scale commercial Arctic shipping would require the development of the port areas and supporting infrastructure, which would cause the flow of people to these areas for labour purposes However, this effect can be considered as mostly temporal and would occur mainly during the construction phase. The increased exposure to potentially dangerous NO2 for people closely interacting with ships in ports should be considered as part of the community health discussion. This would be especially important for the people from remote northern communities who are living in the low-populated remote areas with only complicated and resource-demanding access to the healthcare facilities. The effects of IMO SOx and Nox regulations on the emissions have been very positive for the North and Baltic sea environments and they helped increase the quality of the air in areas adjacent to shipping intensive regions to provide advanced public health protections (Repka et al., 2021).

Lastly, Nox has an effect on net ozone Radiative Forcing. This is basically the difference between the total absorbed and reflected solar energy by the planet. It is estimated, that from equator to 40^{o} Earth accumulates solar energy and radiative forcing is positive. This is explained by low albedo surfaces of the close to the equators areas and a direct angle of solar ray strike. In other words, a lot of solar radiation is accumulated in this region. After 40^{o} moving to the poles Earth's radiative forcing is negative which meant that the loss of solar radiation occurs and depending on the input proportion of the reflected and accumulated solar radiation the planet heats up (net Radiative Forcing is positive) or cools down (net Radiative Forcing is negative) (Kambezidis, 2012). Large ozone response is found in the area between 10^{o} and 55^{o} (Eyring et al., 2010) and it decreases with latitude. This happens due the fact that warmer smaller small areas are characterized by more efficient ozone production and long ozone lifetime compared to the Arctic region (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014). And abundant NOx, CO, and NMVOCs would reduce the ozone accumulation in the atmosphere quite efficiently. At the same time, if shipping is moved to the Arctic sea routes, the effect of the shipping on the ozone concentration would be much more moderate due to climatic characteristics of the region and overall lower ozone accumulation in the area (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014). In sum, by switching from the Suez to the Arctic route the overall effect of the shipping emissions on the ozone concentrations might result in positive changes in ozone accumulation due to the decreased impact on the Suez region that generally has a strong response signal vs Arctic region with a weak signal (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014). In other words, the region the amount of heat that the planet would absorb from the sun will increase.

Existing IMO regulations to lower the available limit of the sulphur concentration in the bunker fuel seems to be an efficient measure that showed some results in the sulphur accumulation reductions in the North Sea and the English Channel regions (Dalsøren et al., 2007). NOx emission reductions are also needed. It has been calculated that nitrogen oxides emissions have a potential to grow as the shipping intensity increases. The predicted average annual growth rate is around 1.7% for the 2000 and 2030 time period and emissions levels could reach the scale of current road transport NOx emissions globally by 2050, which is around 38.8 Tg(NO2)/yr (Eyring et al., 2007).

3.1.2 Black Carbon

Another significant product of the bunker fuel combustion is black carbon (BC). Black carbon is formed as a result of the incomplete burning of ship fuel (S. Elias, 2021). Black Carbon is a term used to describe small particulates of carbon emitted to the atmosphere with the exhaust gases. More Black Carbon emissions would have a significant impact on climate change, especially in the Arctic region. Polar regions are generally more sensible to the climate changes. The amplification of the polar temperatures is achieved through the abundance of the high albedo surfaces while equatorial ecosystems have a high buffer capacity to the temperature rise due to the vast areas where heat accumulation is considered to be normal and heat fluxes are dominating over the region (Ban-Weiss et al., 2012). Unlike NOx and SOx, black carbon is a solid. As it comes from its name Black Carbon is a dark surface material, which means it will have a low albedo value (Myhre & Samset, 2015). Based on the data collected in the end of the first decade of the 21st century, it has been calculated that shipping activity contributed to the 0.3% of the overall black carbon accumulation in the sub-Arctic and Arctic region (Browse et al., 2013) in a period of insignificant commercial scale shipping activity.

The influence of the black carbon on climate change is also complicated. When black carbon is emitted, it accumulates in high layers of the atmosphere and absorbs solar heat which leads to the reduction of the downward solar radiation (Ban-Weiss et al., 2012; S. Elias, 2021). However, it has been argued that the high-latitude black carbon accumulation is relatively negligible (Browse et al., 2013). Yet still in combination with other pollutants emitted in the process of bunker fuel combustion a change regional radiative forcing[10] can be observed (S. Elias, 2021).

On the other hand, since black carbon is a solid that comes in a variety of sizes. Larger and heavier particles of black carbon are often accumulated on the ground. Black carbon from Arctic shipping might have a serious effect. Since throughout the year the Arctic is predominantly white due to the snow and ice accumulation on the continent and on the sea ice crust the albedo of the Arctic region surface would be high. This means that large amounts of solar radiation would be reflected and heating would not be as intensive. However, as shipping through the region increases, the accumulation of black carbon on the surface would increase as well. This will cause the surface to become darker and lose its reflectivity due to the lowered albedo. This itself would contribute to the increased rate of the Arctic sea ice melting and general heating of the region through direct diabatic heating (Ban-Weiss et al., 2012; S. Elias, 2021).

The net direct aerosol effect of black carbon refers to the overall heating/cooling of the planet as a result of the black carbon emissions. It was calculated that in a scenario when shipping through the Arctic replaces the shipping through the Suez channel, the net direct aerosol effect of black carbon would be reduced, which means that it would cause more heating than cooling (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014; Myhre & Samset, 2015). There are two main reasons for that. Firstly, black carbon accumulated on the white surfaces causes significant positive delta (the surface heats up)

[10] Radiative forcing (RF) is a difference between the incoming energy that Earth absorbs from Sun and outgoing radiation that is emitted by the planet.

in the radiative forcing of the landscape, although it is important to mention that positive black carbon effect on the warming on the region would peak around the year 2040 and would decline after that since the ice cover of the region would be already gone in a significant amount and there will be no more such a large delta in albedo between the surface with and without black carbon accumulation (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014). The second reason for the reduction of the net direct aerosol effect of black carbon is linked to the fact that since black carbon is emitted closer to the poles of the planet it cannot reach such high altitudes in the atmosphere compared to the black carbon emissions in the areas close to the equator (like Suez and Panama sea routes). This is described by influence of the Earth's substantial rotational speed which is more significant closer to the equator (NASA, 2023). Therefore, black carbon emitted in the Arctic region would reach lower altitudes, which causes the reduction of its lifetime (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014).

3.1.3 Used Water (Vessel Discharges)

Since ships act as a place where humans are living during the time of the transit, black and grey wastewater is produced. Black water mainly refers to the sewage, while grey water is used water after showers, washing machines etc. (Jägerbrand et al., 2019). Used water can contain different pollutants including pharmaceutical compounds, bacteria, viruses, chemicals, heavy metals and others (Butt, 2007; Herz, 2002). Used waters can be a real threat to the coastal communities since the hazard of pollution becomes quite high which is especially important to consider for northern small communities who are reliant on fresh water access and maritime resource supply as mammals and fish (Dimitrios & Drewniak, 2019). Depending on the size of the ship different regulations for used water treatment apply. Used water discharge is only allowed on 22 km or further distance from land and for all vessels larger than 400 gross tonnages and with over 15 passengers onboard an onboard wastewater treatment facility is required (S. Elias, 2021). All shipping carriers involved in the commercial shipping would fall under this category.

Used waters would be rich in organic matters, nitrogen, and phosphorus. The increase in pollutant concentration along the commercial shipping sea routes would have a negative effect on marine wildlife. Moreover, it is important to take into account the different lifetime of the compositions discharged with wastewater and its influence on the nutrient cycle (S. Elias, 2021). Excessive used water discharges might be one of the contributors to the marine environment eutrophication along with the NOx emissions. In the Baltic Sea around 0.06% of nitrogen and 0.43% of phosphorus from shipping waste waters are contributing to the overall waterborne nitrogen and phosphorus load (Jägerbrand et al., 2019). This will lead to the fast growth of the cyanobacteria populations which are potentially toxic and might catalyze the eutrophication (Larsson et al., 2001). Finally, the risk of the pathogen spread with used water discharge is quite high. This might pose a threat to the public health and the potential discharge of zoonotic pathogens might contribute to the transmission of diseases between humans and animals which is particularly relevant in the realm of the global health crises such as pandemics (Parks et al., 2019). Low enforcing and controlling capacity of the regulators only aggravates the issue. This is a particularly acute problem for the Arctic vector, where due to the severity of climatic conditions and low density of the coastal population, monitoring and reinforcing resources are very low (Rachold, 2019).

3.1.4 Oil Spills

Shipping is associated with a high risk of oil spills, which have serious effects on the environment. This is especially important in the context of Arctic shipping due to the remoteness of the sea routes from the nearest facilities that might be able to conduct restorative activities, and due to the severity of climate, which makes it harder and more expensive to solve the potential oil spill problem in the Arctic environment compared to the environments along the traditional routes (Rachold, 2019). No doubt, oil spills are a serious problem that might occur anywhere, and are not Arctic-specific. However, the Arctic does pose specific problems in terms of mitigation and clean up. The breakdown and volatilization of oils is much slower as a result of low water temperature. Furthermore, the ice-oil interactions are still under-researched and quite unpredictable due to their complexity (S. Elias, 2021).

Oil spills have a significant effect on all the levels in the system where the spill occurred – it can cause alterations and interference everywhere from the DNA level to the ecosystem community level (Neuparth et al., 2012). Moreover, it has been researched that consequences of the oil spills for the ecosystem members can vary in duration. Depending on the exposure the impact might vary from acute intoxication to lethal effect. Long-term alterations in the DNA sequence or DNA damage were found in marine inhabitants exposed to oil spills (Höfer, 1998). Finally, oil spills would be extremely threatening to the algae communities (Jewett et al., 1999).

Oil spills are harmful to all exposed animals and plants. A high number of birds killed as a result of the oil spill exposure was documented multiple times; shellfish suffer from reduced shell thickness and experience declining breeding outcomes; sea otters can have fur loss, which disrupts their thermoregulation and natural protection; seals have neural system problems; whales have disruptions of the filtrating mechanism that is essential as it is responsible for the food supply; and many species of fish have problems with liver damage, growth disruptions and increased death rate (Höfer, 1998; Jägerbrand et al., 2019; Peterson, 2001).

Moreover, since oil is less dense than water it accumulates on the surface. This creates an impenetrable barrier for the solar light and consequently leads to temperature drops in the insulating layers of the water. This might cause the "cold death" of several marine species who would find themselves in new much colder conditions that are not suitable for their lifestyle (B. Ellis & Brigham, 2009).

3.2 Impact on the biome

3.2.1 Ice destruction

Increasing shipping in the region would have a direct impact on the disruption and fragmentation of the natural habitats. Shipping would have an impact on the natural habitats in the Arctic or along the traditional Panama/Suez routes. However, considering that the Arctic is already in a vulnerable state and the effects of climate change in the Arctic are more severe than in other regions and the warming that is already happening faster than in any other region on Earth (WWF, n.d.), adding additional drivers of climate change might have way more significant outcomes. Navigation through the Arctic is possible at the early stages while the periods of the ice-free passages are not all year-long (Jahn, 2018) only with the use of ice-breaking vessels (Z. Wan et al., 2023). The physical crashing of the sea ice coverage might be one of the examples of the interference of commercial shipping with natural habitats. For many Arctic species, continuous ice surface over the ocean is vital since it acts as a shelter, feeding, and mating ground (Jagielski et al., 2021). This applies to a diverse group of Arctic species, but this problem was extensively studied in an application for polar bears (Polar Bear Range States, n.d.). Climate change is already altering and shrinking their habitats (Rode et al., 2022), which pushes bears to explore new habitats previously unsuitable for them. This leads to the increased frequency of human-bear interactions, which are dangerous and might be even fatal for humans. Multiple examples of unwanted polar bear visits to residential zones in search of food in Canada and Siberia have been documented (Heemskerk et al., 2020). A lot of research is done around the implications of habitat fragmentation for polar bear populations; however, this problem is equally important for all other Arctic species. The physical crashing of the continuous ice shield over the sea has a direct impact on the shrinking habitats; however, there is also an indirect impact as well. By smashing ice into smaller pieces its melting rate increases due to the greater surface area (Matala & Steur, 2021)In the context of habitat integrity, this increases the rate of habitat disruption.

The ship movement itself might pose threat to marine habitats. In the scenario when commercial shipping would be a full-scale alternative to the traditional routes, the number of ships passing through the Arctic sea routes would continue to grow (PAME, 2020). Therefore, collisions between sea animals and ships would be much more likely to occur. While collisions with smaller ships and boats might be dangerous for the crew, encounters of sea animals with large cargo ships would be dangerous for the animals. Whaled have died as a result of such collisions (Halliday et al., 2018).

Moreover, increased shipping has a disturbing effect on marine mammals and might cause a rise in stress levels and behavioral changes (Halliday et al., 2018). This might potentially result in the decline of sea mammal populations, which poses a great threat to food security in the region. This might be particularly substantial for Indigenous Peoples (M. M. Bennett et al., 2020).

Even without an actual close proximity interaction between animals and commercial ships, there is still a risk of ecosystem disruption. Ships might interfere with migration patterns. Increased traffic might negatively affect some migratory birds and marine animals (Rachold, 2019). Thankfully, as technology advances the possibility to develop sea shipping routes with respect to the migratory movements of the species becomes more and more realistic. It is possible now to lay the routes in a manner when it will avoid major natural habitats, migration patterns, and local communities, although it is important to account for the high level of unpredictability of the Arctic region. Severe weather conditions and the increasing frequency of ocean storms (Vavrus et al., 2012) and rapidly changing sea ice conditions might force the ships to change their trajectory and the anticipated ambition to avoid interference with the natural habitats would not be fulfilled (S. Elias, 2021). Of course, it is also important to note, that climate change is already changing the Arctic (WWF, n.d.) quite rapidly, so natural habitats and migration patterns would undergo drastic changes either way, although, uncontrolled shipping might only aggravate the situation.

3.2.2 Noise

Noise pollution is one more serious type of pollution the significance which sometimes is underestimated. However, commercial shipping is the primary source of underwater noise pollution (Cosandey-Godin, 2022). Since water is an environment much denser than air, it can spread the sound waves at a significantly further distance compared to the terrestrial systems due to the lower loss of wave power in the water (Brekhovskikh & Lysanov, 2003). Therefore, the noise can spread substantially further distances. For instance, it has been found by the US Marine Mammal Commission's Advisory Committee on Sound that "human noise can shrink the area in which whales can communicate with each other by two to four orders of magnitude" (S. Elias, 2021).

This means, that the area of potential damage from noise pollution can considerably exceed the area of the intermediate influence of the passing ship on its surrounding, since the higher density of the water environment hinders the penetration of the light, which only increases with the depth. The majority of marine animals are using areas below the photic zones as their regular habitats, which means they live in a dark environment. Therefore, marina animals are more reliant on sound rather than on their vision (S. Elias, 2021; Southall et al., 2007). Even such things as hunting and food collecting, caring for the next generation, avoiding predators, and looking for other species are done with the help of sound not vision (S. Elias, 2021). Therefore, the acoustic environment plays an important role in the aquatic ecosystem. Moreover, different sounds depending on their duration and frequency might have various effects on sea animals. American National Standards Institute divided sounds into 5 categories based on the possible effect on fish and sea turtles: "(1) mortality and mortal injury – immediate or delayed death either due to injury or substantially reduced fitness; (2) recoverable injury – injuries, including hair cell damage, minor internal or external bleeding, etc. None of these injuries is likely to cause direct mortality; (3) Temporary Threshold Shift (TTS) – short or long-term changes in hearing sensitivity that may, or may not, reduce fitness. TTS is defined as any change in hearing sensitivity of 6 dB or more; (4) masking – increase in threshold levels of detection by more than 6 dB; (5) behavioral effects – substantial change in behavior for a large portion of the animals exposed" (Popper et al., 2014). The research shows that ship propulsion noise can cause physical damage to some of the marine habitants as well as lead to temporary disorientation (Rachold, 2019).

When speaking about the noise from commercial shipping, researchers mainly refer to the noise from the cavitation of the propeller and turbulence (Rako-Gospić & Picciulin, 2019) as they are fairly consistent throughout the whole trip. Other sources of the underwater noise of anthropogenic origin would be the vibrations from the machinery activity, sonar, and waves from the ship movement (Jägerbrand et al., 2019). The problematic thing here would be that all of these sounds normally occur within the 10 Hz to 1 kHz range, which overlaps with the range of frequencies normally used by the majority of sea animals (Peng et al., 2015). Overall, the fact that sea shipping creates this significant and constant source of ambient noise generally has a negative impact on the marine environment; however, a few examples show that there might be some positive outcomes as well. For instance, it is proposed that propeller noise might attract larvae and stimulates their growth and metamorphosis under exposure to sea vessel noise (Mcdonald et al., 2014). But yet overall, there is no clear answer and no direct correlation between the overall biodiversity issues and the increasing ambient noise from the shipping carriers (UNEP, 2012).

It was observed, that in the 1950-2000 time period, overall background noise associated with the shipping activity was increasing its intensity (due to the increase in the sea shipping volumes) and the increase was in average of over 3dB every decade (Rako-Gospić & Picciulin, 2019). The range of solutions is not very wide and a complete ban on cross-Arctic commercial shipping is not very likely, although it was proposed (S. Elias, 2021). One of the main possible high-resultative solutions might be the development of technology lowering the level of noise pollution and the work in this direction is already on the way as this is tied closely with the propulsion efficiency and consequently, if a suitable solution would be found it would lead to the lowering of the fuel use and subsequently GHG reductions (Cosandey-Godin, 2022). Other mitigations that are more realistic for the current situation, but maybe less efficient, would include the reduction of the maximum possible speed for commercial ships on the Arctic routes; reduced use of the noise-producing ship infrastructure such as sonars; and more precise route planning to avoid highly populated marine regions and areas of migration (Cosandey-Godin, 2022; S. Elias, 2021).

3.2.3 Invasive species

Introduction of the invasive or "non-indigenous species" (NIS) (Jägerbrand et al., 2019) is also a possible outcome from marine shipping. Cold region ecosystems are known to be very sensitive to the introduction of the new species and shipping poses a threat to "biosecurity" of the ecosystems (Chown et al., 2015; Höfer, 1998). The use of the Arctic sea routes is in some way similar to the shipping in the sub-AntArctic region from the invasive species distribution. Ships create a new and fairly constant inflow of the matter to the areas that were previously somewhat isolated and had a static in a time perspective biome (Avila et al., 2020). It has been estimated that transportation of the potential non-indigenous species to the environment via shipping on average takes only 4% of the time (Griffiths & Waller, 2016) required for the transportation of the same species by natural sources. It has been calculated that 44 and 15 cases of environmentally significant invasive spread occurred in the Northeastern and Southwestern Atlantic respectively, and over 130 cases in the Baltic Sea, where over 80 of those are associated with the shipping activity (Jägerbrand et al., 2019).

Invasive species are undoubtedly a threat to biodiversity and ecosystem integrity, but also have economic implications. By creating the competition for the resources to the domestic species or even by excluding them from the habitat and predating on them, invasive spices put a limitation on the resource availability for the local communities. In case of the Arctic northern communities, the continued availability of a particular type of fish might be vital (Eegeesiak, n.d.). Loss of the biodiversity and ecosystem services might be followed by large financial efforts to conduct control, reduction and mitigation of invasive species activities, which means that the economic implications might be serious (Bax et al., 2003).

There are several means by which the introduction of the invasive species can happen. Small particles of seaweed or some marine animals can be transported via the physical adhesion to the ship. There are many examples like the introduction of the Eastern European species Zebra mussels to North America via ship ballast waters. It was first found in the Great Lakes in 1980s and then quickly spread across the continent causing the clogging of water intake pipes of power plants, public water supply systems, and irrigation systems. Moreover, by being introduced to the environment without a natural predator Zebra mussels started to adhere to boat hulls in much larger quantities. This all led to the serious environmental and economic consequences (Strayer, 2009). European green crab is another example of an invasive spice transported via ballast waters. It was brought to North America the early 19th century and then spread across the American coasts affecting the food chain, preying on native shellfish and interfering with the shipping industry (Leignel et al., 2014). Brought to North America in 1960s, Asian carp spread all the way from the Mississippi River basin to the Great Lakes and pose a threat to native fish species since it was outcompeting them in habitat take over and resource foraging. Moreover, the activity of Asian carp has even affected the political agenda of policymakers in Illinois (Just, 2011).

There is a fairly low risk of the invasive species contamination in case of the shipwrecks when some forms of animals or plants might come in the environment if the insides of the ship or cargo contains would be exposed. However, the major source of the invasive species is the ballast waters. Ballast water is needed to help stabilize the ship in the ocean especially in the conditions of the low load. Therefore, ballast waters are unavoidable when it comes to shipping (B. Ellis & Brigham, 2009). Ballast waters and ballast water sediments might contain a wide range of potential non-indigenous species possibly varying in size from microscopic to small size fish (Jägerbrand et al., 2019). UV treatment can be applied; however, its effect is limited depending on the size of the organism (Romero-Martínez et al., 2020). While the effectiveness of UV light might be high for the microscopic organism, mechanical filtration can help protect the environment from larger species. However, overall effectiveness of those mechanisms would depend on the regulation and external control to ensure the compliance with the environmental norms.

The problem with invasive species that in order to cause a significant harmful effect a self-maintaining population of the invasive species needs to be established. It can often happen in absence of the natural predators; however sometimes there is not enough natural material to set-up the population. Sadly, commercial large-scale shipping would act a constant source of the natural material since it would use generally the same routes. Consequently, it would heavily increase the chances of establishing a viable population of the invasive species (Endresen et al., 2004). Time might be also seen as one of natural limitations of the invasive species spread. In order to establish a population a potential invasive species should be able to survive during the trip until the ballast waters are discharged. While it might not be a significant concern for microscopic organisms, time limitation might prevent the spread of larger marine animals such as fish. However, with the overall tendency to increase the efficiency of marine shipping through the increased shipping speed and since Arctic sea routes are potentially shorter than the traditional Panama/Suez alternatives the risks of the invasive species spread would be even higher for the shorter Arctic routes (Trozzi, 2003).

Finally, climatic changes and warming up of the Arctic region would make this ecosystem available for some species that previously considered this environment off limits due to its cold waters and severe weather conditions. The creation of the new ecosystem cells would be highly favorable environment for the spread of the invasive species from warmer southern regions since the environment wouldn't have a natural predator for them (Rachold, 2019).

3.2.4 Benthic environments

There is also evidence of the disruption of benthic environments due to the repetitive and continuous anchor scour. This might be potentially harmful due to the erosion and simplification of the seabed leading to reductions in biodiversity by seabed habitat disruption and demolition (Broad et al., 2020). The harmful effects would be the most significant in the coral reef areas where tens of cruise ships would be stopping continuously (Smith; 1988), however, it is important to note that this would have a disruptive effect on the Arctic marine environment as well.

3.3 Possible environmental benefits

Despite a large number of potential environmental hazards there are possible positive outcomes. The major advantage of Arctic shipping compared to the alternative traditional Panama/Suez routes is the overall reduction in distance. At a global level this means, a reduction in delivery times and associated emissions and in the use of human resources, containers and ships. In this chapter we will discuss those points in more detail.

One of the most obvious advantages that is associated with new potentially shorter Arctic routes is the optimization of the fuel use due to distance reductions (Rachold, 2019). New routes might enable up to 40% fuel savings on the northern sea routes compared to the traditional alternatives, without introducing new and more efficient technologies (Furuichi & Otsuka, 2013). Fuel consumption reductions are important because this decreases the GHG emissions, reducing in turn glbal climate change. Having said this, the net effect of the shift from the traditional routes to the Arctic routes on climate change is still not sufficiently researched to be able to make a compelling argument either way. Provisional research indicates that overall CO_2 emission reductions in the ice-free conditions can be up to 49%-78% compared to the Suez route (Schøyen & Bråthen, 2011). This is not insignificant.

Aside from GHG, the products of fuel combustion contain NOx and SOx which are also harmful for the natural environment. Therefore, the reductions in the concentrations of those pollutants can be also observed as a result of shorter transit times. Despite NOx emissions being highly hazardous for ecosystems and public health they might have a positive effect on climate change as well. NOx emissions can reduce the methane concentrations and lifetime in the atmosphere. NOx emissions increase the OH- radical concentrations in the atmosphere. It is estimated that shipping industry is responsible for 3.67% OH- increase globally every year (Dalsøren et al., 2007). The chemical reaction is simple: OH- reacts with hydrocarbons (methane) by taken away H+ and forming water (Riedel & Lassey, 2008). The overall results of NOx on the methane lifetime might lead to over 7% lifetime decrease (Dalsøren et al., 2007; Eyring et al., 2007; He et al., 2021). However, due to the overall reductions of the NOx in the atmosphere resulting from the shorter sea routes the intensity of the methane dissolution reaction would be lower. At the same time overall methane concentration due to reduced shipping emissions would be also lower. Therefore, the net effect is still yet to be estimated.

Finally, since ships would be more efficient and less fuel would be required to satisfy the industry demands, it might affect the oil and gas sector and incentivize lower production volumes for certain oil and gas products such as bunker fuel. Consequently, secondary emission reductions can be observed on the fuel production stage as well.

3.4 Chapter summary

Environmental considerations are extremely important in the context of Arctic shipping. Shipping industry is responsible for large emissions of CO_2 and other pollutions. The accumulation of such pollutants in the Arctic environment would be potentially dangerous not only for the marine life but also to the local Indigenous communities who are reliant on the maritime resources.

Maritime shipping in the Arctic can be a significant source of nitrogen and sulphur oxides and black carbon which is only aggravating the influence of climate change due to increased heat accumulation on polar terrain. The risk of oil spills and shipwrecks might be even higher due to more severe conditions of the Arctic environment. Since the region is very remote it might be harder to deal with the consequences of such incidents compared to the areas along the traditional shipping routes that a laid in a more explored and easily accessible areas.

Arctic shipping might have a negative effect on the habitats and migration patterns of local fauna. By continuously crashing the sea ice the ice melting rate would increase and natural habitats of some of the Arctic animals would shrink significantly. Lastly, the introduction of the active trans-continental shipping in the region might pose a threat of brining the invasive species which has already occurred in the past, for example in the shipping between Europe and North America. Consequences of such disruption were significant from social, ecological and economic perspectives.

Overall, just like many other things previously discussed here, this is all not location-specific to the Arctic region, and all these incidents and potential threats can happen in any shipping scenario for trans-Arctic shipping or shipping through the traditional routes. However, given the vulnerability of the Arctic ecosystem, all the disruptions here would have much more acute and long-lasting effects. Therefore, it is important to consider it while discussing the advantages and disadvantages of Arctic shipping against traditional routes.

However, due to the distance reductions, there is a possibility of the reduced fuel consumption which might lead to the decrease of the CO2 emission intensity. Although, there are no evidence that this benefit might overweight the risks outlined above and the overall assessment of the environmental effect of the Arctic shipping is that this might have a severe negative environmental outcome on the region.

Chapter 4 Economic factors.

This chapter reviews the local and global impacts of the Arctic shipping from the economic perspective. Given the complexity of the issue it is hard and often impossible to classify the outcomes as purely positive or negative. Arctic shipping provides an opportunity to reduce the consumption of fuel and consequently to reduce the duration of maritime shipping route between Asia and Europe/America. This can benefit the global trade. It might also be one of the means to support the economic development on the regional level. However, there are also negative economic considerations that should be take into account when talking about the Arctic shipping. While net effect on the global economic environment from transition from the traditional routes to the Arctic alternatives is actively discussed in the academic community, yet there is no clear answer. This chapter provides a review of the peer-reviewed publications and gives critical overview of the economic outcomes of the Arctic shipping.

4.1 Economic Feasibility, Benefits, Costs and Limitations

One of the main drivers behind the development of the Arctic shipping is the reduction in the distance between Asia and Europe/America. Arctic sea routes can be indeed up to 40% shorter than traditional routes. And this is the main area to gain economic benefit. Shorter distance would mean 2 things: faster delivery times and reduced fuel consumption.

While the distance is shorter and therefore it would be expected that less fuel is needed, there is a complication. Navigation through the Arctic is much more complicated than navigation through the relatively warmer waters of the southern seas. Arctic passages would likely involve cutting through sea ice deposits requiring greater power and consequently greater fuel consumption. Overall, with the recalculation for the navigation through the ice, net fuel savings would likely be much more moderate. Until 2030 Arctic navigation might have a higher fuel demand (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014) due the more frequent and abundant sea ice presence conditions. As the Arctic Sea ice coverage declines and the need to break through the ice gradually disappears, fuel reductions would start to become tangible. In 2030 and 2050 on NSR Rotterdam – Yokohama sea route fuel reductions would be up to 29% and 37% consequently for the periods of ice-free conditions and overall whole-year fuel reductions would be up 10% in 2030 and up to 16% in 2050 on this route (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014).

While the development of the Arctic shipping is associated with high level of uncertainty and risk potential feasibility of this initiative can be seen as the major driving factor for the development of the project as a whole.

Overall, the discussion around the benefits from Arctic shipping is highly controversial and built around two major topic areas: economic and non-economic benefits. Of course, all other components of this system are tightly interconnected with each other since the system is extremely complex and multi-level. But to be able to operate with it and to be able to compare the scale of potential benefits versus potential risks we can study those categories separately.

4.1.1 Economic scenarios for the development of the Arctic shipping

Now two major potential trajectories of the Arctic shipping development are discussed: slow and incremental, versus a much faster ramping up of infrastructure and routes.

In the first market-driven scenario, there is greater continuity. Traffic might grow as a result of lean launch of the commercial Arctic shipping initiative supported by progressing in the long-time perspective incremental investments to the region (Brigham & Ellis, 2004).This approach would be mainly supporting the growing demand for maritime shipping in the northern region as its climate becomes less severe and a series of infrastructure projects come online. The support of the Arctic shipping through the incremental investments would involve a more targeted approach and would be associated with long lead times. In this scenario, Arctic shipping would not be competing immediately either with its maritime alternatives such as Suez and Panama, or with rail magistrals such as Trans-Siberian or North American land rail bridges. There would be no paradigmatic transformation in global shipping patterns and the power distribution between the main shipping arteries would not change quickly Therefore, positive and negative effects on global economy, ecosystem, climate change, human health and Arctic communities would be insignificant – at least to start with

The second potential scenario for the development of the Arctic shipping involves greater discontinuity and would see a much more sudden increase in the Arctic shipping activity backed by major flows of investment (Brigham & Ellis, 2004; B. Ellis & Brigham, 2009). However, for this scenario to be realized, trans-Arctic routes would have to be able to provide significant delivery-time reductions balanced by only a low to moderate increase in risk. In this scenario it is proposed that global fund level investments would be supporting the development of the Arctic shipping. This would be an internationally orchestrated and very concerted attempt to provide an alternative to the traditional Suez/Panama routes and land rail bridges. Such a scenario we would involve a rapid transition from internal-regional to international trans-continental shipping patterns. Large scale investment would facilitate a wholesale switch away from old routes to the new Arctic routes which means that the scale of potential possible and negative effects would be much higher compared to the gradual incremental investment scenario. This will lead to the global scale change in the shipping patterns and creation of the new international commerce reality.

4.1.2 Economic Concerns

The scenario where the Arctic will be the final destination is more likely to happen in near future 2010-2030s rather than the scenario when Arctic sea routes would be used as the transitways for the global trade (Brigham & Ellis, 2004). However, with a progressive decrease in Arctic Sea ice cover and a corresponding increase in the duration of the ice-free navigation (PAME, 2020; Peters et al., 2011) it seems likely that economic pressures will see a transition to the second scenario: i.e. a transition from small scale incremental investments to strategic global investment.

However, even now there has been a significant increase in international collaboration and more frequent conversations about the future of the Arctic shipping routes. Since the end of the cold war, Arctic countries have engaged in a continuing dialogue with regard to developmental possibilities and the potential for cooperation (S. Elias, 2021). Taken together, this is an indirect signal that major transformation is likely in the medium term bringing both positive and negative effects to the region.

Understanding the possible scenarios for the development of the Arctic shipping is very important to be able to evaluate the scale and the timeline for both the negative and positive impacts associated with this kind of activity. The major reason for transition from existing Panama/Suez to the trans-Arctic routes is to increase profitability, reduce costs and possibly GHG emissions. As the Arctic route would be shorter it’s likely that it will be economically beneficial to use this opportunity. However, there are some topics that as seen as potentially concerning and therefore they need further research to determine how much would they be hindering the development of the Arctic Sea route.

Since Arctic sea routes in general would be of a much higher risk they need to ensure that the shipping time reductions would be significant and at the same time some degree of reliability is required (Brigham & Ellis, 2004). Moreover, higher risk of sea ice collisions might lead to the increase in the frequency of incidents leading to the delays (S. Elias, 2021; Marchenko, 2013). Moreover, as the climate change transforms Arctic climate towards more severe with higher frequencies of the sea storms and other potentially hazardous conditions (Aksenov et al., 2017) it gives the researchers reasons to believe, that it might have serious economic implications that would not be justified by the potential distance reductions. Moreover, as we are only moving to the permanent ice-free conditions along the Arctic sea routes (M. M. Bennett et al., 2020; Screen, 2018), Arctic shipping would have a seasonal nature. In the foreseeable future, the viability of the Arctic navigation through NSR might be commercially reasonable only during July to November time period (Faury & Cariou, 2016). Inconsistent weather conditions might potentially lead to the ship or cargo damage which would also lead to increased expenses associated with the Arctic shipping route. Additionally, high risk would entail increased insurance costs for the shipping sent through the Arctic route (Lasserre, 2014). And if those expenses exceed or are even close to the potential savings from the distance reductions, the feasibility of the Arctic Sea routes would come into question; i.e. from an economic perspective, the potential productivity gains have to outweigh the maximum costs associated with unpredictable risks, by a considerable margin.

Economic risks would include all the possibilities of physical damage to the cargo ships and potential health concerns for the crew. With climate change, the risk of natural disasters becomes greater all over the world and the Arctic region is no exception. The opening of the Arctic Ocean combined with the increasing Arctic cyclone activity makes sea storms more severe and frequent (Vavrus et al., 2012). Moreover, it has been established that climate change would also increase the frequencies and strength of such climatic conditions as ice ridging, fog, waves, and icing (Aksenov et al., 2017), which adds to the complexity of trans-Arctic navigation.

The issue of drifting ice not only acts as a limiting factor but is also likely to be the cause of shipping accidents. While analyzing the history of the accidents along the North-East passage in the second half of the twentieth century if was observed that ice drift and compression caused about half of the shipwrecks (Marchenko, 2013). This data is covering a period when the results of climate change were significantly less severe compared to the time in the near future when commercial shipping through the Arctic is predicted to begin. Therefore, we can only assume that ship-ice interactions will be much more frequent and possibly more accidents to come. However, we should also take into account mitigating factors such as the development of satellite monitoring technologies, as well as the advances made in ship design to be prepared for such encounters (Christensen et al., 2019). Lastly, due to the remoteness of the region and paucity of search and rescue facilities, ice collisions in remote territories would certainly increase the likelihood of sinkings and fatalities (Elias, 2021).

The increasing frequency of adverse weather events poses a real risk to onshore shipping infrastructures. Along with rising sea levels, such risk factors that should be accounted for while developing the shipping infrastructure like ports and other facilities (Christodoulou et al., 2019). Moreover, the increased intensity and frequency of storms would affect coastal erosion (Vavrus et al., 2012). Not only larger investments would be required to mitigate the potential consequences of climate change, but also more effort is needed to cover the high-risk investment.

Economic risks would be also associated with the potential damage to the ships or losses of cargo in the conditions of severe sea storms which would only increase in the future. Aside from the economic risks from physical damage/loss, there would a high probability of delays because of "unpredictable drifting ice, especially at the beginning and the end of potential Arctic shipping seasons" (Lasserre, 2014). This might lead to serious monetary penalties and contract breaks with customers. Moreover, since sea shipping is a quite competitive market with overall similarly offered products across all the major players, such violation of the delivery times or cargo losses might entail all kinds of marketing and optics problems for the company and damaged credibility (Lasserre, 2014). This in turn might lead to the shrinking of the business among all the other lines of business and mass outflow of customers to competitors.

4.1.3 Physical risks

In the conditions of climate change, we will see an irreversible increase in median seasonal temperature in the region leading among other things to the shrinkage of the sea ice cover, which is going to be most significant in the area of the Barents Sea (North-East passage) (Vavrus et al., 2012). However, climate change would not release the risk tension associated with trans-Arctic shipping. We can see a steady trend in the increase of the climatic anomalies in the region leading to a higher level of unpredictability of the weather conditions and consequently higher risk. The study of the winter seasonal evolution of anomalies of zonal mean temperature at 80^{O} N indicates extreme positive temperature anomalies to be statistically significant throughout the winter months peaking in January to February time period (Nakamura et al., 2015).

Moreover, sea-ice coverage decrease combined with the statistically significant increase in frequency and strength of extreme Arctic cyclones would pose even more immediate danger to the ships potentially passing through the Arctics (Vavrus et al., 2012).The share of drifting ice is to be increased over time as the climate change effects are more and more significant (Omstedt & Svensson, 1992). Navigation in the conditions of drifting ice would be more dangerous compared to the shipping alternatives and would require the use of technology and/or supporting vessels to ensure safety (U.S. Committee on the Marine Transportation System, 2019). Since drifting ice conditions are especially dangerous for large vessels (Sheehan et al., 2021) whose maneuverability is significantly lower, drifting ice can act as a serious limiting factor raising the level of unpredictability and uncertainty associated with trans-Arctic shipping.

In an attempt to avoid areas with a high concentration of drifting ice, ships might be required to choose longer routes which lead to extended shipping times, increasing both economic costs and emissions. Any increased GHG emissions on the route would cut against possible GHG savings associated with Arctic routes being nominally shorter than Panama/Suez alternatives (J. S. Fuglestvedt, Dalsøren, Bjørn, et al., 2014). The unpredictability of the weather conditions and estimated delivery time violations would pose a potential economic risk on the shipper, which might lead to earnings reductions that might be equal or greater than the potential additional earnings from Arctic routes being shorter and fewer fuel requirements (Lasserre, 2014). Moreover, the increasing frequency of the drifting ice conditions leaves fewer Arctic Ocean areas that would be open for navigation leaving only narrow and shallow areas available, which makes the navigation of the larger carriers more complicated (Sheehan et al., 2021). This might also have geopolitical implications. In the scenario of the opening Arctic, there are multiple possible ways to create shipping routes. While some of them would be passing through national/domestic waters (B. Ellis & Brigham, 2009), others might be going through international waters, avoiding any national fees and charges (Stephenson et al., 2013). This might be seen as an economic advantage, but also it will make the shippers more independent of national governments and reducing regulatory oversight. Conversely, in the conditions of increased drifting ice volumes, when the shipping opportunities would be more limited, and the only possible shipping route would involve traversing national territorial waters, any such advantages would be diminished. Given the fact that the geopolitical tension in the Arctic region is already quite high due to systemic disagreements between US and EU on one side and China and Russia on the other (Dimitrios & Drewniak, 2019), such uncertainty adds to the potential risks of Arctic shipping.

Considering the combination of the severe temperatures, unpredictable weather, as well as the increasing probability and frequency of climatic anomalies and the increasing occurrence of drifting ice, navigation through the Arctic is associated with high risks of physical damage to the ships and health threats to the shipping crew. As a result, there is a high probability that crews will need access to emergency damage repair or emergency medical care. The severity of the Arctic climate, the remoteness of the region, the possibility of being locked and conditions associated with the long polar night make all kinds of emergency save and rescue operations much more difficult and expensive, as well as less predictable and reliable. (Rachold, 2019). The potential inability to get immediate help should be accounted for in the overall risk management of the Arctic shipping. This is only aggravated by serious level of the underdevelopment of the region.

4.1.4 Underdevelopment of the Arctic shipping infrastructure

The Arctic is characterized by an extremely low level of infrastructure development of the kind that is usually taken for granted as vital for smooth commercial shipping operations. This presents a serious challenge for companies seeking to exploit the NWP. From an economic perspective, there is a clear need for infrastructure development as a prerequisite for uninterrupted shipping to happen (Noble et al., 2013). On a high level, this means two things. Firstly, commercial shipping will either have to wait until such time as infrastructure has been developed to a level comparable with alternative routes; or NWP shipping will have to begin in the conditions of underdevelopment and greater risk. And secondly, since the infrastructure is not developed yet, high investments are required to build all the supporting port, maintenance, and safety and rescue facilities. Costs for that would be at some point accounted for in the shipping fares on the trans-Arctic routes, which will add to the overall shipping price. Therefore, possible money savings due to distance and fuel use reductions might be evened out by higher shipping fares.

However, it is obvious that without existing and increasing shipping through the Arctic, it would be unreasonable to believe that there will be serious advancements in the infrastructure development in the region (Faury & Lasserre, 2019). Between 2013-2014 only the region saw only 124 by comparison with the nearly 16,000 oil tankers that passed via traditional Suez route (Elias, 2021). Full-scale infrastructure development would require a large number of high-risk investments. High level of unpredictability and high rate of changes in climate leading to increased frequency of severe anomalies and extreme climatic effects (Vavrus et al., 2012) makes those investments even more high-risk due to the potential of the physical damage to the infrastructure as well as leaves the opportunity for unforeseen changes making commercial shipping unprofitable through the region, which leads to low or no investment returns in the infrastructure. Hard conditions and the remoteness of the region also play a significant role in the risk associated with the infrastructure development as well as increases the construction and maintenance costs.

Massive investments in the infrastructure that would be are needed, mean that investment will depend on certainty of high returns. Since such costs would be split with all the shipments sent through the Arctic route, this would increase the net cost of the shipping. Overall, the investment landscape is rather clear. In order to develop Arctic shipping for global trade and not just as a small regional activity, developers will have to demonstrate large cost reductions. Right now, it can be seen that clear support of a strategy for economic growth in the Arctic exists, however, there is no direct correlation between economic growth and social development and population well-being (Duhaime et al., 2017). It has been observed that marine shipping industry is especially "myopic when it comes to long-term planning" (Brigham & Ellis, 2004).

Even more urgent and acute for safe trans-Arctic shipping would be the insufficient number of search and rescue entities actively functioning in the region. Since Arctic shipping routes are coming through generally uninhabited areas, the search and rescue infrastructure is not as frequent and active as along the traditional shipping routes. Insufficient human resources involved in the search and rescue activities combined with low density of the search and rescue facilities poses a potential to be unable to manage the increasing demand associated with commercial shipping. This problem is particularly acute along the coast of Russia and Canadian Arctic (Rachold, 2019); therefore both North-East and North-West passages would require further development of the search and rescue (SAR) infrastructure.

This would include the expansion of the existing SAR network to create more emergency response centers, SAR operation groups with helicopters and aircrafts, navigation aids and communication systems, emergency supply storages and medical facilities, high quality weather forecasting and monitoring systems and finally the expansion of SAR ice-breaking vessels as well as the creation of the bases for personnel and rescue teams (Sheehan et al., 2021).

Another vital for safe shipping question that is arising from the underdevelopment of the region is the quality of maps needed for navigation. Only up to 6% of Arctic waters are mapped in accordance with international standards (Rachold, 2019), which means a lot of preparatory work requiring international collaboration is needed. Low quality of mapping material again increases the risks and consequently the costs of trans-Arctic shipping. Moreover, this is complicated by a high level of variability associated with constant sea ice migrations often leading to collisions with ships and other accidents (Marchenko, 2013). As satellite technology is advancing, new opportunities to get up-to-date detailed maps of the region occur, but there is still much uncertainty (Aksenov et al., 2017).

4.2 Possible economic benefits

While the possible economic risks and limitations are serious, the industry sees some tangible economic benefits of the Arctic Sea routs against the traditional routes.

4.2.1 Time reductions

Average shipping times from East Asia to Europe via Suez Canal are in the order of 30 days and to North America over 25 days via Panama canal (Melia et al., 2016). As discussed above, time reductions are considered to be the main driver for investment. Many calculations have been made showing the potential for reduced delivery times. However, most such calculations pertain to ice-free conditions and do not account for possible detours relating to drifting ice or areas of high concentration of migratory animals and densely populated natural habitats.

As the decline in Arctic sea ice accelerates, two potential sea routes will become available for the commercial shipping:

i. Asia to Europe Northeast Passage (NEP) or Northern Sea Route (NSR) along the coast of Russia

ii. Asia to North America North West Passage (NWP) along the coast of Alaska and Canada

However, it is also possible that by the second half of the century a transpolar sea route would be open for shipping which would be even shorter than both NWP and NEP (M. Bennett, 2019). When sea ice conditions become more predictable it became possible to operate in the Arctic. NSR was actively used in Soviet Union to support the construction of oil and gas and mining facilities in the Soviet Arctic (Moe, 2020). Transition from Eastern Asia to Europe through Russian waters by different estimations might provide up to 40%-time reduction compared to the Suez route (J. S. Fuglestvedt, Dalsøren, Samset, et al., 2014; Furuichi & Otsuka, 2013). A sample route between Northern Europe and East Asia would be over 21200 km when navigating via Suez Canal Route (SCR) and the same route can be reached in under 13400 km if travelling through the Arctic (NSR) (Rachold, 2019). This might result in 6.5-14 days reduction in travel time (S. Elias, 2021) which makes this delivery option more flexible for the customer and allows shipping companies to get more net profit from one ship per year. In the short-term sea ice conditions in the Arctic would remain unpredictable to some degree, therefore the overall vessel speed would be lower in the Arctic routes compared to the Suez/Panama routes. Considering the potential speed losses on a sample route from Rotterdam to Yokohama time saving would be around 6 as the transit time via the Suez route (11580 nautical miles) would be possible on average speed of 20 knots while NSR (6930 nautical miles) would only allow the average speed up to 17 knots making the shipping time a little over 18 days of pure travel time (Rachold, 2019).

Similar time reductions are observed on the East Asia to North America route. For instance, New York to Yokohama would take around 25 days via the Panama Canal (9720 nautical miles) and just under 21 days via NWP (7480 nautical miles) (Melia et al., 2016).

The North American Arctic sea route also provides an opportunity to get from Eastern Asia to Western Europe as an alternative to NSR. In this case distance reductions are even more significant. It would only take around 13600 km via the Northwest Passage, while the Panama route would be 24000 km (Sheehan et al., 2021). As the sea ice cover continues to decline, the transit time is expected to decrease. Overall time reductions on Asia to Europe routes will be approximately 10 days shorter than traditional routes by mid-century and approximately 14 days shorter by the end of the century. A similar trend is observed for the Asia to North America route but with more modest time-reductions: up to 4 days with a potential for further growth (Melia et al., 2016). All this creates a lot of space for further academic discussion around balancing the potential monetary benefits of shipping time versus higher economic risks and required investments.

However, Arctic Sea routes provide another possible source of additional economic benefit. Shipping via Panama and Suez routes is obviously associated with canal transit fees: up to $240 000 (Lasserre, 2014) for Suez and up to $250 000for Panama (Willemsen, 2023). Moreover, although those fees are constantly rising, such inflation hasn't significantly reduced traffic because there is no alternative. It is always more economically reasonable than rerouting it all the way around Africa and South America (Ying Shan, 2022). These fees represent a large source of income for Panama and Egypt respectively. There is certainly the possibility that coastal passage fees in the Arctic Sea would see similar increases as countries seek to monetize geographical advantage. But as the Arctic Sea ice retreats a new transpolar sea route will become available that would avoid such fees entirely (M. Bennett, 2019). In addition, Arctic routes do not entail the queue stops and waiting times associated with the canals. Perhaps more importantly, the Arctic routes avoid the risk of the delays due to the obstructions such as Suez Canal blockage in March of 2021 by the Ever Given container ship (Russon, 2021). This collapse led to over 300 vessels carrying in total up to 17 billion USD being stuck in Suez Canal and up to 12% of world trade that depended on the Suez Canal passage was disrupted (J. M. Lee & Wong, 2021). There is also a not insignificant risk to the Suez Canal from geopolitical unrest in the Middle East.

Arctic routes certainly provide an alternative solution enabling to potentially avoid such situations. By providing lower cost competition with the canals, the opening of the Arctic would also lead to significant price reductions in relation to canal fees – which will reduce costs of world trade across the board.

Reducing dependence on the Suez and Panama canals would have another positive effect on large cargo ships. Cargo ships vary in size from Handymax – one of the most common types of cargo ship (up to 80000 DWT - Deadweight tonnage) to Very Large Crude Carriers (VLCC) and Ultra Large Crude Carriers (ULCC) that can be up to 320 000 and 550 000 DWT respectively (Bilogistik, 2019). Of course, size of the ship would determine if it can enter the port or not, for instance, ULCC ships would often require especially custom build terminals. And the size of the ship would determine if the ship can pass through the canal. Panamax and Suezmax are the ship sizes designed to be able to fit into

Panama and Suez canals. Panamax size ships have the capacity of up to 80000 DWT and the size of 294 m long by 32.3 m wide; Suezmax have the capacity up to 200000 DTW and have no length/width requirements, they only should not exceed the 68 meters heigh limitation of the Suez Canal bridge (Bilogistik, 2019). As we can see, Suez and Panama canals are not available for large ships. Continuous improvement work is done by canal management teams to extend the capacity limits. However, larger ships are still unable to pass through the canals (LeVine, 2015). Panama and Suez canals provide around 9000 and 13000 distance reductions by eliminating the need to ship all around South America and Africa respectfully (Rodrigue, 2020). For larger ships there is no alternative except for use those longer routes, however, Arctic route may provide a possible solution.

Moreover, shipping through the traditional routes is often associated with high piracy risks (Rachold, 2019). This is an especially chronic problem for the Suez Canal route. Bab al-Mandeb strait (entrance to Red Sea), Strait of Hormuz (Persian Gulf area), wide-open ocean of the Somali basin (east African coast), Gulf of Guinea Region (west African coast), straits of Malacca and Singapore, South China Sea – those are the regions with high risk of piracy and multiple reported cases of armed attacks on ships (BIMCO et al., 2018; Rodrigue, 2020). Shipping through the Arctic region would eliminate the piracy risk.

Overall, reduction in shipping time is important both for the shipping companies and for the customers. Firstly, reducing the delivery time, the amount of fuel, the quantity of human resources required, also reduces ship wear and tear and the rate of capital depreciation – resulting in lower unit costs (Rachold, 2019). Secondly, it would also allow companies to deliver more cargo per year with the same fleet(Lasserre, 2014). At the same time, shorter delivery times (by up to 40%) are also important for the customers increasing the efficiency and responsiveness of manufacturers across the supply chain. (Furuichi & Otsuka, 2013). This can facilitate just-in-time logistical systems and help avoid business losses from both under- and over-stocking (Kamisli Ozturk, 2020). Overall, such an improvement would lead to the optimization of the supply chain and reduction of the warehousing costs (Krichen, 2022),reducing the operational business expenses. Finally, for suppliers' shorter delivery times reduce the reputational risk associated with delays (Erplain, 2022).

4.2.2 Industrial development of the Arctic

The potential of the Arctic region to become a transit way for the global trade routes still remains. However, large investments in the development of this project are not likely. On the other hand, active industrial development of the region would incentivize the development of the regional Arctic sea shipping routes. With a warming climate, the region becomes increasingly economically attractive for a variety of industries including fishing, mining and oil.

Mining and oil extraction have existed in the Arctic for a long time. The NSR was originally developed to support the Soviet mining industry (Moe, 2020). In the post war period, the authoritarian communist leadership was able to coerce Arctic territories to support the industry resulting in significant population growth. Starting at the end nineteenth century demographic expansion in the Arctic North accelerated in the Soviet epoch. Construction of the railway network supported the active inhabitation of the north-western Soviet port Murmansk, and adjacent region of Kirovsk that was the center of apatite ore extraction back in the time; settlements such as Igarka were founded to support timber industry that was using large Siberian rivers to transport the wood to the newly built northern port towns like Dikson, Tiksi and Pevek that also supported industrial fishing; finally major extraction industry clusters were founded which entitled the growth of the settlement around them like Kolyma, Magadan, Vorkuta and Norilsk (Zamyatina, 2022). This led to the increase in the use of the high north region and to the boosting frequency and volume of use of NSR. Even nowadays Russia has the largest share of the population living in high latitudes (Bhagwat, 2022). Similar trends can be seen in the western hemisphere too – development of Fairbanks and Anchorage in early 1900 in Alaska and Whitehorse and Dawson in Yukon (Zamyatina, 2022). Overall, with the industrialization of the Arctic and sub-Arctic territories, the population has increased dramatically. In late twentieth century there were also attempts to populate the region by fiat. For example, the forced High Arctic relocation of the indigenous people in 1950s started with the relocation of several Inuit families to Ellesmere Island and Cornwallis Island during the Cold War to keep those regions populated (Makkik, 2009). It is important to underline the extent to which these attempts to populate and develop the region, were coercive and non-consensual. This notwithstanding to the extent that these settlements remain populated they may become centers for the new wave the industrial development in the region.

Extant mining projects in the Arctic are expected to see an increase in production volumes. For example, iron extraction in the Canadian Arctic is increasing (PAME, 2020). One of the richest iron deposits on the planet was discovered just over 80 years ago, but exploitation only began in the second decade of the 21st century the Mary River Project. This is one of the most northerly iron mines in the world and over 3.5 million tons of iron ore is transported from the mine via sea during open water season (PAME, 2020). Despite the fact that the expansion of the mine was not approved recently by the Nunavut government, the Baffinland Iron Mines Corporation – the owner of the mine – is developing a plan to keep the mine functioning for the extended period of time ,which would continue to generate demand for cargo shipping in the region (Tranter, 2022).

It has been predicted that the region will open up hitherto undeveloped oil and gas deposits as well as numerous seams for precious metals, minerals and even diamonds (Dimitrios & Drewniak, 2019). Moreover, as the world gradually transitions to the Net Zero economy (Jenkins et al., 2021) the demand for batteries is likely to soar, with a corresponding demand for such metals as lithium, high-grade iron ore, copper and aluminum (Rio Tinto, 2021). And climate change will open the deposits of such rare materials as lithium and nickel worth over $1trn USD (Energy Monitor, 2021). Of course, this would have serious implications for the geopolitics of the region. However, the presence of such resources means that large extraction projects are probably inevitable. One particularly significant resource is copper. A vital Net Zero transition metal, the Arctic is endowed with abundant deposits. Firstly, this metal is a critical component in the manufacturing of wires and cables that are essential for battery and energy accumulators. Secondly, copper is essential for the wind energy generation (Petkova, 2021). Alignment with Net Zero goals is important in climate change mitigation and adaptation which depends upon a rapid transition to the renewable energy sources. Renewable wind energy is very copper-intensive. For instance, an average wind turbine (3.6MW), that can supply over 3000 European households contains up to 30 tons of copper (IEA, 2021).

Of course, an argument can be made that the mere fact that there are such resources and that these are becoming accessible in the wake of climate change, doesn’t mean that the region should be developed, and the resources exploited.

However, as we have already seen, that despite overall “green” intentions, development is beginning to take place. Trade-offs originating from the attempt to balance urgent need for holistic environmental protection actions and waste economic prospects potentially crucial for green economy transition created the ‘Arctic Paradox’ in the EU policymaking that is still hindering the ratification of a clear stance on the Arctic development strategy and limits from the environmental safety perspective (Schunz et al., 2020). This creates a gateway for a variety of projects that might be seen as potentially highly dangerous for the Arctic environment.

For example, Norway is often seen as one of the European leaders in transition from hydrocarbons to renewable energy sources (Herrera Anchustegui & Glapiak, 2023). At the same time because renewable energy generation industry is highly dependent on metals as copper and lithium (IEA, 2021) Norway has increased the intensity of its metal extraction. In 2021 Norwegian government allowed the construction of a new Nussir copper mine because it was considered essential to support the transition to Net Zero economy and the market of renewable energy production (Simpson, 2021b). Despite the dialogue with indigenous representatives from the Saami council and independent environmental expertise stating that the restoration period for the marine life of the coastal area affected would be over 3 centuries, this project was still greenlighted because the imperatives of Green Economy were seen to outweigh the potential damage (Simpson, 2021b). Moreover, despite having a progressive green agenda, clearly defined climate targets and focus on Net Zero transition, Norway remains one of the top producers and exporters of oil and gas (Simpson, 2021a) with all of its oil and gas extraction facilities are located in the Arctic region. Compounding this ambiguity, the Norwegian has government persistently refused to specify a date for the final cessation of oil drilling (Kottasová, 2021). It is clear that in practice without binding agreements regarding the exploitation of the region(Schunz et al., 2020), more and more projects are being initiated to utilize Arctic natural resources. Similar examples can be found along the Russian side of NSR. Recent finalization of construction works at the Yamal LNG and the Novy Port oil fields in Russia would require a heavy support of the maritime industry to insure smooth production flow (Moe, 2020).

The approval of the large bill to support the development of the new oil field in Alaska by the Biden administration in winter of 2023 is another recent example to this point. In general, the administration flagged the intention to reduce oil and gas drilling all over the US, including onshore drilling in Alaska (Associated Press, 2023). However, in mid-March 2023 Biden administration approved an $8 billion USD plan to create a new large oil field nearly 960 km away from Anchorage, Alaska. Pushed by American petroleum company ConocoPhillips and supported by Alaskan Republican Senator Dan Sullivan, the Willow project is projected to bring economic inflow to this remote region, create over 2800 jobs and generating over $17 billion USD in revenue for federal, state and local governments (Helmore, 2023). The project will extract around 600 million barrels of oil (which is roughly 1.6% of current US oil production) and emit over 278 million metric tons of carbon (Newburger, 2023). The development of Willow drilling plan was announced just shortly after the updated plan to ban oil extraction was published. This plan included banning of new extraction projects in the Arctic Ocean and limited onshore extraction on the coast of Alaska in the area over 13 million acres (Associated Press, 2023).

Thus, despite a clearly articulated general inclination towards a less carbon-intensive future, in the absence of strict legislative limitations, new industrial projects in the Arctic are being, and will continue to be approved. Hence, the possibility of the increased industrial activity in the Arctic over the next few decades remain high, entailing a rising demand for the shipping in the region to support the industry. This pressure will increase as climatic change makes more remote and previously unreachable oil fields in the high Arctic accessible.

However, such remote extraction will always depend on maritime shipping (Peters et al., 2011). Moreover, not only industrial shipping and extraction industries are expected to undergo a period of rapid growth. Many other projects are now also under development in the region. Because the European Space Agency that was previously had strategic partnership with Russia, is now cancelling its contracts with Russian partners after Russian invasion to Ukraine the joint EU – the Russian Lunar mission has been suspended (David, 2022). Autonomy for the European space industry has become a strategic priority. In early 2023 it was announced that the Esrange Spaceport had completed milestones for a facility in the in Swedish Arctic (High North News, 2023) – providing an alternative to the French Guiana facility for the Europe-located satellite launches. Projects like that are expected to be more frequent and they would bring more human activity to the region which would create a high demand for regional sea vessel traffic.

4.2.3 Port infrastructure development

Even if developed only as a regional transport artery and not as an alternative for global trade, this would require large investments in the supporting infrastructure. This requirement for frontloaded infrastructural investment is one the limiting factors on the development of Arctic shipping as a transcontinental transit corridor from scratch. In the more incremental scenario whereby the development of regional shipping paves the way for international transit, the supporting infrastructure would be partly completed at the first stage. This would allow a lower scale of investment during the initial phases.

Several deep-water port projects across the Arctic are currently under consideration and/or in the early construction phases. This can be seen as the early sign of the overcoming the underdevelopment of region barrier.

Russian activity along the NSR includes multiple deep-water projects. In 2020 Russian authorities announced the intention to build a large deep-water port in Kola Peninsula (North-Western part of Russia) and increase the fleet of icebreakers by 40 units (GCR, 2020). This$7 billion+ investment initiative is intended to support large joint China-Russia "Arctic Silk Road" project as a part of which a new port with a capacity of 4.5 million container units (comparable to the Port of Tokyo) is proposed (GCR, 2018). Another major port construction just 55 km north of Arkhangelsk (Russian European North-East) was discussed in joint project with Chinese company Poly International (GCR, 2016b). Large investment as seen in the redevelopment projects for Dikson, Dudinka and Yenisei maritime ports as they are expected to serve the growing Coal, Oil, Gas and Nickel Industries the port load would increase (Russia Briefing, 2021).

Scandinavian countries also directing major investments in the preparation of the port infrastructure to the potential growth of the shipping volumes along the NSR. Large modernization project of the city of Tromsø is estimated at over 40 million USD in the Norwegian Arctic (GCR, 2016a). The port terminal is expected to double its passenger capacity to up to 2.4 million per year after the renovation is complete. Another Norwegian port – Kirkenes, located on the Eastern side of the country close to the border with Russia – is also one of the potential strategic points for the trans-Arctic shipping. If the commercial and political isolation of Russia by western countries as a response to the invasion to Ukraine continues, Kirkenes would become the first port where the ships would be allowed to dock after crossing the Arctic Ocean before continuing their journey to Europe. Moreover, the Finnish government is considering a project to connect Helsinki and Kirkenes via railway to create a land rail bridge between the NSR and the Baltic Sea (Staalesen, 2018).

Iceland is another important point in the map of the port infrastructure essential for the trans-Arctic shipping. It was calculated that in the existing conditions from the economical perspective it might be more feasible to ship through Norway or go directly to the destination point (M. M. Bennett et al., 2020) however, depending on the policy regulations, weather conditions and other factors Iceland might be crucially significant for the shipping through the NSR. A German company Bremenport is about to begin the construction of the Finnafjord port - a deepwater large seaport on the North-Eastern part of Iceland (Bremen Ports, n.d.).

Similar large port construction and renovation projects are in place in North America to support the navigation through the NWP. In Canada a large deepwater port on the eastern side of Nunavut just across from Greenland is planned to be built. This 40 million USD project would be acting as the entrance to the NWP and would service the passing passenger and cargo vessels (The Canadian Press, 2021). Another large project is also in motion in the western part of Nunavut. Grays Bay Road and Port project would connect several mining sites in the western part of the province and create a port that would act a potential halfway point for the ships passing through the NWP (George, 2021). However, this $554 million project was mainly supported financially by the Kitikmeot Inuit Association that just announce about their withdrawal form the project in March 2023 (Beers, 2023). Therefore, the overall fate of the project is unclear.

Finally, in the US the projects around the development of the northern maritime passage port infrastructure are also happening. Port Nome on the Eastern coast of Alaska is considered to be the best contender to become the touchpoint for the NWP and transshipment hub (Reedy, 2020). A 618 million USD port modernization plan that includes the expansion of the outer basin and creation of a separate deepwater basin to be able to accommodate larger transcontinental cargo carriers was initially approved by the U.S. Army Corps of Engineers and await the approval on higher levels of government (M. M. Bennett et al., 2020).

In most cases, all these projects are only at the initial stage of development, however we can clearly see a consistent approach in different economies allowing us to conclude that the marine infrastructure that would be able to support global scale sea shipping through the Arctic Sea routes is discussed, zoned and have a high chance to be brought to life. Despite all the environmental controversies construction and day to day maintenance of the new port infrastructure in the Arctic generates a constant significant and fairly reliable inflow of money into the region as well as it provides thousands of workplaces which can not only help retain existing population in on the land but also attract newcomers.

All those projects are incentivized by the possibility of the increased demand for the Arctic port and sea ship maintenance infrastructure. This creates more and more workplaces over the years for the local communities. While some jobs are only temporary, for instance construction jobs, others would remain in the region permanently. In this category we can place for example the employees of newly built ports and other infrastructure objects. The dynamics of the labor market is a very complex thing that would have a set of complex outcomes for the sustainability of the region and work in the evaluation of this is only at the early stages (Skryabina, 2021). So, it is still too early to make any final conclusions, but we can say that in the short-term perspective this will lead to the increase in the economical sustainability of the region, as well as it can help retain local population within the region which is one of the major issues for some of the Arctic regions (Korchak, 2022).

4.3 Chapter summary

Clearly the case for Arctic shipping is mostly economic. Shorter sea routes will reduce fuel and operational expenses, increase the effectiveness of navigation, and provide a shipping solution with higher added value for customers which might enable the shipping companies to make more net profit. However, the viability of the Arctic shipping depends a lot on the net cost reductions, as there are some factors that would increase expenses such as higher risk and insurance costs, higher energy demands to pass through the sea ice and the need in large investments in the infrastructure development of the region. Two main strategies for the development of the Arctic shipping now exist: (1) large upfront investment to facilitate a rapid switch in global trade or (2) a much more moderate investment would facilitate regional sea trade, as a stepping stone to further expansion as environmental conditions improve The second scenario is more likely in the upcoming decades and the transition of the global trade form traditional to the Arctic routes is more likely to happen after the year long ice-free conditions are achieved which is expected to happen after 2050.

While Arctic shipping has a potential to bring added economic value to the industry through the reduction of the shipping times and possible reduced fuel consumption, there are some topics that are still alarming for the industry. High risks associated with the severe conditions of the Arctic Sea might not only increase insurance costs, but also create the immediate threat to the health and well-being of the shipping crew and of the cargo carried by the vessel.

Lastly, the development of Arctic shipping might initiate the development of the infrastructure, that would have positive effects on the local economy. However, active project development in the norther territories would have a significant effect on the local communities which is discussed in the following chapter.

Chapter 5 Social, community and cultural impacts

This chapter provides a high-level overview of the impact of Arctic shipping on the local communities. The relationship with the Arctic communities is a very complex topic that requires a combination of different research methods to fully explore the issue. Given time and resource constraints, at this stage only a review of the peer-reviewed literature was conducted. Further research on the issue is required. The chapter is not aiming to provide a definitive conclusion as to whether the Arctic communities would benefit or suffer from the increased shipping activity in the region. This chapter just highlights some of the outcomes that we can already predict and tries to start the discussion on the long-term of these outcomes for the community. And since the representation of the community voice is missing in this review this review should only be seen as the beginning of a research dialogue.

It is clear that Arctic shipping would be essential for any trajectory of industrial development of the region. Such development seems likely given the demand for in the region's rich metal and mineral resource. While Arctic shipping can bring both positive and negative environmental and economic outcomes it would also have a strong influence on the northern and Indigenous communities. Of course, the community effect of the shipping, combined with the extractive industry and other infrastructure development, would be multifaced. On the one hand, increasing industrialization of the region would create a stable economic inflow providing job opportunities and increasing the retention of population and particularly younger demographics. This would include jobs on the industrial sites, ports and other shipping facilities and new jobs providing access to local goods and services. On the other hand, increasing industrialization and growing intensity of the commercial shipping would also have negative effects on the Indigenous communities, interfering with the traditional livelihoods of Indigenous people as well as it will limiting the access to fresh water and hunting which are essential for their traditional way of life. All the potential negative effects from Arctic shipping such as habitat fragmentation, disruption of the migration pattern, oil spills and pollution would pose a serious threat.

With respect to economic gains, it is important to attend to the possibly unequal distribution of such benefits. It is quite conceivable that local communities would see only the negative impacts with wealth flowing disproportionately to the shippers, extractors and manufacturers. To evaluate this problem of economic equity we need to understand the potential adverse impacts of the Arctic shipping on these communities, and the extent to which companies would ensure the proper oversight of these issues, manage the risks, and whist sharing the economic benefits.

5.1 Possible Positive Community Effects

The economic challenge is compounded by the complexity of social and cultural context. Despite having large deposits of natural resources, the Arctic has been characterized by low levels of economic development. With their traditional lifeways disrupted, indigenous communities have become dependent on central states. There are many reasons for low levels of economic development. A challenging climate impedes population growth that would otherwise drive development. It also greatly increases the cost of infrastructure development (Pilyasov, 2022; Vopilovskiy, 2021). This is not only because of physical challenges in relation to construction but also the cost of labor and materials generally, as well as the nature of the materials and designs that are required to withstand the elements. The transportation of materials and maintenance costs entail much more complex solutions adding to overall costs.

From an investment perspective there is a tension between the scale of capital outlay and the inherent risks on the one hand, and the long-time horizons of profitability on the other. Although "high risk – high reward" approach is appropriate for some investors (T. M. Andrews et al., 2018) for others investing in the Arctic infrastructure can be not the priority due to the high costs and risks of operating in the region (Lunde, 2014).

Moreover, despite the vast deposits of oil and gas and mineral resources, some vital resources in the Arctic are limited or unavailable. Inability to produce enough food in the region creates a chronic problem of food insecurity (Collings et al., 2015). Increasing industrialization and growing severity and intensity of the weather conditions due to the climate change risks associated with freshwater access only increases (Baskin & King, 2016). This puts local communities in a very vulnerable position since they are highly reliant on the freshwater access which is vital for them. This only adds to the overall risk of investment, hindering the inflow of financial resources.

Although, there are large mineral deposits these are not always easily accessible. With climate change such resources are becoming more available the face of the region is likely to change dramatically over coming decades. This does not reduce the capital costs of mining in the region and the dependence on advanced and expensive technology (Huskey & Larsen, 2015).

The politics of climate change also affect investment creating another layer of hesitancy: large international investors do not want to be exposed to the reputational risks of investing in projects that would not only make an impact to climate change but also engender more local sustainability problems in the region (Oguntuase, 2021). These are just some of the reasons for the ow level of the economic development of the region.

In this context, the development of the Arctic Sea shipping routes might provide a robust foundation for accelerated regional development. The creation of shipping routes would stimulate the development of the infrastructure. Some of this – like ports and search and rescue facilities – will be constructed out of necessity. But this will in turn generate demand for softer forms of infrastructure including hotels, food stores, radio towers and other objects in the areas of increased human activity like ports or mines. More importantly, this would create new jobs (Coates, 2020; Vorotnikov & Tarasov, 2019). Unlike many mining projects, shipping development does not come with a sunset clause. It would be designed to be a part of the Arctic economy in perpetuity. This would represent a marked change in local economic development. Temporary economic projects such as mines, may operate for years. But eventually they reach the end.

5.2 Possible Negative Community Effect

While there are likely to be some significant positive outcomes for the communities that would be mostly economic, it is important to recognize that intensive industrialization of the Arctic and development of such projects as international maritime shipping route would entail a lot of negative impacts for the communities. And the net result is yet to be estimated.

Arctic communities are often very reliant on the availability of natural resources, especially wildlife (Brinkman et al., 2016). Since the increase in the commercial activity in the region and growing intensity of the maritime shipping in particular have serious environmental impacts, it can cause multifaceted and far-reaching consequences lasting in a long-term perspective for the local communities. Oil spills, pollution, and other environmental hazards can become more frequent which would bring devastating impacts on the local ecosystems and biodiversity. Many Indigenous communities are reliant on their land. Food and freshwater security come from their connection to the natural environment which is essential for communities to maintain their traditional ways of life (B. Ellis & Brigham, 2009; Gladun et al., 2021). By exposing the region to industrial activity, we are creating a new level of threat and risk to the indigenous communities. Despite economic benefits, increased infrastructure development such as creation of ports, roads and railways might itself lead to the environmental issues. Increasing traffic would lead to higher pollution and habitat fragmentation which would also negatively impact animal communities which are important for the Indigenous lifestyle (Spellerberg, 1998). The risk of the habitat distraction and other various forms of environmental degradation would be higher.

Fuel demand generated by a growing number of ships passing through the region and entering the ports might be also seen as a negative factor. Of course, it will generate income flow in the region and support the development of a robust economic system. But this might also increase the competition for the fuel access. Current underdevelopment of the region is often associated with the energy supply problems (Gasnikova, 2022). To avoid the fuel shortage and satisfy both the demand of the ships passing through the Arctic sea routes and the demand of the local communities, a well-thought out and comprehensive energy supply plan should be in place. If the situation is not handled appropriately, a serious energy crisis might occur in the region which combined with the already existing low level of resiliency and high vulnerability might lead to dramatic consequences for the local communities (Critchley, 1982). At the end this might only aggravate the water scarcity, food insecurity as well as exacerbate existing challenges related to poverty and economic development.

On the other hand, the expansion of shipping could lead to the displacement of the local communities. The displacement might occur if the territory originally occupied by the local communities would be proposed for the construction of new ports, harbors, and transportation corridors. There are several cases where due to the adverse impacts of climate change, several Arctic communities had to be displaced while the displacement risk for some of the remaining communities is still very high (Marlow & Sancken, 2017). Aside from the fact that forced displacement would cause a lot of inconvenience to the communities it can also be one of the reasons for the loss of Indigenous languages and cultures (Gladun et al., 2021).

Cultural loss is another serious potential threat that can occur and therefore that should be considered with a appropriate level of oversight. Intensive Arctic shipping would compete with the historic hunting grounds of Indigenous people in the ocean. Game species act not only as a source of food and daily essentials but also as a conduit for culture, language and tradition (Eegeesiak, n.d.). Negative environmental impacts from the increasing industrial activity would be likely to reduce populations of terrestrial and aquatic animals. Any inability to hunt would potentially bring food insecurity and but also undermine of the reproduction of indigenous knowledge. And while food insecurity can be resolved by policymaking and external support, the restoration of the lost Indigenous knowledge is extremely challenging if at all possible (Huntington et al., 2022).

Lastly, the creation of the new jobs would enhance the economic position of the region and stimulate the migration to the region which can be seen as a good thing. But it will ultimately mean that the influx of outside workers would bring globalization and incentivize the assimilation pressures on local communities (Hämäläinen et al., 2018). Close contacts with people outside of the community can possibly lead to the spread of new cultural norms and practices that can be seen as undermining the traditional ways of life for Indigenous peoples (Ford et al., 2015). This would again threaten the integrity and verity of unique Indigenous languages, cultures, and knowledge systems that are in the foundation of local cultural identity and resilience.

5.3 Practices in place to mitigate social risks

Since Arctic shipping poses a substantial risk on Northern and Indigenous communities, there are already some practices to avoid, reduce or mitigate. One of the practices that was widely adopted in North American Arctic is the development of community-led monitoring programs. Such programs are aimed actively to involve the communities and foster collaboration between the local communities with researchers and government agencies. In this context community-led monitoring programs would focus on the environmental and social impacts of Arctic shipping and consult Indigenous communities to improve the understanding of the associated risks associated in order to develop more effective mitigation frameworks (Johnson et al., 2015).

A good example is the community work conducted by The Arctic Eider Society. This organization works across Hudson Bay and Inuit Nunangat and focuses on tracking of the shipping impacts on Arctic marine environment. The project engages with the communities and provides training to facilitate high-quality data collection on wildlife sightings, shipping traffic, and other environmental variables (Arctic Eider Society, n.d.).

In a similar vein several community-led projects are focusing on the protection of the whale habitats, which are seriously affected by existing shipping patterns and would be subject to even more substantial impacts with any increase in the intensity of commercial shipping (Reeves et al., 2012). Such organizations as The International Whaling Commission and Alaska Eskimo Whaling Commission have established several Bowhead Whale monitoring programs to survey their migration pattern changes, behaviour and population compositions. Bowhead Whales are vital for Indigenous communities including the Inupiaq, Yupik, and Inuit peoples of Alaska, Canada, and Greenland (Reeves et al., 2012). Bowhead Whale mostly was one of the major subsistence resources as whaling was always a part of Indigenous lifestyle and culture. It not only provided food but was also a source of materials used in closing, household and construction. The process of Bowhead Whale hunt is deeply connected to cultural identity and spiritual beliefs of some Indigenous peoples and it is an important part of several rituals and ceremonies (Sakakibara, 2017). Lastly, whale hunting is one of the few forms of economic activity that is available and well-known to the community members. As the reliance on the availability of Bowhead Whales is very high the International Whaling Commission and Alaska Eskimo Whaling Commission are constantly engaging with communities to monitor and collect data on the location, abundance, and health of the whales (AEWC, n.d.; IWC, n.d.). Such large international collaborative projects as the Arctic Shipping Best Practice Information Forum established by the Arctic Council's Working Group on the Protection of the Arctic Marine Environment (PAME) are working on the knowledge accumulation and transition on the sustainable shipping practices and effects on the northern communities. The forum is addressing the International Code for Ships Operating in Polar Waters and focuses on such topics as hydrography, search and rescue, communications, training, industry guidelines and ship equipment (PAME, 2017). The forum intends to foster collaboration between government, industry, and community to spread best practices for the mitigation of the social and environmental risks form Arctic shipping.

Collection and adaptation of the Indigenous knowledge is another crucially important activity that can bring significant results for community risk mitigation. Indigenous knowledge can provide new perspectives on the consequences of Arctic shipping and highlight knowledge gaps that might have occurred because of the tunnel vision (Huebert, 1995). Introduction of the Indigenous knowledge in policymaking can help develop more resilient, effective and culturally sensitive policies that would not only lead to the overall sustainability increase but would also reflect the needs and priorities of Indigenous communities (Vlasova et al., 2021).

Infrastructure development is also an essential step towards ensuring safety and integrity of the communities while it is conducted with respect to the community needs and does not entail significant environmental threats. To support the implementation of mitigation strategies and to meet the growing resource demand in the region a number of strategic infrastructure projects should be developed in the region. For example, Canadian Government committed to the investments in the development of new ports and transportation corridors to enable sustainable and ecologically considerate economic development of the region. This would include the development of a new deep-water port in Iqaluit, Nunavut, construction of the all-weather highway between Inuvik and Tuktoyaktuk, expansion of the port of Churchill and the development of a new transportation hub and airport expansion in Rankin Inlet, Nunavut. Although, some of these projects have caused ecological concerns they are still essential to meet growing economic expectation from the region. When Indigenous knowledge and infrastructure development are happening together there is a high potential of the high-efficient end solution that would be beneficial for a diverse group of stakeholders including Indigenous people, private and public sectors (Vlasova et al., 2021).

Regulatory mechanisms can also be effective in ensuring the protection of the integrity and safety of the northern and Indigenous communities of the Arctic. For instance, IMO have developed International Code for Ships Operating in Polar Waters or the Polar Code (IMO, 2017). Polar code contains frameworks and recommendations for ship design, navigation as well as sets environmental protection objectives. If navigation is compliant with the Polar Code, it might eliminate a certain degree of risk for the communities.

While there are a lot of factors that would affect northern and Indigenous communities it is important to understand the corporate perspective. Possible positive and negative outcomes from increasing development of the supporting infrastructures such as ports and roads, as well as the outcomes from the creation of the new jobs in the region, are dependent on the final approach that will be taken by shipping stakeholder. Therefore, it is important to clearly map the existing disposition of major industry players as this might help to evaluate the possible scale of change whilst giving insights as to specific actions that might be needed. Such conclusions can be drawn from the sectoral or geographical concentration of industry players who would be in support of Arctic shipping. If, for example, they would be coming from the same region, maybe it would be a signal to a more urging need for the more robust and obligatory policy and regulatory development. Overall, it is clear, that the well-being of the northern and Indigenous communities is tightly bound to changing nature of the business ambition for the development of the commercial Arctic cargo sea route.

Chapter 6 Governance

Governance considerations have several dimensions that should be addressed in order to provide a comprehensive assessment of the positive and negative implications of Arctic shipping.

1. There are issues pertaining to the local and international governing bodies responsible for the development of industry standards and norms and specifically alignment with the SDGs.
2. There are internal corporate level governance considerations coming from the shipping companies themselves. While some are actively embracing the Arctic shipping opportunities, other companies are either eschewing such possibilities as a matter of policy or are suspending judgment.
3. There is a wide spectrum of considerations about the general industry transition to sustainability alignment. This includes the development of alternative technologies and supporting infrastructure to step away from fossil fuel as the main energy source for the shipping industry and reduce emissions as pollution levels.
4. There are geopolitical considerations that define the development of the industry. Active melting of the Arctic ice creates military opportunities and threats that exacerbate political and ideological tensions between China, Russia and NATO countries in particular Also, the geopolitical aspect influences the opportunity for international collaboration. A major player in the Arctic region, in the wake of the Ukraine war, Russia has become isolated from the western world. Joint development of the Arctic sea route infrastructure seems very unlikely for the foreseeable future.

In this work, only the first 3 groups of considerations are discussed. Since this paper is designed as a first step of the PhD research some areas of research were purposely eliminated from the research scope. However, it does not mean that they were considered insignificant. While international regulation and geopolitics are extremely material, it is important to acknowledge that this research has been done during the period of the Russian invasion of Ukraine. This led to the unforeseen exclusion of Russia from the international business and scientific society. Since Russia plays a major role in the region including parts of likely future region shipping routes, it is impossible to exclude the Russian perspective. However, the situation right now is extremely fresh and changes quickly, therefore it was decided to dedicate the research capacity to the other topic and discuss these issues when more clarity is obtained to avoid the creation of the scientific conclusions that are likely to be outdated in a short period of time due to a fast-changing nature of the situation.

Therefore, in this chapter, two governance considerations are discussed: (1) international agreements for sustainability alignment of the industry, industry decarbonization and (2) internal corporate-level governance approach to Arctic shipping.

6.1 International agreements for sustainability alignment of the industry

This section discusses the current state of the industry transition to a low-carbon performance and efforts to minimize the negative effect on the environment. The review of peer-revied articles and protocols provides a summary of selected international protocols that are developed to limit the emissions and pollution caused by the sea shipping industry and guide the transition of the industry towards Net Zero by 2050. Additionally, this section discusses the alternatives to the traditional ship fuels since most of the emissions are coming from the combustion of fossil ship fuel. Finally, this section discusses the potential trade-offs that would entail the transition towards these alternative fuels. While some of the fuels might provide significant GHG reductions compared to the use of HFO these alternatives are potentially more expensive and require significant technological changes to the sip design and maritime shipping infrastructure.

In recent years, the shipping industry has been a subject to an increasing number of regulations focusing on the environmental effects of the shipping and climate oversight in the industry. However, there is still no comprehensive and unanimous approach to address urgent regulatory issues and every more pressing implications of environmental crisis and climate change. Transition to Net Zero quickly becomes the priority not only for high emitting industries, but for a wide range of sectors. Significant efforts were made by different regulators to define interim absolute and intensity targets for the industry as well as develop high level transition framework to guide major players towards the Net Zero 2050 emission goal (Fahnestock & Smith, 2021). Transition from fossil fuels to alternatives is one of the main mechanisms that is widely supported since it will not only help reduce industry emissions but also would lower the demand for oil and gas industry. It is obvious, that industry decarbonisation is one of top priorities for the regulators and industry players for the upcoming decades.

The overall trend to the transition towards green or Net Zero emissions is heavily reliant on the decarbonization of the shipping industry since it is fundamental part of global trade and consequently an integral part of the economy as a whole. Green shipping refers to the implementation of environmentally sustainable practices in the shipping industry.

Green shipping supports the decrease of the environmental impact of the industry by supporting the transition away from the use of the non-renewable resources and transition towards more sustainable business practices that would incentivise pollution reduction. Green shipping implies the use of environmentally friendly materials and low-impact fuels as well as increase in the percentage of the use of recyclable and recycled materials.

Recycling and waste reduction practices are important to reduce the waste from the industry that is accumulating in the ocean. Moreover, green shipping requires significant work in the technological side of the industry to support cleaner and more efficient solutions like hybrid engines, solar power and wind turbines to limit the use of fossil fuels (IMO, 2014).

In addition, the impact of marine and air pollution from ships is also a predominant factor in determining sustainable shipping. Pollutants such as sulfur dioxide and nitrogen oxides produced by ships can have negative environmental impacts, including ocean acidification and human breathing problems. Finally, another important factor in determining environmentally friendly shipping practices is eco-efficiency. This includes reducing fuel consumption, minimizing traffic congestion and optimizing vessel design to reduce the environmental impact of shipping.

The ambition to decarbonize and increase the overall sustainability of the industry is not simply aspirational. Shipowners and shipping operators just like many other business owners across the economy regardless of the industry see value in introducing green practices (C. Liu & Deng, 2022). Sustainable shipping entails the reduction of the fuel consumption, which not only means reduction of the operational costs, but also might reduce some pollution and carbon taxes applied to the industry. This will also provide higher protection from the financial and reputational risks (Lasserre, 2014) associated with possible oil spills or other highly hazardous for the environment emergencies that can occur in shipping. Increasing energy efficiency can also lead to direct savings by increasing the lifetime of the vessels and reducing the maintenance expenses. Lastly, active decarbonization and a clear progress on improving climate performance can be seen as a powerful competitive advantage, which is especially important in shipping industry since all the major players offer a very similar solution and the reputation of the company often would be a defining factor when choosing the shipping provider. Overall, the definition of green shipping requires taking into account many factors related to sustainability, including the management of recyclable materials and waste, the type of equipment used by ships, the impact of pollution on the sea and air, and green efficiency, determined by factors such as fuel consumption, traffic congestion and ship design (Chang & Danao, 2017).

Sustainability regulations are gradually becoming mandatory in a variety of industries. The transportation industry is considered to be one of the high-emitters, therefore likely to face mandatory binding regulations and frameworks to comply with sustainability goals. Even now in the reality of mainly voluntarily green regulations for the industry, we can clearly see that non-compliance with those regulatory requests often lead to fines and other penalties as well as potentially high damage to the reputational performance of the company (H. Liu et al., 2023). The majority of the existing regulations for the maritime industry that are ratified and accepted by the international community are developed by IMO – the International Maritime Organization – a United Nations agency responsible for the oversight safety and security of international shipping which also includes pollution prevention functions.

The International Convention for the Prevention of Pollution from Ships of 1973 (MARPOL Convention) is an international treaty focusing on preventing marine ship pollution. MARPOL pays specific attention to controlling oil discharge, pollution by other contaminants and chemicals, and ship sewage discharge (IMO, 1973). One of the important pieces of standards introduced by the MARPOL convention was the requirement to discharge ship waste at the designated port reception facility, unlike before when the discharge might have occurred directly in the ocean anywhere along the shipping route. This was one of the important steps to ensure pollution reduction and potential hazardous environmental impact.

Ballast Water Management Convention is another major agreement also developed by IMO. This international agreement is fighting the spread of dangerous aquatic organisms and pathogens possibly transported and introduced in the environment as a result of ballast water discharges from ships. This convention incentivizes the operators to develop a ballast water management plan and sets specific standards and targets for ballast water treatment to make sure that the proposed plan is tangible and resultful (IMO, 2004).

Ship Energy Efficiency Management Plan (SEEMP) is another mandatory requirement for all average and large ships. This regulation is applicable to all the ships over 400 gross tonnage, which includes all significant commercial shipping vessels. SEEMP reinforces energy-efficiency through the adaptation of efficient energy management practices and support of the technological advancements to reduce fuel use and greenhouse gas emissions (IMO, 2011).

Finally, there is also a specific protocol focusing on the emissions at the specific areas. Developed in 1997 Emission Control Areas (ECAs) norm defines designated areas with significantly stricter emissions standards. Those areas are generally i areas of intense shipping, such as the North American Atlantic and Pacific coasts, the coast of the Gulf of Mexico, the Red Sea and Guinea Gulf in Africa, the Baltic Sea and the North Sea and other areas across the globe. To operate in ECAs, ships are required to meet the pollution limit requirements, which entails the use of more expensive low-sulphur fuels and have a proper oversight of ship emissions.

We can clearly see that greening of the industry is becoming one of the priority issues for the policymakers on regional and international levels. International agreements and protocols introduced by IMO address sustainability-related issues from different perspectives and provide regulatory tools to develop goals and targets for the industry, financial incentives, and compliance and enforcement tools to support the alignment with Net Zero goals (Doelle & Chircop, 2019). However, due to the still early stages of development, potentially significant problems of actual regulation enforcement and high-level of conservatism of the industry as a whole (Rachold, 2019). we can see an urgent need for further action and clearer pathways to align the industry with Net Zero goals. Another important hindrance that might cause additional delays is the failure of the Paris Agreement on climate change to address emissions from maritime shipping explicitly (Doelle & Chircop, 2019).

Effective protocols and standards to promote sustainable practices in the shipping industry are essential for achieving results in enhancement of the sustainability of the industry (Zhou et al., 2023). The role of both public and private regulation is equally significant in achieving this goal (Huang et al., 2017). While government regulation can provide a framework for sustainable shipping, private regulation on the corporate level can also play an important role in promoting and enforcing sustainable development standards (Yliskylä-Peuralahti & Gritsenko, 2014). The supervision of sustainability in the shipping industry is still developing and requires constant attention and effort.

The Sustainable Shipping Initiative (SSI) is one of the bright examples of an industry initiative focusing on reinforcing the effort to make global shipping more sustainable. SSI brings together companies from the shipping industry as well as non-governmental organizations, academia and other stakeholders to work together on sustainability issues (SSI, n.d.). SSI's ultimate goal is to create an environmentally and socially sustainable shipping industry that benefits a prosperous and sustainable global economy. By bringing stakeholders together and encouraging collaboration and ingenuity, and sharing experiences and best practices, SSI aims to lead a more sustainable industry and influence policy and regulation accordingly. Development of such initiatives is crucially important to increase the sustainability of the industry as it will not only affect the change by individual industry participants directly but might also lead to further effective collaboration (Hessevik, 2022). For example, SSI played an important role in the creation of Ship Recycling Transparency Initiative (SRTI). This is a project that works on increasing the level of transparency and accountability in ship recycling. Poseidon Principles is another project that was brought to life with support of SSI. Poseidon Principles are a set of non-binding guidance and regulatory recommendations for assessing and disclosing the climate alignment of shipping portfolios. However, the overall effectiveness of such practices can be questioned but this discussion is outside of the scope of the research.

6.2 Industry decarbonization

Decarbonization of the industry is one of the key areas of current attention. Even modest estimations propose at least a doubling of shipping activity volumes by 2050 (Melia et al., 2016). Without any action, business as usual scenario would fuel consumption reaching 450 to 810 Mt in 2050, which would possibly entail the increase in CO2, NOx and SOx emissions up to 1308, 28 and 12 Tg respectfully (Dalsøren et al., 2007). Proper oversight has been proven to be an effective tool to regulate the and reduce emissions like CO2, SOx, NOx and black carbon (S. Elias, 2021). That might include fuel-type restrictions, for example the ban of heavy fuel oil, and mechanical controls like the introduction of exhaust cleaning systems.

The search for technological solutions to reduce emissions is crucially important for the mitigation of emission and pollution increases. However, even major technological improvements in the efficiency and emission reductions from fossil fuel powered shipping might be evened out by the growing demand for industry load and overall reduction would still be unachievable (IMO, 2014). CO2 reduction targets developed by the International Maritime Organization require at least 40% CO intensity reductions by 2030 and 50% by 2050 (year 2008 is taken as the baseline) (Ampah et al., 2021). Transition to green fuel might bring large CO2 emission reductions. Biofuels depending on the feedstock and the means of generation would lead to 25-100% reductions, green LNG, green hydrogen, green ammonia can reduce emissions by 30%, 43% and 35%; consequently, ships powered by renewable energy sources can be 100% CO2 emission free (Ampah et al., 2021).

The approach to achieve that goal that is prevailing all across the industry is to switch towards low or zero-carbon vessels while simultaneously working on introduction of the energy efficient technologies and search for the economically feasible alternatives to fossil fuels (Ampah et al., 2021). Transition to the alternative fuels is one of the major steps that needs to be achieved to reach both the intensity and more importantly the absolute CO2 reduction ambition (Bouman et al., 2017). Based on the existing level of technological development the following options are often considered as the most likely to be put in commercial use alternatives for fossil fuels: biofuels, electro fuels, hydrogen, ammonia and renewable electricity coming from biomass, solar, and wind.

6.2.1 Liquid Natural Gas

One of the most often proposed alternatives to the traditional fossil fuels for shipping is Liquid Natural Gas (LNG) (Elgohary et al., 2015). The introduction of LNG as one of the likely alternatives to bunker fuel is mainly backed by environmental reasons rather than by economic benefits (Ampah et al., 2021). The use of LNG would potentially reduce the CO2 and NOx emissions as well as practically fully eliminate SOx emissions. CO2 emissions might be reduced up to 25% when transitioning to LNG (Agarwala, 2022). Moreover, LNG powered vessels are associated with significantly lower maintenance expenses, which can balance the expenses coming from the investments in the LNG manufacturing infrastructure development and ship modernization. Another important benefit of LNG is coming from its natural properties. LNG is less flammable and volatile compared to traditional bunker fuel which means that it can potentially reduce the risk and costs of fuel storage and use as well as provide a safe solution for the crew and the vessel. However, the risk of the accidents should not be eliminated completely and proper safety norms should be in place (Półka et al., 2021).

One of the main regulatory benefits of transitioning to LNG is that it helps shipping operators to achieve temporary compliance with the majority of the CO2, NOx and SOx emission regulatory norms (Acciaro, 2014) but not net zero GHGs, which is the immediate objective. This provides a potential for the shipowners and service providers to avoid high economic fines and provide a regulation compliant service that might a requirement in the supplier code of conduct for some of the shipping clients.

However, LNG has a lower calorific value compared to bunker fuel (Ampah et al., 2021) which means that more fuel is required to be consumed to achieve comparable power output. Therefore, economic feasibility of the transition to LNG might not be very high especially on the early stages of the transition path. Moreover, it will depend a lot on the fuel prices that are fluctuating significantly now; therefore it might be still too early to make final decisions on the economic aspect of the LNG transition and on the potential financial savings in the short term (Acciaro, 2014).

Despite the fact that LNG has some environmental benefits compared to bunker and heavy oil fuel, it is still considered to be one of the fossil fuels and therefore problematic. Firstly, LNG is not renewable an its limits can be reached at some point in future. Secondly, as a fossil fuel LNG requires extraction, transportation and processing which would entail environmental consequences such as pollution, GHG emissions and habitat destruction. The process of liquefying natural gas is very energy intensive itself and therefore requires additional energy use on the production stage that would only increase global energy demand and that would associate with larger scope 1 and scope 2 emissions of production stage (Munt & Lebedev, 2023). Furthermore, in case if LNG is considered as the primary alternative to the traditional fossil fuels for the industry it would entail large demand for the development of the LNG production infrastructure (Grobarčíková et al., 2016) as well as pipelines and storage facilities that would create an investment flow towards the support of a less polluting fossil fuel rather than an investment flow to support the transition to new renewable green energy sources. In other words, it would further entrench fossil fuel dependencies and make the necessary transition more difficult. Moreover, as a fossil fuel, the use of LNG as a ship fuel would be followed by CO2 emissions. They can be smaller than the emissions from the ships operating on the traditional heavy oil fuels, but still those emissions would take place and it’s important not to diminish their significance and impact on the environment as well as their contribution to climate change (Agarwala, 2022). LNG provides high-energy density and high-temperature heat, while the overall efficiency to emission ratio would be much more balanced in electric or hydrogen fuel cells powered solutions (Livaniou & Papadopoulos, 2022).

In sum, LNG is often seen under the spotlight of the academic research, and it would be fair to say that this is one of the most researched bunker fuel alternatives so far (Ampah et al., 2021). The existing predisposition of the shipping industry to the use of LNG (Agarwala, 2022) due to its relatively lower emission and pollution levels compared to the traditional fuels can be one of the major factors in massive transition towards LNG as an interim solution on the path to Net Zero. LNG has a potential to reduce the level of emissions and even eliminate SOx pollution form the sea shipping as well as it can provide an opportunity for economic saving due to reduced risk from accidents and lower maintenance costs. However, LNG is not a renewable source of energy, and it still entails significant CO2 emissions; therefore, it should not be considered as a final solution for industry decarbonization, but it may become the major interim option in the transition path.

6.2.2 Ammonia

Ammonia fuel cells are often seen as a potential solution for the decarbonization of the marine shipping industry (Cheliotis et al., 2021). One of the major benefits of ammonia against LNG is that ammonia fuel cells do not contain carbon, which means that when ammonia fuel is burned no CO2 is emitted to the atmosphere. Moreover, ammonia fuel doesn't have sulphur atoms in its composition either; therefore, SOx pollution would be eliminated too (Ampah et al., 2021).

Another major advantage of ammonia fuel cells is their efficiency. Since ammonia fuel cells directly convert chemical energy to power for the ship to move and skip the combustion stage the energy losses are reduced significantly. Traditional fuel transforms around 30 to 40% of energy to electricity and the rest goes to support the side reactions and at the end is lost as heat and light (Cheliotis et al., 2021). Higher fuel efficiency means that there is a potential to have large cost reductions on the storage facilities on land and more importantly on the ship. This means that the carrying capacity of the ship would increase because less fuel must be carried.

From the mechanical perspective ammonia, fuel cells when used don't produce as much noise and vibration as the combustion of the traditional bunker fuel (Asmare & Ilbas, 2020). This not only increases the quality of the workspace for the ship crew by providing them with a more comfortable work environment with reduced noise pollution, but also eliminates excessive vibration, which can increase the lifespan of the machinery due to reduced mechanical wear of the working elements. Wear and tear reductions can lead to maintenance cost reductions.

However, ammonia is highly flammable and toxic; therefore, it can be very challenging and potentially dangerous to transport and store ammonia fuel (Aziz et al., 2020). High toxicity of ammonia poses a real threat to the crew operating on the ammonia powered ships. Since ammonia is a gas, it can easily spread. Therefore, much more elaborate and complex multi-level security systems need to be in place to ensure the protection of the human health.

It is also important to mention that, despite high energy efficiency of the ammonia fuel, ammonia has a high ignition temperature – around 630 degrees Celsius (Kurien & Mittal, 2022). This means that the energy requirements to ignite ammonia would be much higher than to ignite diesel or bunker fuel, for example. Moreover, in colder environments even higher energy supply would be required for this process. In context of the Arctic shipping ammonia fuel would have a serious disadvantage against other fuel options, however, there are potential ways to overcome this issue like fuel preheating or design changes in the ship engine design to optimize the ignition and increase the overall efficiency of the process (Selvam et al., 2021).

Another challenge with ammonia fuel can come from its manufacturing process. Depending on the technology in use ammonia might be produced with no or with high CO2 emissions. Only when ammonia fuel is manufactured with electrolysis powered by renewable energy sources would it be net zero. Green ammonia if formed when electrolysis splits the molecule of water into atoms of hydrogen and oxygen and then combines hydrogen with nitrogen atoms to form the molecule of ammonia (B. Lee et al., 2021). If renewable energy sources are used for this reaction this ammonia production process can be absolutely free of CO2 emissions. Another way to produce ammonia would be from fossil fuels like coal and heavy fuel oil via the Haber-Bosch process (Humphreys et al., 2021). This reaction combines the atom of hydrogen from the fossil fuel with the atom of nitrogen from the atmosphere. Haber-Bosch process is not only highly energy-demanding, but it is also contributes to the large CO2 emissions as a by-product of the reaction. Therefore, even if ammonia itself would be a good alternative to fossil fuel for shipping industry, the CO2 emissions embedded in the fuel production process would be problematic. The transition towards ammonia-powered shipping that would use ammonia from the Haber-Bosch process would not be sustainable and would only make the industry more carbon-intensive.

Despite high potential for the reductions in CO2 and SOx emissions associated with the transition to ammonia powered shipping, the NOx emissions would rocket (Kobayashi et al., 2019). Aside from the contribution to climate change, NOx leads to increasing frequency and intensity of ground-level ozone, acid rain, and smog (Sivaramanan, 2015).It therefore poses direct threat for human health due to the tangible aggravation of the air quality. Since most of the emissions from shipping occur within 400 km from the coast (Endresen et al., 2003) this would be highly significant for the human wellbeing and might ultimately lead to the development of respiratory and cardiovascular health problems (César et al., 2015). There are potential ways to reduce the amount of NOx emissions as a by-product of the ammonia fuel use. Most of those solutions focus on increasing the efficiency of engine performance or using selective catalytic reduction and exhaust gas recirculation to remove NOx after it was formed but before it is emitted to the atmosphere (Brandenberger et al., 2008).

Just like transition to LNG transition to ammonia fuel would require an increase of the production volumes by several orders, which no doubt would entail serious investments in the infrastructure development and research. At the same time, unlike the production of LNG, ammonia is already consumed by other industries in fairly large volumes (Kim et al., 2020). However, large amounts of ammonia globally are produced in an energy intensive way with high CO2 emissions. Using those facilities to support greening shipping fuel industry would be incorrect. Only carbon-free production of ammonia fuel cells would actually increase the sustainability global shipping, and such facilities are still in small numbers around the world; hence financial support for net zero ammonia production is needed. Most of the investments would have to be directed on the refocusing of the ammonia production industry to meet maritime fuel demands. This also means relying on ammonia manufacturers that are already experienced in with potential difficulties associated with storage and transportation of ammonia fuel. Therefore, regardless of how challenging it might be, the level of readiness for the transition to and adaptation of ammonia fuel on a large scale is fairly high globally and this fuel has a high potential to be one of the steps to net zero shipping.

Finally, the guidance to regulate the use of ammonia fuel cells in maritime shipping and ensure the use of green ammonia manufactured without the large CO2 emissions associated with Haber-Bosch process is still under development and no clear policies and regulations are in place which leaves room for uncertainty and hesitation among major players in the industry as well as provides room for numerous elaborate loopholes (Olabi et al., 2023). Even MARPOL rules do not explicitly address the use of ammonia in shipping. However, MARPOL sets NOx, SOx, and particulate matter (IMO, 1973) limits for the shipping industry, which would have an effect on the adoption of ammonia fuel by the broader industry. More explicit and precise safety standards for storage, handling, and transport of ammonia fuel are urgently needed to eliminate any risk to human health. Stricter regulation of the manufacturing processes is also needed. A clear distinction between green and not green ammonia needs to be emphasized as the different environmental effects of these two types of ammonia is very substantial. A close cooperation between policy makers and industry representatives is needed to ensure the alignment of the industry with a viable Net Zero transition pathway.

6.2.3 Biofuel

Biofuel is another alternative to bunker fuel with high potential to reduce CO2 emissions from shipping (Yaoyang & Boeing, 2013). The major sources of biodiesel include soybean and rapeseed oil, which also have food uses; however, alternative feedstocks, such as algae, used cooking oil are also available (Mohd Noor et al., 2018).

It has been shown that biofuel has a great potential to reduce emissions when used by itself. When biodiesel is blended with regular fossil fuel it can deliver a substantial decrease in pollution and emissions (Ampah et al., 2021). Transition to biofuels might help to achieve up to 90% of CO2 reductions (Battaglia et al., 2021; Heo & Choi, 2019). Compared to …, biofuel combustion generally leads to lower sulfur oxides, nitrogen oxides, and particulate matter emissions due to low levels of sulphur and nitrogen (Heo & Choi, 2019). The energy effectiveness of biofuel is higher than that of regular fossil fuel; therefore, lower quantities of fuel need to be combusted to get the equivalent energy release (Hsieh & Felby, 2017). This itself also contributes to the pollution reductions. Moreover, biofuels have a high cetane rating, which means that they can improve engine performance, reduce engine wear, and lower maintenance costs (Venkatesan & Nallusamy, 2020).

Another important benefit of biofuels against fossil fuels is that many countries would not be as reliant on oil imports as they are now. This might increase overall global energy security through the widening of the number of countries that are able to produce biofuel and decrease oligopoly in the energy market (Månsson et al., 2014).

One of the serious controversial topics around the discussion about the large-scale transition to biofuel is its relationship with food production industry. Since soybean and rapeseed oil are major sources of biofuel, biofuel industry might commence competing with agriculture (Hirani Arvind H. et al., 2018). There is a distinction between different ways to produce biofuel. First-generation biofuel refers to the fuel produced from sources that are a part of the food industry. Most commonly, rapeseed and soybean oil are turned into the first-generation biofuel. Second-generation biofuel is manufactured from non-food biomass like perennial grass, trees or food waste and used cooking oil. Third-generation biofuel uses algae and this can be a very efficient way to produce the fuel since algae would have a high growing speed and fairly moderate demands for conditions to be cultivated at (Saha et al., 2019). Lastly, fourth generation biofuel uses metabolic engineering to increase the carbon capture and storage potential of the plant and then uses the increased accumulation of carbon all over the plant to turn it into the fuel (Saha et al., 2019). Biofuel produced from used cooking oil might be one of the most sustainable solutions since it is reusing an unavoidable by-product of the food industry and not only reduces overall waste, but also generates fuel without competing with the food production industry (Foteinis et al., 2020).

In the reality when lands available for efficient and feasible agriculture are limited and there are still such systemic problems as hunger and food insecurity (Koizumi, 2013) transition to biofuel add to these issues since the agricultural lands would be now shared between food production industry and growing plants for biofuel.

Limited land availability and prevalence of the first-generation biofuel manufacturing facilities might be one of the limitations standing on the way to the domination of the biofuel as a major sea shipping fuel (Cai et al., 2011). While second and third-generation biofuels are more sustainable and are preferred doe marine shipping use, their manufacturing volumes are critically low now and can’t satisfy the large demand of the sea shipping industry. Therefore, just like with LNG and ammonia biofuel can act as a green alternative to fossil fuels but some investments in the production infrastructure are unavoidable.

Moreover, production of biofuel is associated with such environmental problems as deforestation, increased land erosion and habitat destruction (Gao et al., 2011). Of course, the production of any type of fuel would have at least some impacts on the environment and it is important to consider all the possible outcomes to be able to evaluate the level of sustainability of the scenario when marine shipping is operating mainly on biofuel from all the perspectives and not only from the direct emissions from fuel combustion.

6.2.4 Methanol and ethanol

Another alternative to the traditional bunker fuel is methanol. Methanol combustion emits CO2; however, methanol fuel is low on sulphur and nitrogen, which can help avoid emissions of NOx and SOx. Methanol powered ships would have up to 95%, 99%, and 7% reductions in PM, SOx, and CO2 emissions (Ampah et al., 2021). Methanol has a high-octane rating, which means that it can be used for high-efficiency fuel as a major standalone component or as a booster to increase the efficiency of the major fuel substance (C. Wang et al., 2019). Mixing methanol with traditional ship fuels would not only increase the efficiency of the mixture but also reduce NOx and SOx pollution (Najafi & Yusaf, 2009), which makes this fuel blend more compliant with regulatory norms and protects shipping providers from some risk of fines and pollution penalties. Furthermore, methanol is less flammable compared to the traditional heavy fuel oil which makes it safer in use and reduces safety expenses as well as the economic risk from the accidents (Najafi & Yusaf, 2009). At the same time, the lower flashpoint of methanol still makes this fuel potentially hazardous, and it should be treated appropriately to avoid human wellbeing threats and environmental problems coming from fuel leakage and spills.

Economically, transition to ethanol would no entail large investments. Methanol is compatible with existing ship engine design and only minor changes would be required (Ampah et al., 2021). Moreover, existing pipeline infrastructure is suitable for methanol transit and storage.

Low lubricity of the methanol fuel compared to bunker fuel is potentially problematic. Low lubricity fuels might not be able to provide proper lubrication for fuel injectors and fuel pumps, which would increase their rate of wear and tear (Lapuerta et al., 2010). However, blending methanol with additives from vegetable oils or animal fats might increase the viscosity and lubricity significantly (Kulkarni et al., 2007) and consequently provide a more efficient engine functioning.

One of the main environmental limitations of the use of methanol and ethanol as alternative shipping fuels lies in the manufacturing process of those substances. Such fossil fuels as coal and gas are often used in the methanol and ethanol production, therefore this process might be associated with large CO2 emissions (J. Ellis & Tanneberger, 2015). Total CO2 emissions from methanol would depend heavily on the way it was manufactured. Methanol produced with non-renewable sources such as natural gas can lead to up 10% higher emissions compared to heavy fuel oil (Brynolf et al., 2014). On the other hand, with methanol produced from biomass feedstock, the overall manufacturing emissions would be up to 55% lower compared to the heavy fuel oil production (Yaoyang & Boeing, 2013). The cost of methanol production would vary significantly. While methanol produces from fossil fuels would be comparable to traditional fuels used for shipping, green methanol would be significantly more expensive (Sehested, 2019). However, as the technology develops and with the increase in stickiness of regulations higher expenses on fuel might be justified by potential to avoid potential monetary pollution penalties, fees and fines.

6.2.5 Hydrogen

Green hydrogen is one of the most promising sustainable fuel solutions for multiple types of shipping including marine shipping. Hydrogen operating ships do not cause CO2 and SOx emissions (J. Andrews & Shabani, 2012). Since hydrogen is a clean burning fuel no particular matter is emitted either. All other types of pollution are also minimal except for the NOx emissions (Ampah et al., 2021; J. Andrews & Shabani, 2012). Hydrogen has one of the highest energy-to-weight storage ratios, which makes it a very efficient fuel (Ampah et al., 2021).

Propulsion of hydrogen powered ships would be not only efficient, but also significantly quieter compared to the ships running on traditional heavy fuel oil (Madsen et al., 2020). This can help significantly reduce noise pollution and therefore decrease the harmful effect on the environment. Moreover, vibration intensity of the engine would be reduced as well. This can help reduce wear and tear and expand the lifespan of the shipping machinery, which cuts the maintenance expenses as well as reduces the resource demand to produce replacement parts.

Production of hydrogen fuel might be a priority for the energy industry and one of the real opportunities for oil and gas business to transition towards more sustainable and low-emission business. However, large investments would be required to satisfy the growing demands of the industry. Technological and design alterations need to be done in the storage facilities and new ship engine design fitted to work on hydrogen is required (J. Andrews & Shabani, 2012)

As with many other alternative fuels, the level of CO2 emissions from the manufacturing process varies significantly based on the technology. The majority of hydrogen is now produced from natural gas (Bicer & Dincer, 2018). This process has very high CO2 emissions and such hydrogen cannot be considered a sustainable fuel. Steam Methane Reforming process might cause up to 12 kg CO2 per kg of hydrogen produced (Song et al., 2022). Partial Oxidation is another type of hydrogen production that involves natural gas. This process can provide up to 25% CO2 emissions (Muradov, 1993) compared to steam methane reforming, which is still CO2 intensive. However, this is more energy demanding. Coal Gasification is one of the most CO2 intensive ways to produce hydrogen. This process can emit around 17-25 kg CO2 per on kg of hydrogen (Verma & Kumar, 2015). Green hydrogen is produced from the electrolysis with the use of green electricity. The CO2 emissions from this chemical reaction are fairly low (Bicer & Dincer, 2018), but this process is highly energy demanding. Therefore, it is important to make sure that for this process green energy would be used, otherwise even for hydrogen coming from electrolysis scope 2 emissions would be high.

6.2.6 Electricity-powered ships

The trend to transition towards electricity-powered ships is becoming more and more popular in the industry. With successful introduction of electric cars and significant technological advancements, fully fossil free electric maritime shipping might become reality. Increasing emission regulations and policies are forcing shipping companies to invest in alternative solutions that would not rely on fossil fuel on any of the ship fuel production stage (which includes the use of green grid for fuel production) and consequently would provide GHG emission free shipping (Jurdana & Sladić, 2015). Moreover, development of electro-powered marine ships is often followed by the introduction of autonomous navigation systems that can be one the steps towards ensuring safer and lower risk navigation. The Yara Birkeland electro-powered ship is one of the recent examples of advancements in the sector. This fully electro-powered ship began its operation in 2021 and is now on the way to fully autonomous navigation in Norwegian sea (Yara, n.d.).

Just like hydrogen powered vessels, electro ships have a very low level of noise pollution and that should decrease some of the negative effects on the natural environments significantly. Moreover, the maintenance of electric engines is less cost-intensive, providing an additional source of cost reductions once the technology is executed and put into general use. However, the current stage of technological advancement might one of the serious barriers for the development of large-scale ocean ships. Expensive production of powerful vessel electric engines and low capacity of batteries to enable non-stop long navigation is limiting the options in the short-term perspective (Nishimura et al., 2001). Moreover, high dependence of the electro-powered ships on batteries would increase the demand on the rare-earth metals, copper and other elements that are essential for battery production (Energy Monitor, 2021; Petkova, 2021). This would lead to increase in the mining intensity and potentially make the environmental effects of the industry even more significant. As these controversies are unavoidable, it is important to consider them in the evaluation of the overall level of sustainability of this alternative to traditional fossil fuel.

Policymakers and regulators are introducing programs to incentivize development of electro-powered navigation. For example, Horizon 2020 is a program developed by the European Union to attract funding for developing zero-emissions shipping solutions with a technological focus on combination of green electricity energy cells and green hydrogen fuel (EU Parliament, 2014). This program aimed to attract over 80 billion euros for research and innovation projects prioritizing climate transition solutions.

6.2.7 Section summary

In sum, it is clear that active work to find greener alternatives to bunker fuel for maritime shipping is one of the global research priorities. Many of the solutions propose the use of methanol, ammonia, hydrogen or biofuel that can lead up to 100% reduction of CO2 and SOx emissions with is important from the environmental perspective. Moreover, transition to such fuels can help shipping operators to become compliant with regulations and avoid additional fines or other fiscal penalties. However, every possible solution entails a set of problems. Economic reasons like the need of large investments to enable the transition of the shipping industry towards new fuels as well as support the reformation of the fuel production facilities to refocus on the new fuel types. More important are environmental problems often associated with higher leakages, spills, fires or other incidents that would pose risk to environmental and human health. Moreover, it is important to consider the way these “green” alternative fuels were produced. Despite possible reductions in the direct CO2 emissions from fuel combustion transition towards wide use of these fuels might still have a large impact on climate change if cheaper and more emission intensive processes are used in manufacturing. Finally, emissions associated with energy production that would be further used in fuel manufacture plays important role in determination if the fuel would be sustainable or not. Such fuels as green ammonia and green hydrogen are produced by electrolysis which is a very energy demanding chemical process. If renewable energy is used to run the electrolysis, these fuels would be CO2 emissions free. However, if for this process the coal energy were used, net CO2 emissions would be large and potentially even exceed those from the ship navigation on traditional heavy fuel oil. Lastly, it is important to acknowledge that production of new ship parts to support green navigation, especially the production of batteries for the electro-powered ships, would lead to the increase in the demand on metals and minerals which would lead to expansion of mining activities and consequently the impact of the mining industry on the ecosystem would be more substantial.

While the transition to alternative fuels is a process that requires an input for a lot of stakeholders: including the readiness of the corporate players, availability of technology and appropriate application framework and guidance from the international organizations such as IMO, the position on the support or abandonment of the idea to develop Arctic sea shipping routes is often regarded at the individual corporate level.

6.3 Corporate governance for sustainable Arctic shipping

This section provides an overview of the existing positions of main corporate players on the possibility of commercial Arctic shipping. We can see 3 groups of companies.

1. Companies who have decided to embrace the opportunities for Arctic shipping. These companies are changing the business model to enable extensive commercial shipping in the region in the future.

2. Companies that have conducted market evaluation and concluded that the risks outweigh any market opportunities in the medium term.
3. Lastly, there are companies that remain agnostic and have yet to develop a clear position or strategy.

This section also reviews some concerns around the intentions behind the decision to avoid Arctic sea routes. Those companies adopting a more cautious approach may rationalize the decision in terms of sustainability considerations, whereas in fact it arises from a simple risk aversion and the requirement for substantial upfront capital investment. Finally, this section looks at the disclosure standards and the quality of disclosure to conduct a preliminary assessment of how significant and important climate risks are for the companies. The findings in this section show the connection between the degree and quality of the integration of climate issues in the corporate strategy and the position on Arctic shipping. Since the overall approach for this research is to provide a wide high-level overview of the topics related to the Arctic shipping rather than an in-depth review of one specific research topic the review of the corporate perspective is only initial.

When it comes to the real world it is important to understand the corporate perspective on the Arctic shipping since the industry stakeholders would be the actual agents of the impact. And while the regulatory body is still under development the overall sustainability of the Arctic shipping and the community impact management would be oversaw by the corporate. On the corporate arena there is no one view on the potential of Arctic shipping. Many companies recognize potential cost reductions and delayed feasibility increase of the Arctic shipping routes, but they also recognize higher physical, regulatory and reputational risks associated with this shipping route. While some companies have clearly publicly stated their opposition to the idea of using the Arctic sea routes, others have started investing in this solution and making some progress. Many shipping and manufacturing companies mainly from European and North American regions such as CMA CGM, Kuehne+Nagel, Hapag-Lloyd, DHL, MSC, Asos, Nike, Gap, Columbia, Puma and others took the Arctic Corporate Shipping Pledge committing to restricting their activity in the region and in particular to not use Arctic shipping routes (Ocean Conservancy, n.d.). At the same time some Chinese companies have been working with shipping partners in Russia on gradual transition to at first small scale Arctic shipping to try out this opportunity and possibly increase the shipping volumes in future.

The need to balance the risks and opportunities of Arctic shipping is the priority that is embedded in the decision-making process on the matter. However, it is yet unclear who would be the overall decision making body or process. Many of companies who are against the commercial trans-Arctic shipping are focusing on the severe environmental impacts, water and air pollution, increased rate of climate change and ice melt, habitat disruption and other things. At the same time those companies who have stated their interest in the Arctic sea routes have to evaluate the viability of the process and account for high reputational and operational risks. Moreover, since large investments are essential, this should be also included in planning. Finally, low reliability of the duration of the navigation season and high level of the unpredictability of the sea conditions also pose a shade on the potential achievability of the desired benefits (Melia et al., 2016).

Right now, we can see that there is a clearly formed group of shipping operators that includes top industry leaders who are actively advocating against Arctic shipping. However, the overall intentions of this initiative are questioned by some researchers as this might be seen as a large greenwashing activity build on the idea that those companies had no interest in the Arctic sea routes all along but now they are just using this cause for green publicity.

On the other hand, there is a fairly disunited and diverse group of stakeholders who are interested in engagement in the Arctic shipping. At this stage most of them are only seeing the Arctic sea routes as the regional transport arteria that will support the fast growing fossil fuel and mining industry in the Arctic. No large investments to develop the Arctic sea routes as the new international trade routes are neither promised nor done. However, these companies do not deny the potential of the Arctic sea routes to become a viable alternative to the Suez and Panama routes in a more distinct future. Therefore, they are likely to be involved in the development at early stages to have a competitive advantage against other companies when the navigation season in the Arctic would be long enough to sustain year-long commercial shipping.

Finally, there is a group of companies who had some exposure to the Arctic shipping before but not yet settled on a clear position.

For this chapter the following research method was applied. The list of potential corporate stakeholders was developed as the result of the review of main international shipping companies. Companies who had or intended to have exposure to the Arctic were highlighted in that list. The review of the corporate perspective of these companies was conducted through a comprehensive review of the non-peer-reviewed industry media sources. After that the review of the carbon emission disclosure on the CDP platform was undertaken. Where CDP is "a not-for-profit charity that runs the global disclosure system for investors, companies, cities, states and regions to manage their environmental impacts" (CDP, n.d.).

For more detailed information of the corporate perspective on the Arctic shipping possibility, a framework of the corporate stakeholder interviewing was developed. This part of the research is expected to be done in the following stages during the PhD.

6.3.1 Companies supporting shipping through the Arctic

Some shipping companies have advocated for the development of the Arctic Sea shipping routes as they would transform the global trade industry drastically. These companies are prioritizing shipping time reductions as their main source of economic and environmental benefits and publicly advocating for transition to Arctic shipping and investments in the industry. Moreover, in their statements we can often hear the argument about the inevitability of the Arctic sea ice melting and opening of the Arctic routes by mid-century. These companies are generally aligned in their position that the region would be ready to satisfy the shipping demand and the industry needs to be prepared to allow full-scale navigation as soon as the climatic conditions would allow. Next, we will discuss some of the examples of the companies how have made public statements in support of Arctic shipping.

Cosco Shipping is one of the largest shipping companies. This Chinese state-owned shipping company already shown its interest in Arctic shipping, supported the development of the shipping fleet and provided investments in the Arctic port infrastructure development (Zhang et al., 2020b). The company actively monitors 11 vessels designed to navigate through the Arctic and continuously conducts trial shipping to prepare for commercial navigation and providing an Arctic shipping solution for its customers (COSCO, 2020). The company started sending ships for trial runs in the Arctic waters in 2013 and by 2018 conducted 14 successful iterations (Jiang, 2018). Company estimates that the transition of its operations to the Arctic sea routes could bring savings of around 27,500 tons of CO_2, however, they have not addressed the issue of phasing-out fossil fuel and have not yet developed the transition plan to switching to green fuel (Humpert, 2022b). The company has stated its intention to balance the economic and environmental risks and benefits in its Arctic shipping strategy. COSCO executive leadership is fairly confident that current trend will make the Arctic sea route a viable and feasible option and they are committed to continue activities in line with existing company focus on the development of NSR as Arctic shipping “service awaiting demand” (Staalesen, 2019). At the same time company acknowledged that only several of over 130 ships in the company’s fleet meet the technological requirements to be able to operate in the Arctic and further investments in the ship fleet development are needed (Staalesen, 2019). The company has actively engaged in the development of the oil and gas industry in the region. In 2016-2016 COSCO ships were delivering construction modules for Yamal LNG plant to the port of Sabetta on Yamal Peninsula in Russian Siberia (Humpert, 2022b). Finally, COSCO has officially signed the agreement with PAO Novatek, PAO Sovcomflot, and Silk Road Fund in 2019. This agreement is fostering the long-term partnership to finance and implement the year-round logistics arrangements along NSR between Asia and Western Europe with an ultimate aspiration to develop the international commercial transport corridor between the Pacific and Atlantic basins (COSCO, 2019).

Guangzhou Salvage is a national public institution directly under the Ministry of Transport that was formed in 1974 and that operates over 40 sea vessels. This entity focuses on offshore engineering, windfarm installation, heavy lift transportation, hydraulic engineering, ship building and emergency rescue and salvage at sea (China Daily, 2021) and was also involved in the development of the industrial projects along the Russian Arctic coast including the Yamal LNG facility (Humpert, 2017).

Sovcomflot specializes in the transportation of liquefied gas, oil and oil products, and is one of the world's largest tanker fleet operators (Interfax, 2022). The company has publicly established its commercial interest in the development of the Arctic navigation. It would be important to mention that right now company is only seeing Arctic sea routes as the regional transitways to support the development the industrial development in the Russia Arctic, however it does not decline the applicability of NSR for global trade in a long-term perspective. Sovcomflot together with another Russian company Novatek have been involved in the development of LNG facilities in Russia Arctic like Yamal LNG and Arctic LNG 2 on the

Gyda Peninsula (Hine, 2020). The company already owns and operates a large fleet of icebreakers and cargo ships that are suited for the Arctic navigational conditions. In August 2017 Sovcomflot operated one of its tankers - the Christophe de Margerie and conducted first navigation through the NSR from Norway to South Korea in only 22 days which is a record-breaking time (Barkham, 2017). In 2021 Sovcomflot announced the expansion of the duration of navigation season through the Arctic (Hine, 2021). Company is actively engaging with Russian National Nuclear agency – Rosatom to collaborate on the development of the nuclear-powered icebreakers. Ural - third nuclear-powered icebreaker, was launched in St. Petersburg in 2019 to support the activity in the Arctic (World Maritime News, 2019).

After the Russian full-scale invasion in Ukraine the company was a subject to international sanctions and had get rid of the part of its fleet (Pirieva, 2023). In summer of 2022 (after the war has already begun) a Sovcomflot subsidiary "SCF Arctic" has established two legal entities JSC "Arctic Fleet" and JSC "TM" that would be actively involved in the Arctic navigation in future (Interfax, 2022). In May 2022 South Korea cancelled contracts to purchase 3 Arc7 LNG carriers from the company after the introduction of EU sanctions (Humpert, 2022a).

Teekay is a Canadian shipping company with headquarters in Vancouver specializing on the delivery of crude oil. With the opening of the Arctic the company has been involved in several LNG projects. In 2019 the company took part in Yamal LNG project (Teekay, 2019). Company owns 50% of the Georgiy Ushakov ice-breaking LNG carrier and has an interest to increase it's investment in the fleet to support the development of the region (LNG World News, 2019). In 2017 the company has signed an agreement to support the development of Yamal LNG by over 800-million-dollar investment (Bergman, 2017). Current business connections of the company with Russian business partners are abrupted after the begging of Russian invasion to Ukraine and vast sanctions. However, Teekay continues to explore new opportunities in the Arctic that would be aligned with high safety standards and environmental protection regulations and the company aspires to contribute to the development of sustainable global trade. Current view of the company's management on the Arctic sea routes is only limited by enabling regional trade and supporting the industrial projects in the region and Teekay is not explicitly exploring the opportunity of contributing to the development of the international trade routes thorough the region at this moment.

Fednav – another Canadian shipping company takes the same approach to the Arctic navigation. Fednav continuously collaborates with industry partners, indigenous communities, and regulatory bodies to discuss the sustainability aspects of the Arctic Navigation (Fednav, n.d.). Fednav has been operating in Arctic waters for over 60 years now, but it only used Arctic shipping as a regional source of transportation to serve the oil and gas, mining and other industries in the region, for example Canadian Royalties Inc. nickel and copper mines in northern Quebec (Clark, 2013).

Aker Arctic is a Finnish shipbuilding company. This company has been working on designing ice-breaker ships to support the navigation in the region. In 2021 they have designed an 8,000 TEU icebreaking container ship that would be able to navigate through the region both in summer and in winter. Moreover, the company estimates that the navigation of such ship would be "only slightly more costly" compared to the Suez route (Nilsen, 2021).

6.3.2 Companies not supporting shipping through the Arctic

On the other hand, there is a group of companies who have already publicly stated that they will abstain from using the Arctic sea routes. This mainly refers to the use of the Arctic shipping for the global trade and do not touch upon the internal regional navigation. These companies highlight the acute significance of the environmental risks associated with Arctic shipping and they are collaborating with the industry players and major industry customers (like larger retail and high-tech companies) to advocate against the use of Arctic sea routes.

CMA CGM - French-based shipping operator - one of 4 largest international container shipping companies was one of the first to announce its position to abstain from trans-Arctic international shipping (Humpert, 2019a). Company stated that none of over 500 vessels in the company fleet will not be used to take part in the Arctic shipping since the risk of air and water pollution is too high and the environmental consequences are much higher than the potential economic benefits. The company decided to continue focusing on the "greenefication" of its operations through transition to less CO2 emissions. In 2017 CMA CGM became one of the first companies to introduce LNG powered engines to 8 larger container ships (CMA CGM, 2017). Of course, the environmental benefits of transition to LNG fuel would depend a lot on the way the fuel was manufactured, but this is still a transition in the right direction.

Maersk now has a clear position against international trans-Arctic shipping; however, several years ago the company was researching the opportunities. In 2017 Maersk actively discussed the opportunity of commercial navigation through the Arctic region. The CEO of the company said in the interview that the company "is closely following the development of the Northern Sea Route. Climate change is changing how long the Northern Sea route is ice free. The Arctic option is developing." (Humpert, 2018). First trial run was conducted in 2018 when Maersk sent a 3,600 TEU container ship along the NSR (Morgan, 2018). Although it was disclosed that this was a one-time exercise that was mainly conducted to conduct scientific field data while the company's position on the commercial navigation in the region still remained to be on the opposing side. In early 2019 the company was engaged in several discussions with Russian shipbuilders and icebreaker operators to potently send more goods through the NSR to diversify its opportunities and release the dependance on the Suez Canal route (Reuters, 2019).

However, later in 2019 the company announced that it would not invest in projects that are supporting the use the Arctic shipping routes as an alternative for global trade and became a signatory of the Arctic Shipping Corporate Pledge (Ocean Conservancy, n.d.). However, Maersk recognized that these routes could provide an economically viable alternative to existing routes, although the environmental risks are to significant. Current Maersk position regarding Arctic shipping was expressed by the company's Press Officer Janina von Spalding: "Maersk does not see the Northern Sea Route as a viable commercial alternative" (Humpert, 2022b).

Both CMA CGM and Maersk have made public statements expressing concerns about the environmental impact of shipping through the Arctic and have indicated that they will not pursue shipping through the region. In 2019, Maersk stated that it would not use the Arctic shipping routes as a viable alternative to existing routes due to environmental risks. Similarly, CMA CGM has expressed reservations about using Arctic shipping routes and has instead focused on developing more sustainable shipping practices and reducing its carbon emissions.

MSC is a Swiss company providing both cruise ship services and cargo shipments. MSC became a signatory of the Arctic Shipping Corporate Pledge in 2019 and publicly announced its position for the first time to not use the Northern Sea Route for trans-continental cargo shipping (Schuler, 2021). Mr. Soren Toft current CEO of MSC highlights the high impact of black carbon and GHG emissions of the Arctic ecosystems and calls to join the forces to fight climate change by adopting net zero transition plans and avoiding the use of NSR and NWP for global shipping. The company does not see the use of the Arctic sea routes as a viable long-term investment, neither they see a short-term benefit in the current market conditions (Schuler, 2021). The company would prioritize the investments in green fuels and more efficient ship design to decrease the environmental footprint from its operations.

Hapag-Lloyd – 5th largest container carrier (2019 data) also joined Arctic Shipping Corporate Pledge. The company stated that there are no plans to use the Arctic shipping routes as the environmental impact of the fossil fuel combustion on the Arctic environment would be very significant. Jörg Erdmann, Senior Director Sustainability also notes that there is no economic feasibility for this sea route as the ice conditions are too unpredictable and the navigation window is too short (Hapag-Lloyd, 2019).

German logistics company **Kuehne+Nagel** that provides airfreight, sea freight, overland shipping warehouse services also stated its commitment to sustainable maritime shipping. The company has initiated the Net Zero Carbon program and collaborates with a variety of international initiatives for sustainable logistics such as UN Global Compact, the Arctic Pledge, Getting to Zero Coalition, Sustainable Air Freight Alliance, Clean Cargo and the Science-Based Targets Initiative (Kuehne+Nagel, 2021). The company also publicly stated that they will not conduct shipping through the Arctic sea routes as the company sees a great potential for environmental damage. Kuehne+Nagel would prioritize other initiatives to contribute to making the industry more sustainable. For example, as a part of Zero Coalition the company is working on the development of viable deep-sea Zero Emission Vessels to be in operation by 2030 (Kuehne+Nagel, 2021). As a part of their sustainability ambition the company joined

Clean Cargo Working Group and starting 2017 will provide its clients with the amount of CO2 emitted for all their sea freight shipments (Veconinter, 2017).

Evergreen Marine Corporation is a large international shipping company with headquarters in Taiwan. The company joined the Arctic Shipping Corporate Pledge initiative started by Ocean Conservancy non-profit. The company has acknowledged the impact of CO2 emissions on climate change and publicly stated that they will no only avoid Arctic routes for global trade but also they will be working towards achieving net-zero emissions since regardless of the precises location where those emissions occur they still have an impact on the environmental condition of the Arctic region and of our planet as a whole (Greencarrier, 2022). According to the Gliese Foundation sustainability evaluation Evergreen got the second best score for environmental performance among other large international sea carriers in 2020 (Gliese Foundation, 2020). The company was the first one among Asian sea carriers to publicly state its position on the Arctic shipping and to show a commitment to following the environmental agenda by actively working towards setting reduction targets, developing transition pathways and providing a TCFD-aligned reporting.

Overall, the signatories of the Arctic Shipping Corporate Pledge control a large share of the container shipping market. Only CMA CGM, Evergreen, Hapag-Lloyd and MSC control over 40% (2019 data) (Middleton, 2019). And now the list of signatories includes other large international companies as well. This creates a unified power to protect the region from active over-exploitation by global trade providers but this also poses a threat of increasing greenwashing of such initiatives and low-effectiveness at the end. The risk of greenwashing is quite high in the "anti-Arctic shipping movement". It is very hard to tell now whether the companies have in fact examined the risks and opportunities associated with Arctic shipping and took a well-thought out and balanced decision or they had no interest in the Arctic navigation right from the beginning and use this just as good publicity to promote themselves as "green" entities (Humpert, 2019b). However, companies like Maersk and Hyundai Glovis did conduct a series of trial runs to evaluate the environmental effects and the economic feasibility of the Arctic sea route. Either way, emerging corporate co-dependent influence to abstain from Arctic shipping would have an overall positive effect posing a large reputational risk on the companies who would continue their exposure to the international Arctic sea routes.

Overall, the majority of companies who are claiming to avoid trans-Arctic sea routes are mainly driven the environmental risks of such shipping in the area and by a high level of unpredictability of the sea conditions. Not all the companies have conducted the evaluation of economic feasibility and environmental outcomes of Arctic shipping. Some of them have simply joined the international initiatives like the Arctic Shipping Corporate Pledge. Those companies that have done trial runs also highlight that the economic feasibility of the trans-Arctic commercial shipping is very low now since the navigation should be often supported by the icebreakers and the overall navigation season is very short.

6.3.3 Companies without a clear position

Finally, some companies have not yet stated their position on Arctic shipping. The number of such entities is fairly low, but it is important to mention that the position on Arctic shipping is very fluid and keeps changing with the high rate as environmental, economic and political environment is fluctuating.

China Merchants Group is one of the companies that have studied and discussed its potential development of the Arctic port infrastructure and navigation along the NSR but yet has not taken any final decisions on the matter. This is a Chinese state-owned company that is investing in the development of commercial ship operations and development of the port infrastructure. Being a state-owned business potentially exposes the company to the Arctic shipping market since Chinese government continuously expressed interest in the development of the Arctic shipping route (Moe & Stokke, 2019). In China's Arctic policy current role of the country in the Arctic presence was seen as "near-Arctic state". China's ambition to diversify transit options and provide a more economically competitive from the delivery time perspective solution is often seen as one of the main moving forces of Arctic ambition in the country (Moe & Stokke, 2019). Overall, if a full-scale global trade through the Arctic sea routes the chances of China Merchants Group involvement in the Arctic navigation are very high, in the meantime the company has not developed a plan nor clearly articulated its ambition to invest in the development of the global Arctic trade route.

A Japanese company **MOL** (Mitsui O.S.K. Lines) that provides container shipping, dry bulk shipping, and liquid natural gas transport services is another example of a company who has potential exposure and opportunities in the Arctic region, but who have not settled on a clear strategy whether to use Arctic sea routes for global trade or not. MOL recently became a member of the Arctic Economic Council (AEC, n.d.) to contribute to the sustainable development of the Arctic region. MOL participated in joint projects with Chinese COSCO on the operation if icebreakers to support the development of the Yamal LNG project in 2018 (MOL, 2018). MOL actively participates in councils and research projects to evaluate risks and opportunities of the Arctic Shipping. In 2019 MOL took part in the 1st Council of Northern Sea Route held by Russian corporation Rosatom, also MOL signed the Memorandum of Understanding ("MOU") with the Admiral Makarov State University of Maritime and Inland Shipping ("Makarov University") in the same year (MOL, 2019). This was done as a part of the company's approach to evaluate the concept of the commercial navigation through the Arctic against such values safety, reliability, and efficiency of transportation. MOL has shown some interest in Arctic Shipping, although the company has not done any commitments yet and take an approach to take time and evaluate the situation more thoroughly.

Korean company **Hyundai Glovis** has started first attempts to discover the Arctic shipping opportunities in 2013. Long awaited plan to expand its shipping operations into the Arctic region led to the successful trial shipping of vessel carrying coal, diesel and gas from Russian port Ust Luga to Gwangyan Port. 35-day long transit successfully delivered over 44,000 tons of cargo (The Maritime Executive, 2013). In the political environment of early 2010s Korean government was inclined to continue the cooperation with business partners in Russia in joint development of the Arctic opportunities. After that the company has not conducted any of the projects focused on the Arctic shipping and have not made any statements to clarify its position on the matter (Hyundai Glovis, 2021).

DP World a large shipping and port operating company from UAE also have not yet settled on a clear Arctic Strategy. On one hand, the company have done some large investments in the infrastructure development of the projects that would potentially essentially links in the trans-Arctic supply chain. For example, DP world invested in the modernization and expansion of the Prince Rupert port in the northern coast of British Columbia in Canada (Kontos, 2023) and Duke Point Terminal Expansion in Nanaimo region (Nanaimo Port Authority, 2022). In 2021 the company has signed the agreement with Russian authorities to invest in the port infrastructure development along Russian Arctic coast and port expansion in the Russian far East to satisfy the potentially growing demand from the transition to the Arctic global trade (Kramer, 2021). However, there is no indication of the current status of the project and there is a likely chance that after the beginning of the war and after the introduction of international sanctions the project was scratched. On the other hand, no clear public statements have been made so far.

The Japanese shipping company **K Line** (Kawasaki Kisen Kaisha, Ltd) is also one the companies that had potential exposure to the Arctic shipping in the past but yet have not decided on the final position. The company has recently stated some concerns about the viability of the Arctic global trade navigation because of the unpredictable ice and weather conditions and low level of the port infrastructure development. However, the company has a large share of its business dedicated to energy transportation, primary LNG. In 2006 the company has conducted a successful delivery of a new 140,000 cbm type LNG carrier designed in compliance with environmental standards and powerful enough to operate in Arctic conditions. Therefore, the company might return to the Arctic shipping arena to support numerous LNG projects that are happening in the area.

In most cases the development of the navigation in the region is still considered to be just on the regional scale. Companies are interested in supporting the development of industrial projects like the construction of mines and LNG facilities as well as delivering cargos to and from those facilities. Despite the potential growth in the intensity of such navigation due to the active development and exploitation of the natural resources in the Arctic, this navigation would not be in competition with the traditional Panama and Suez sea routes. However, signs of investments flow in the Arctic port infrastructure have been identified. This leaves room to believe that in a long-term perspective these routes still can be seen as alternative for global sea trade and consequently companies that have supported their development from the early stages would be better prepared to dominate on those routes.

However, the importance of balancing potential benefits of Arctic shipping with the need to protect the local ecosystem and ensure the safety of crew and cargo on the Arctic direction is often seen as the major concern. The region still presents significant challenges and risks that are often associated with severity and unpredictability of Arctic conditions.

We can clearly see that companies who are somewhat supportive of the idea of Arctic navigation are only seeing this as a regional route and while some investments are made no explicit intention to shift global trade patterns is identified. Meanwhile, the group of companies advocating against the use of Arctic sea routes often communicates the message that the global sea trade patterns should remain unchanged as increased navigation through the Arctic would have planet-wide irreversible ecological consequences. Therefore, despite that there are two voices about the Arctic shipping, they are often talking about the shipping of different scale. Those who are in favor are mainly advocating for the support of the regional navigation while they are still leaving the room for global trade in the region in a distinct future. While those who are against Arctic shipping are mainly addressing the question of transcontinental shipping right away.

Finally, it is important to note that the position on such new and underdeveloped matters can change fairly quick. Companies are still trying to figure out what economic, environmental, regulatory, and reputational risks thew would face if they start active transition to the Arctic sea routes. The economic feasibility of these routes is extremely complex and includes a variety of factors that are still understudied to be accounted for with high precision. As the understanding of all these factors advances the corporate perspective on the use of Arctic sea routes for global trade would change and it might significantly change the list of companies that are supporting and opposing Arctic shipping. As of right now we still don't see any signs of serious commercial global sea trade activity on the Arctic routes, but as the sea ice conditions are improving and the navigation season is lengthening the role of the Arctic Sea routes in the global sea trade might shift.

6.3.4 The role of climate related financial disclosure in evaluating sustainability performance of the company

The position on the Arctic shipping of the company is often influenced by the overall approach to address sustainability issues on the corporate governance level by the company. We can compare the companies' position with their environmental disclosure. Climate-related disclosure can provide critical information about the risks and opportunities that can occur in front of the company as a result of climate change and how the company is planning to address them. High-quality climate-related financial disclosure is important for investors to identify companies that are prepared to face possible material risk from climate change and have a clear transition and risk mitigation plans. This is also important to see how companies understand their own exposure to climate risks. When dealing with such a significant topic as the development of Arctic shipping route it is important to rely on companies who have a clear understanding of all the consequences of such a project. Evaluating the quality of climate-related disclosure can be a proxy to help understand the overall approach that the company is taking when dealing with climate risks.

For example, we can study the disclosure recommendations developed by the Task Force on Climate-related Financial Disclosures (TCFD) that contain guidelines for the companies to report on the internal oversighting of the climate-related risks which includes governance, strategy, risk management, and metrics and targets used to evaluate those risks.

TCFD disclosure does not only provide valuable information for public and private investors, but also helps companies to evaluate their performance against climate change and therefore the adaptation of the TCFD-aligned disclosure practices can be seen as an important indicator of the acknowledgement of climate change by the company and transition to the business practices that would reduce the climate risk (Bingler et al., 2022). Carbon Disclosure Project (CDP) also evaluates corporate disclosure against climate change metrics. Although the CDP score only reflects the quality of the submitted disclosure rather than the quality of the climate action it can also provide an insight on the company's position about the significance of climate risks for its operations.

	Position on the Arctic Shipping	TCFD disclosure	CDP Score
Cosco Shipping	For	Disclosure aligned with TCFD to some degree	D score
Guangzhou Salvage	For	No data	No data
Sovcomflot	For	No data	No data
Teekay	For	Considered, not yet implemented	No data
Fednav	For	No data	No data

Aker Arctic	For	No data	No data
CMA CGM	Against	Disclosure aligned with TCFD to some degree	C score
Maersk	Against	Disclosure aligned with TCFD to some degree	A- score
MSC	Against	Disclosure aligned with TCFD to some degree	Last time submitted in 2020, no score available
Hapag-Lloyd	Against	Disclosure aligned with TCFD to some degree	B score
Kuehne+Nagel	Against	Disclosure aligned with TCFD to some degree	Last time submitted in 2022, no score available
Evergreen	Against	Disclosure aligned with TCFD to some degree	B score
China Merchants Group	No position	Disclosure aligned with TCFD to some degree	F score
MOL (Mitsui O.S.K. Lines)	No position	Disclosure aligned with TCFD to some degree	A- score

Hyundai Glovis	No position	Disclosure aligned with TCFD to some degree	A- score
DP World	No position	Disclosure aligned with TCFD to some degree	A- score
K Line	No position	Disclosure aligned with TCFD to some degree	A score

Table 1. Comparison of the position on Arctic shipping with the climate-related financial disclosure for selected companies.

As we can see, the majority of reviewed companies who have stated their interest in the Arctic navigation have not yet adopted the TCFD (Task Force on Climate-Related Financial Disclosures) regulations not they are disclosing their carbon footprint through the CDP (Carbon Disclosure Project). At the same time companies who have publicly abstained from the Arctic navigation and expressed concerns about the severe environmental consequences of it are generally following TCFD recommendations and those that have been evaluated by CDP got high scores which means the quality of their carbon disclosure is reliable. TCFD and CDP disclosure cannot be seen as the direct force impacting the company's position on Arctic shipping. However, compliance with TCFD and CDP reporting can be seen as the indicators of the acknowledgement of the significance of climate risk for the company and somewhat aspiration to develop the Net Zero transition plan. Poor performance on those indicators for companies who are supporting the Arctic shipping can be considered as the confirmation of the overall approach of the company to evaluate the role of environmental risk in the business model. While some companies are shifting its operations towards sustainable and viable in a long term perspective solutions that would be resilient to the new economic conditions that would be strongly affected by environmental agenda by mid-century, others are taking the "steal and run" approach that is focusing on the generating of the maximum available amount of profit in a short-term without considering the long-term perspective (Jørgensen & Pedersen, 2018). The role of companies in achieving global sustainability and fighting climate change is very significant. Being a problem-solving machine is by definition in the nature of any company. So, if the profitability and business success would be directly bounded with the sustainable development strategy, it will subconsciously change its approach to do business toward a more sustainable one and consequently become a means of solving the issue. At the same time to achieve the transition to generally accepted sustainable business practices industry needs to "shift from the concept "steal-and-run"" (Jørgensen & Pedersen, 2018) and adopt restorative and regenerative thinking.

However, it is important to mention that TCFD disclosure is still just a voluntary disclosure and there are no regulatory mechanisms to obligate companies to align with TCFD. There are other regulatory frameworks in place that attempt to regulate the quality of climate-related disclosure. While most of them use TCFD as a starting point and adopt it for the local regulatory environment, there are some examples when the regulation would vary. Developed by International Sustainability Standards Board the IFRS (International Financial Reporting Standards) framework provides a detailed guidance on development of the financial and accounting metrics to ensure adequate and precise oversight of climate-related issues and align company activity with climate objectives. On the other the Disclosure Framework handbook developed by the UK Transition Plan Taskforce in 2022 provides a more holistic approach addressing financial climate-disclosure on a more conceptual level. This guidance pays more attention to such topics as engagement and lobbying rather than focusing on the definition of specific financial metrics.

Overall, we can see that the quality of disclosure would have a direct correlation with the overall approach to addressing climate change on the company level. CDP evaluation provides a detailed overview on different categories of the climate action taken by the company including climate-related governance, climate risk management, GHG targets and reporting and others. In 2022 over 10 thousand companies were evaluated. 182 companies listed marine transport and Intermodal transport & logistics companies as the major focus of their business. The analysis of the CDP scores for this sector is presented in table 2. Over 40% of those companies either failed to submit CDP report in 2022 or did not receive a score. Only 8% of companies received an A score for their disclosure which implies that those companies have sufficient climate oversight and signs of proactive climate leadership. That being said for such categories as Business Strategy, Financial Planning & Scenario Analysis, Emissions reduction initiatives and low carbon products, Governance, Risk management processes, Scope 1 & 2 emissions (incl. verification), Scope 3 emissions (incl. verification) and GHG Targets the majority of companies who received a CDP score got C. C score means that the company only shows signs of awareness and while it considered the effects of climate change on their business there are no substantial core changes in the disclosure. Over a quarter of evaluated companies got a C score for their governance, scope 3 emissions and GHG targets disclosure. At the same time, 25.3% of companies got an A score for governance. Therefore, the gap in the quality of climate governance is significant. It is important to enhance the quality of climate oversight on the company level to ensure that the materiality of climate risk is not only acknowledged, but also integrated in the decision-making and company strategic action plan.

CDP scores 2022 for Marine transport and Intermodal transport & logistics companies

	A	A%	B	B%	C	C%	D	D%	F/no disclosure	
2022 Overall Score	15	8.2	40	22.0	30	16.5	16	8.8	81	44.5
Business Strategy, Financial Planning & Scenario Analysis	25	13.7	30	16.5	36	19.8	10	5.5	81	44.5
Emissions reduction initiatives and low carbon products	29	15.9	8	4.4	35	19.2	29	15.9	81	44.5
Governance	46	25.3	3	1.6	47	25.8	5	2.7	81	44.5
Risk management processes	36	19.8	18	9.9	43	23.6	4	2.2	81	44.5
Scope 1 & 2 emissions (incl. verification)	38	20.9	7	3.8	42	23.1	14	7.7	81	44.5
Scope 3 emissions (incl. verification)	12	6.6	5	2.7	50	27.5	34	18.7	81	44.5
Targets	15	8.2	28	15.4	48	26.4	10	5.5	81	44.5
										Total companies

Table 2. CDP scores 2022 for Marine transport and Intermodal transport & logistics companies

The overall sustainability of the trans-Arctic commercial shipping would highly depend on the way stakeholders consider climate change in their strategy. Therefore, it is important to stimulate the alignment of the companies with climate-related financial disclosure frameworks and with such reporting initiatives as CDP to develop a more conscious and climate-active corporate culture. Otherwise, in the reality of high-risk the opportunity for the adaptation of "steal-and-run" approach might become high which would have only negative effects on the sustainability of the trans-Arctic shipping project.

Aside from the quality of disclosure, there are other indicators that can help evaluate overall company's approach to address sustainability issues. Lobbying activity can be a real indicator of the true intentions of the company. This data can often be hidden from the wider public and it might be hard to know what the companies are doing behind closed doors and how do they allocate their lobbying budget. However, many investors are now requestioning reporting on the lobbying activity from their investees (Welsh & Passoff, 2023).

Inclusion of the climate-related incentive in the overall pay for directors is another powerful tool to develop a substantial climate oversight as well as define the scope of individual accountability for the climate performance among the top management of the company. The research shows, that over 90% of studied companies in Canadian have some kind of an ESG incentive to the executive compensation, however, about 70% of theses incentives are tied to short-term goals, while many of the ESG and climate change issues should be addressed through a continuous robust action plan (Confidential, 2023a). In many cases ESG incentive would include one or several of the following targets: progress against net-zero target, reduction in absolute GHG emissions, carbon intensity improvement targets or/and carbon neutrality targets (Confidential, 2023a). In the same pull analyzed Canadian companies it was found that include 80-90% of the studied companies include Indigenous Engagement and Reconciliation, Philanthropy and Community development and relations component in their ESG incentives and further enhancement of the targets touching upon the relations with Indigenous people is anticipated (Confidential, 2023a). Such incentives are particularly important for the top management of companies from high emitting sectors. For example, it is proposed that the remuneration systems for top management in Oil and Gas sector would explicitly include targets focusing on the compliance with emissions reduction goals aligned with Paris Agreement (Confidential, 2023c). Glass Lewis proposes to define the minimum threshold for the long-term performance-based incentive as 50% of total compensation (Glass Lewis, 2023). One of the Canadian air transportation companies recently disclosed that 20% of its annual top management incentive plan will include ESG criteria and that the company in developing a framework of introducing ESG considerations in the long-term incentive pay structure (Confidential, 2023b).

6.3.5 Section summary

Overall, we can clearly see that the transportation industry is acknowledging the possibility of Arctic shipping. The question of whether it will become the top priority for all the industry leaders remains unsettled. However, there is already some clarity about the position of some of the major corporate stakeholders. As the climate changes continues to impact the Arctic region the profitability and the number of risks associated with trans-Arctic shipping might change which can modify the position of several companies. Without a mandatory and unified approach to regulating the corporate performance in the region and overseeing climate-related corporate governance some cases of potentially hazardous situations might occur. With further development of the climate-related financial disclosure frameworks and with adoption of more enhanced governance practices such as ESG and climate incentives for executive compensation the possibility to ensure a high-level oversight of the potential climate risks becomes more and more real. Another issue that is outside of the scope of the research is a bigger issue of the prospects for coherent governance decision making on whether and, if so, how increased Arctic shipping should be allowed and controlled, including through specified standards.

Chapter 7 Conclusion and next steps for the research.

7.1 Conclusion

Arctic shipping is a very complex prospect that would have a significant effect on global and regional sustainability. While it could bring economic development to the region and provide an opportunity for GHG reductions for the sea shipping industry, it could also cause serious and irreversible issues for the ecosystem and local communities. At the same time if Arctic shipping is used for the international commerce, it will change the face of global trade routes and consequences of that are yet to be studied.

This research can be seen as the first step in the long process of collecting all the entry data to understand the complexity of the Arctic shipping's impact on the social, ecological, economic and governance aspects. This research has aspired to set a clear foundation for further exploratory work to develop a framework for the sustainable shipping standard that would address the issues from multiple perspectives. Such a standard should be developed with respect to (1) possible negative outcomes that the industry should avoid by any cost, (2) the specificity of the authorities and stakeholders that would be obliged to apply and follow such standard and (3) the potential limitations of the application and enforcement of such a standard.

This research provided a comprehensive analysis of the literature based on the combination of the generic sustainability considerations and context-specific sustainability parameters to summarize the full range of parameters and considerations that are essential to understand what sustainable development and shipping in the Arctic is. In this research, over 300 pieces of literature were analyzed. This research provides an initial framework for further analysis of costs, benefits, opportunities, risks and opportunity-costs in relation to the development of Arctic shipping.

Therefore, the next step in this research would be the close interaction with industry and relevant governance authorities, commencing by interviewing the industry stakeholders' representatives as proposed in chapter 6 as well as other stakeholders and governance authorities with prior development of a suitable interviewing framework for those groups. This would give us access to first-hand information on the industry expectations of the Arctic shipping, timeline and major hindrances as well as governance bodies' concerns and expectations. By combining multi-faced entry data that includes potential positive and negative outcomes of the shipping with the first-hand data on the industry views and the gaps in legislation and regulation the material for Arctic shipping standard would occur.

The development of such a standard should be the ultimate goal of this research. However, only by providing a clear and robust guiding framework, can we have a satisfactory foundation for evaluating and enforcing the compliance of the industry with the set environmental, social and economic objectives.

This research clearly indicates that Arctic shipping is a real opportunity. The shipping industry is an important part of the global economy. Currently there are over 90 000 shipping vessels worldwide (S. Elias, 2021). Over 90% of manufactured goods is transported with the use of sea freight yearly, and over 4 trillion USD in goods are transported via sea (GTC, 2019). A 10-fold increase in the volume of container shipments was observed between 1980s and 2010s (The Maritime Executive, 2021). Negative effects are also likely, however. Marine shipping has a significant effect on ecosystems and accounts for 2-3% of global GHG emissions (Ampah et al., 2021), 10-15% of NOx and 4-9% of SOx emissions globally (Dalsøren et al., 2007). As marine shipping will continue to be an important part of the economy and shipping intensity will keep growing, a 50-250% increase in emissions is anticipated by 2050 (Wan et al., 2022) unless dedicated steps are taken to find low or no emission alternatives for powering the ships. Aside from emissions, shipping is also a potential source of used water discharges and oil spills and might pose a threat of the introduction of invasive species. Physical impacts of shipping would include noise pollution and mechanical ice destruction which not only contributes to climate change but also leads to habitat fragmentation.

The dynamics of the Arctic Sea ice cover show a clear trend towards reduction. Between 1979 and 2013 the melting season extended by around 5 days every decade (Rachold, 2019) and around 37% of the sea ice were lost from 1979 to 2018 (Grosfeld et al., 2016). By current estimations, the Arctic region will be reduced in size by over 40% by 2100 (Vavrus et al., 2012). Increasing shipping in the region is contributing to climate change. Up to 62% of Arctic warming is associated with anthropogenic GHG and aerosol emissions (Yu et al., 2022).

Continuing trend in the duration increase of ice-free days on key Arctic routes over last decades can be tracked in the region. Currently ice-free conditions along selected routes are under 2 months per year; however, by 2030 the navigation season might increase by 2.5 months (U.S. Committee on the

Marine Transportation System, 2019). Year-long ice-free conditions are anticipated by 2100 (Melia et al., 2016). A transpolar route might open by 2050 or if the 1.5-degree alignment by 2050 is achieved, the trans-polar sea route is expected to be open by 2100 (M. Bennett, 2019; Jahn, 2018; Notz & SIMIP, 2020). And the ship traffic is already gradually increasing. Between 2013-2019 traffic intensity grew up by 25% (PAME, 2020) and total distance increased by 75% over the same period (PAME, 2020).

From the economic point of view, Arctic shipping is also controversial. On one hand, Arctic shipping can be seen as possibly achieving tangible distance reductions between Asia and Europe/North America. This would not only lead to the reduction of the shipping time, but also potentially reduce the fuel consumption and consequently the emissions. However, given the hard conditions of the Arctic region and higher fuel consumption to go through the ice-covered sea route, net fuel savings might not be tangible. Aside from time reduction, shipping through the Arctic sea routes can reduce the dependence on access to the Panama and Suez canals. This means the elimination of the transit fees. Moreover, unlike canals Arctic sea routes would be available for all the shipping vessels regardless of their size.

On the other hand, Arctic shipping is much riskier and more dangerous. Therefore, various financial and reputational risks are entailed. Insurance costs also can be higher compared to the traditional routes. More importantly, to enable safe and coherent navigation a significant infrastructure development is required. While some deep-water port projects are under development, many other things are still needed including enablement of fuel supply, sufficient search and rescue facilities and other essentials. Finally, especially in the first half of the 21st century navigation along the Arctic sea routes would have seasonal nature. Therefore, there is no unanimity whether Arctic shipping is a viable solution and the benefits overweight the costs.

It is yet unclear if Arctic shipping could replace traditional shipping routes in the short-term. However, Arctic shipping can play a major role as a regional source of transport to support the industrial projects in the region. Given the active industrial development of the region and the essentiality of the shipping to support the industry the intensity of the navigation in the Arctic would increase with no doubt. Climate change opens new opportunities and new mineral deposits are becoming available for extraction. Given the global trend for the transition to low-carbon economy the dependence of the society and global economy on such critical metals as copper, lithium, aluminum and others would only increase. Hence, more mining is anticipated in upcoming decades. Increased industrial activity would also have a huge effect on local communities.

While Arctic shipping might act as the foundation for accelerated regional development, incentivise local infrastructure development, drag investments to the region, stimulate the demand for local services, become a source of new jobs with no sunset clause and ensure long-lasting economic inflow to support regional economy there are some serious potential problems for the local communities as well. Since the impact on the environment would be significant, Arctic shipping might reduce the availability of natural resources that are vital for Indigenous communities. Not only they are a part of the diet but also hunting and fishing are an important part of the Indigenous culture; therefore there is a risk of cultural loss as well. Moreover, active industrial presence and arctic shipping might develop the competition for resource availability between local communities and incoming workforce to support those projects (food, medication, fuel). Finally, major infrastructure development projects might pose a potential threat of displacement.

To reduce the negative environmental impact of shipping, there are several international protocols that regulate emission norms and set the guidance for ballast water discharges and other potential environmental impacts. International efforts like the Sustainable Shipping Initiative and Ship Recycling Transparency Initiative are working on the development of frameworks for sustainable industry activity. One of the major areas of effort in this field is the transition towards alternative fuels. The emissions from different alternative fuel options would vary. One of the most prominent interim solutions is the LNG powered navigation. While this option is not carbon-free, it can provide up to 25% CO_2 emission reduction compared to HFO. Other international initiatives like the Arctic Pledge are advocating for withholding from Arctic shipping. On the individual corporate level, there is a diversity of views on these issues. There are some companies who are actively supporting the idea of Arctic shipping, others who are against it and also a group of companies without a defined position on the issue.

This research showed that based on current estimations, the impact of the Arctic shipping on the environment, local communities and economy could be tremendous and the overall positive or negative impact is yet to be determined. Some issues like geopolitics or net effect on the climate change are still discussed and there in consensus in the scientific community. However, we can clearly see the evidence of the possible tangible negative environmental impact from shipping on the region. At the same time, shipping can bring various economic benefits and enhance local economy. However, this is likely to have a negative effect on the integrity and virginity of the social communities of Indigenous people of the Arctic. No doubt, Arctic shipping is a real and very complex problem that requires further research in order to come anywhere close to the possibility of developing a sustainable Arctic shipping standard.

In sum, we can say that the discussion about Arctic shipping includes a wide range of parameters that are absolutely essential to understand the possible means to align this activity with sustainable practices. Broadly these parameters can be divided into 4 categories: (1) environmental factors, (2) economic factors, (3) social, community and cultural factors and (4) government aspects.

While those 4 categories can include a wide scope of sub-parameters, this research identified the following ones as the most material for arctic shipping and possible further analysis of costs, benefits, opportunities and risks:

1. Environmental: chemical pollution, GHG emissions and contribution to climate change, noise pollution, habitat disruption, shipwrecks and oil spills, invasive species.
2. Economic: possible time and fuel reductions, infrastructure development, navigational safety, role of Arctic shipping in the industrial development of the region.
3. Social and cultural: regional development trajectories, local economy support, just transition, wealth distribution, impact on the natural resource availability, competition for resource availability between local communities and outlanders, displacement, cultural loss and assimilation.
4. Governance: diversity of regulatory systems in different jurisdictions involved in the Arctic shipping, geopolitics, international governance for sustainable shipping, industry transition to alternative fuels and green shipping, corporate level governance.

Next steps for this research should be build on the findings presented in this paper and among other applications could be a logical step to establish a clear foundation for the subsequent development of an evidence-based SASS that would be sufficiently robust to direct the industry onto a sustainable trajectory.

7.2 Next Steps

The greatly expanded Arctic shipping is an anticipated development with potentially significant environmental, economic and social impacts. It encompasses many opportunities and risks, and the overall outcome would highly depend on the way it will be executed. Therefore, in the first step to ensuring sustainable existence and sustainable operations we should be able to provide a clear data-supported answer to the following questions: what is the influence of Arctic shipping on global sustainability? What are the environmental impacts of Arctic shipping? To what extent does Arctic shipping contribute to climate change? How does it affect local communities and the local economy? How do corporate stakeholders view the situation and viability of the Arctic shipping? What knowledge and research are needed to guide the development of sustainable shipping standards?

Those questions are directly applicable to the intention of the development of the Arctic Sea shipping opportunities (Ryan et al., 2020). The movement of the sea vessels through the NSR and NW passages might resolve multiple problems that are faced right now by the logistics community worldwide. It will not only allow ships to avoid the usage of the Suez and Panama channels that have some limitations (Reuters Staff, 2021) but also significantly reduce the shipping time which in the first place means direct and indirect cost optimization (Melia et al., 2016). Right now, the concept of Arctic shipping is still in its initial phase and the shipping is not happening at its full possible capacity (Arctic Economic Council, 2017). This means that we still have time to work on finding answers to the question of understanding all the components which are required to define the sustainable Arctic shipping strategy.

The use of the Arctic region as a potential place for sea shipping can provide us with numerous benefits and gains, along with many limitations and potential threats. It is important to have a clear understanding of all benefits and potential hazards that we might possibly face while increasing our presence in the region. This is all urgently needed to make sure that natural and biophysical boundaries of the system are not surpassed, and our actions would not cause irreversible ecosystem and social disruption. To understand all that we must define all the possible threats and strengths and based on those considerations create a data-supported strategy for a sustainable approach to conducting business in the region. Moreover, we must define possible limitations of the application of the proposed approach and know the maximum number of interactions available which in our case would be the number of shipments or tonnage of cargo shipped per year (Young, 2021).

Since Arctic shipping involves a very diverse group of stakeholders, for successful communication and cross-stakeholder engagement we should define the potential cultural, political, and religious moral backgrounds of the groups of stakeholders involved in the activity to respect their needs and views in the proposed approach. And more importantly to fit the approach to a more realistic and place-based understanding of the involved stakeholders and their needs.

If we take a more detailed look on our aspirational outcome, we can see that it tackles a number of issues related both to the local development of the Arctic region and global sustainability. The desired outcome of successful and sustainable Arctic shipping should have the following characteristics:

1. Firstly, commercial shipping through the Arctic pathways would contribute to the development of the northern region and reinforce the economic and social components of sustainability for local communities by providing direct and indirect financial inflow. Direct economic gains would come from the increasing number of workplaces due to higher demand (shipping itself and service providers including emergency rescue, food supply, etc.). The indirect category can include growing investments for the development of the region in general (Faury & Lasserre, 2019). For example, now in Iceland, a brand-new deepwater seaport is in place. This would be a specifically designed port for the big ocean vessels which would intentionally use it as a part of the North-East Passage shipping (Bremen Ports, n.d.). Such projects would not only bring the investments to create infrastructure in the region but also generate several new workplaces which seem likely to remain available for a long period (unlike the mining workplaces which might become unavailable as soon as the mine is closed).
2. The limit of Arctic shipping would be defined clearly. This means that before the industry starts the intensive use of the Arctic Sea Routes, we would know the biophysical limits of the system as well as the consequences of trespassing those limits. It is unsustainable to initiate the active use of these sea ways for commercial shipping with sole focus on t maximizing the short-term benefits. Arctic shipping developed with a high level of collaboration between stakeholders and with the prioritization of the long-term social, environmental and economic benefits could be an example to other projects worldwide. Based on the high importance of compliance with

biophysical limits, a need for enhanced regulation and external control is evident. Moreover, aside from just defining the maximum number of shipments/ the maximum scale of impact on the system, there should also be a conversation about some conceptual limitations like the exclusion of some potential routes, attention to seasonal peculiarities like migration patterns, seasonal habitats and designated high-risk areas.

3. Recognizing and respecting the complexity of the region are also crucial. One of the main contributors to the complexity is the number of different stakeholders and governing authorities involved. They are not simply numerous but also of different scales and different backgrounds. The level of involvement and significance also varies for different stakeholder groups. Moreover, some of those stakeholders would have completely different sets of moral foundations affecting their judgments and priorities. Different stakeholders would have a different agenda to advocate for. While stakeholders representing Indigenous people might be prioritizing the protection of the environment and resources availability for the local communities as well as the integrity of the communities themselves, industry stakeholders might have a different agenda. Acknowledging this wide diversity of key topics is an important step in the understanding of the roadmap of how these issues can be addressed holistically as different components of the system, rather than as a number dispersed not interconnected issues. Moreover, governing authorities are also extremely important in this system. Since governing authority over the Arctic region is divided among a number of politically, religiously, historically, socially, and culturally different communities (Russia, China, Europe, and North America), ensuring cooperation in establishing sustainability-enhancing approaches to Arctic shipping is likely to be difficult. This is why it’s important to include a set of actions focusing on proactive work to avoid the possible tensions between different parties, to ease and speed up the process of finding suitable solutions to evident problems and to avoid miscommunication developing and policies a defined set of rules. Tight interconnection between the various perspectives of stakeholders and governing authorities is an unavoidable need while studying the issue and potentially developing the SASS.
4. Finally, governance of the use of the Arctic Sea routes would recognize the potential for adverse as well as positive effects, hindering as well as contributing to global sustainability. Arctic shipping can act as the opportunity to reduce the CO_2 emissions from the shipping due

to the shorter ways and consequently shorter delivery time. Moreover, it could provide possibilities for reducing the use of resources needed to create shipping containers and ships themselves. Since the delivery time would be shorter, one ship could transfer more cargo per year since it could simply make more trips in the same time. This means that resources (metal, human resources, energy) required in the manufacturing industry could be optimized. Besides all that, this development can also contribute to global sustainability simply by providing a quicker opportunity to deliver cargo, which can be vital in some cases. It would make the business process more flexible and adjustable to change since the delivery times can be more than two times shorter. Finally, the gradual shift to the northern sea routes could lower tension and consequently dependence on the human-made channels which are now used for transcontinental shipping (Panama and Suez Channel). Those channels could significantly reduce the delivery times, although they retain some serious limitations. For example, extra big container vessels are unable to pass through those channels, and sometimes extraordinary situations might appear (e.g., when the Chinese vessel Ever Given was stuck in the Suez channel and paralyzed the movement through the channel for several weeks which affected the supply chains all over the world and caused shortages in some places). Lastly, we have to recognize the need to identify the main tradeoffs and consider how they could be avoided or mitigated.

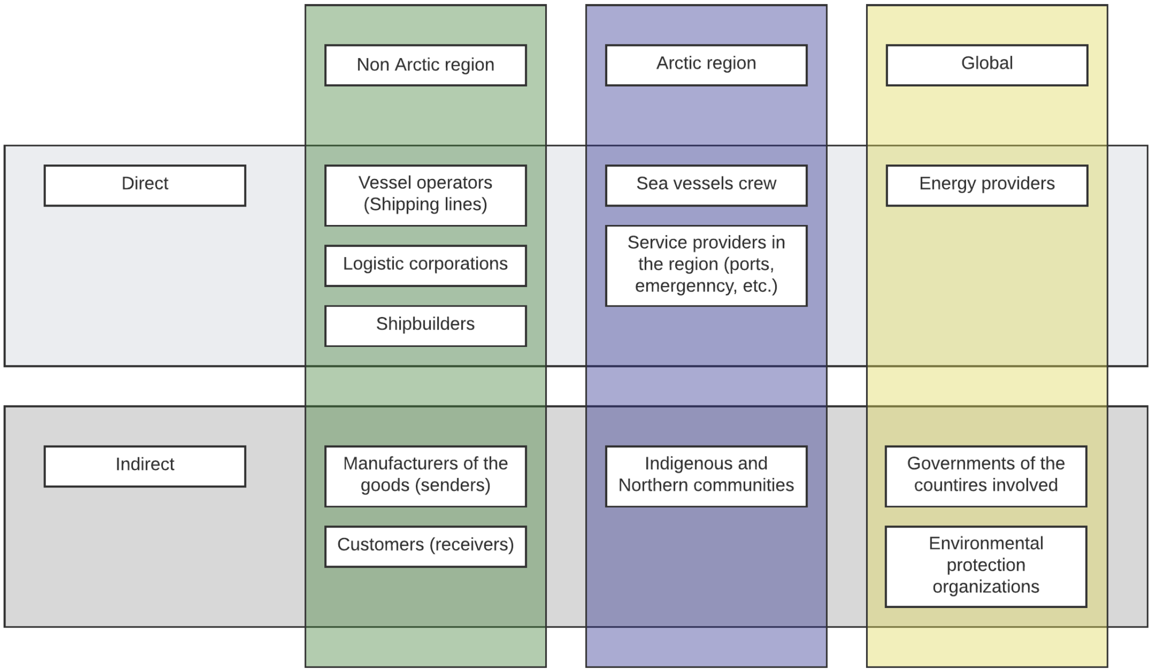

Figure 1. Parties involved

To achieve our aspirational outcome, a clear action plan for development of such a serious project should be created. It should start with the definition of the existing situation, fundamental assumptions, and set of steps moving the Arctic shipping from the current situation to the desired outcome.

It would be fair to say that even the current opportunities for shipping through the North Sea Path have not been fully used now. There are many reasons for that, and the existing sea ice coverage is one of the main ones. However, there are still technological gaps that need to be overcome to step into the phase where trans-Arctic shipping can be fully possible (Joseph et al., 2021). Moreover, one of the main assumptions that we should be aware of now is that there is a serious polarisation among stakeholders in terms of the feasibility and sustainability of such an initiative. One group of commercial companies that includes both customers (manufacturing companies that ship their goods via sea shipping) and carriers (logistics companies that are providing the shipping opportunity) is acting in strong opposition to the development of Arctic shipping. One of the main arguments is that it would put in danger the integrity and complexity of the vulnerable Arctic region. No doubt, this point has solid scientific support and should be further discussed (Zhang et al., 2020a).

At the same time, some companies including many Asian (Japan and South Korea) reject the possibility of shipping through the Arctic since they don't see it as economically feasible. From their perspective, such benefits as shorter delivery time and lower resource use are overcompensated by high risk of the Arctic shipping related to the iceberg danger and occasional need in icebreakers (Matala & Steur, 2021). Moreover, serious consideration of trans-Arctic passages for commercial shipping large investments should determine what is needed to develop the required infrastructure and high-quality human resources to maintain the process.

Finally, there is the third group who see Arctic shipping as a potential opportunity and are undertaking serious actions to make it real. For example, there is already in place the development of the Arctic Shipping infrastructure in Iceland (Bremen Ports, n.d.) and there are agreements between several companies to collaborate in this project. For example, there is a common project between DP World (UAE) and FESCO (Russia) to develop North-East passage shipping. However, after the war in Ukraine, those contracts and collaborations with Russia might be frozen or canceled and there is no yet reliable information about the fate of this project. Arctic shipping is associated with numerous legal and sovereignty issues (Molenaar Erik et al., 2010). After the war in Ukraine and serious aggravation of the diplomatic relationships between Russia and the rest of the world, the possibility of the use of the North-East passage in Russian waters might be complicated or limited for some time.

All things considered, we can see that there is a serious gap between the existing situation and the desirable future. In Figure 2 the proposed transition framework from the current situation to the aspirational outcome is presented.

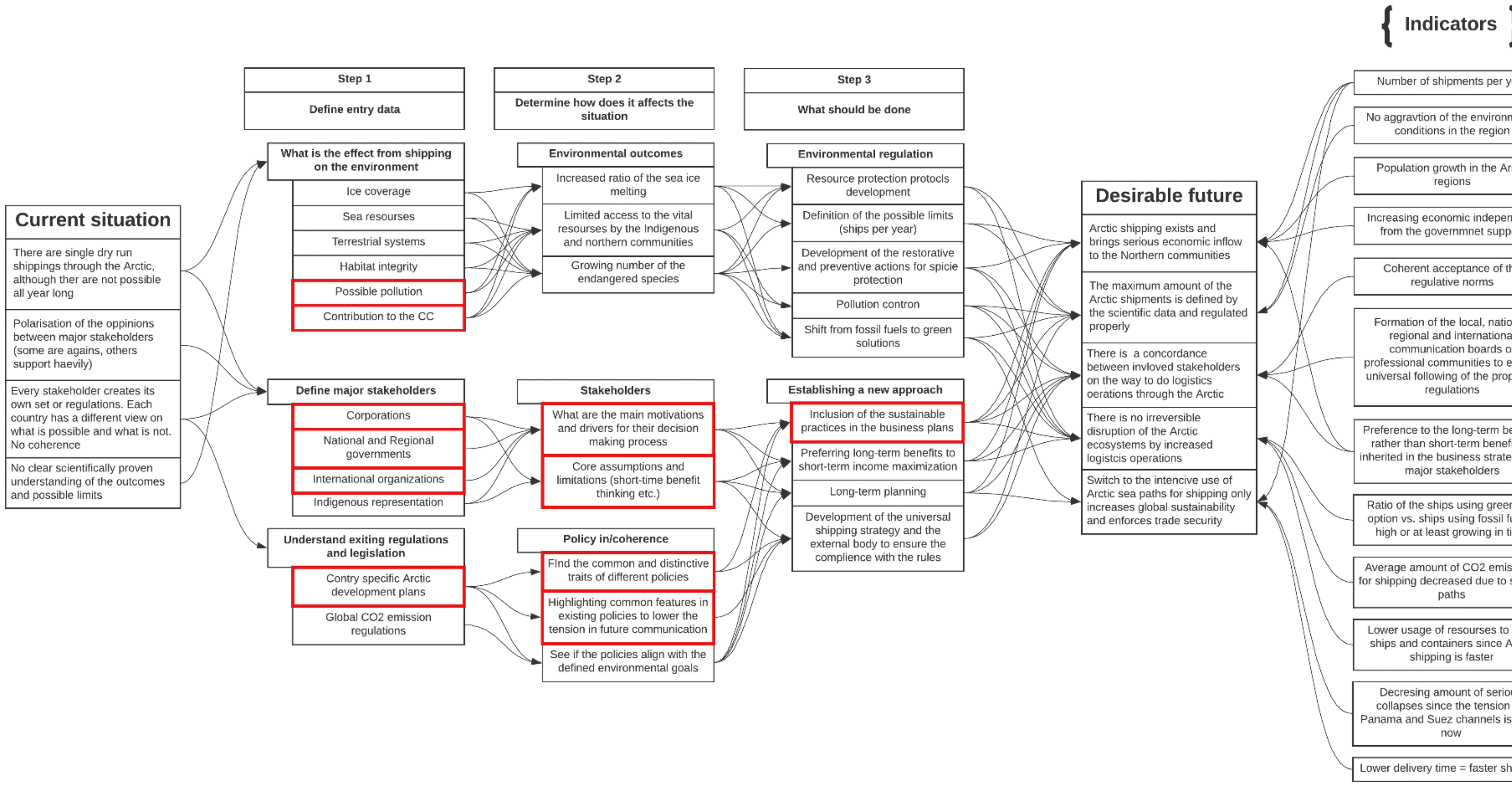

FIGURE 2. SYSTEM DIAGRAM OF THE PROPOSED THEORY OF CHANGE FROM ENVIRONMENTAL PERSPECTIVE. ACTS AS AN ILLUSTRATION OF THE APPROACH THAT SHOULD BE TAKEN.

This can be divided in 3 major steps. <u>In the first step</u>, we should get a proper understanding of the existing situation. This includes primarily the understanding of the environmental outcomes. How would the increased shipping in the Arctic region affect terrestrial and aquatic ecosystems? In particular, the question of habitat fragmentation should be discussed. Since sea shipping can be considered a serious intrusion into natural life, it could entail complications and interruptions in the migration patterns of local animals. The question of habitats is also directly related to the problem of melting sea ice (Bonn, 2003b). Even if the overall climate change contribution from the shipping can be disregarded (since it would likely lower CO_2 emissions compared to shipping on the exiting routes due to shorter distances) Arctic shipping would still be affecting and destroying the sea ice coverage simply by physically crushing the ice. Therefore, this consequence of shipping should be discussed. We should be able to understand if this can be avoided and what is the actual contribution from shipping to the sea ice cover decrease and consequently, how does it affect the natural habitats and the integrity of the existence of the several animal species in the region.

Moreover, the region is used and inhabited by local northern and indigenous communities who are strongly reliant on access to natural resources and freshwater (Eegeesiak, n.d.). This means that the influence of Arctic shipping on the natural environments would have huge importance not only for the preservation of the wildlife as it is but also for ensuring the continuous sustainable and self-sufficient existence of the local Indigenous and Northern communities.

Aside from the environmental and Indigenous peoples sides of the question, there is deep uncertainty related to the complexity in the number of stakeholders and policies regulating the shipping activity in the region on multiple levels. We should have a clear and detailed understanding of all the direct and indirect stakeholders. The same thing should be done with the policy aspect. Right now, there are many existing policies regulating activity in the Arctic taken on different levels. Relevant policies include internal corporate sustainability plans that would include an Arctic shipping strategy, intra-corporation agreements like the Arctic Pledge initiated by the organization Ocean Conservancy, which was joined by numerous manufacturers and shipping companies. Moreover, there are also many national Arctic development plans that are reflecting the positions of the countries with jurisdiction over Arctic shipping. And although they might seem similar, some aspects can be controversial if we compare some of those plans, for example, the Arctic development plan of China and the plan of Germany or Canada.

When we gather all the entry information, we can move to step two where we try to define how findings from analyses of all this data may affect approaches to expansion of commercial shipping through the Arctic Sea. Here we would have to take a look at the actual consequences of the proposed activity. For example, how many existing or additional endangered species be at risk as a result of the increased shipping? What is the contribution to the environmental and climate change in the region? What are the risks associated with shipping for the local communities? How can those risks be balanced by the possible benefits? Are there any trade-offs that should be considered? Moreover, we must go deeper into the stakeholder-policy part of our work and try to see the main common features among all this diversity. At the same time, we can also determine the major points of disagreement that come from cultural, religious, political and etc. differences.

Finally, in the third step, we can use all the information above to work on the development of preventive and mitigative measures and indicator systems to be compliant with the defined limits. The list of activities here can be broad. It might include the actual definition of the shipping limits (number of ships per year) and the creation of the regulative norms and controlling bodies that would ensure compliance. Besides regulations, some sustainable behavior initiating activities might be included – for example, some measures to enforce the shift to alternative energy sources in shipping through the Arctic. Moreover, those actions can and should be followed by the revision of the core business approaches and adaptation of the new perspectives on the major components of the business models. Reinforcement of the prioritizing of the long-term benefits over the short-term income should be one of the main vectors of the shift. Additionally, the ideas of de-growth can be also adopted in the business models, at least aiming to diminish the importance of the constantly growing profits and foster transition to the non-material benefits could be articulated for the Arctic shipping business models.

One of the main complexities in this work is that it is situated where multiple scientific fields overlap. The work involves environmental aspects; at the same time, touches upon the Indigenous communities and goes into the social and cultural sides of sustainability. The environmental part by itself covers a huge variety of topics from pollution and emissions to endangered species, natural habitats, and even the physical process of crushing the ice and its contribution to the ice melting. Moreover, there is a broad policy and geopolitics side of the question. Finally, of course, the economic side starts from the general assessment of the feasibility of this opportunity to the economic parts of sustainability on a global (supply chain change, trade security) and regional scale which would include investment attractiveness, infrastructure development, economic effect on the communities, workplaces creation, economic inflow and etc.

So, it is clear that the survey of components of change presented here is just a first step to the development of the actual action plan to move us from the place where we are now to the reality where the possibility of Arctic shipping was discussed from all the possible angles and the decisions on the usage or non-usage of this opportunity are shared, coordinated and respected globally. Next steps of the research should enhance the understanding of the components involved in the complex process of the Arctic shipping and their interactions. On the next step, the research should focus on the following topics:

1. Corporate stakeholder interview and enhanced research of the corporate perspectives.
2. Further research on the topics excluded from the scope of this research.
    a. State of the regulatory environment in jurisdictions potentially involved in Arctic shipping.
    b. Geopolitical considerations and their influence on Arctic shipping and international collaboration.
    c. In-depth analysis of the existing international regulations, frameworks and standards regulating sipping sustainability
3. Consolidation of the researched sustainability considerations in the action plan for developing a sustainable arctic shipping standard.

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Appendix 1 - Interview framework

One of the major research pieces that is proposed for the next stages of this research is the interviews. While the master's thesis was mainly setting up the foundation of the research work, it provided scientific ground to initiate the development of the next steps including the development of the interview framework.

The section of the future research that would include interviews is built around the following questions:

1. What are the possible outcomes of the Arctic Sea shipping, and
2. What is the nature and impact of corporate governance of the shipping companies in the Arctic.

The proposed methods are required to attend to the following core aspects of the research context: novelty, multi-perspectives, closeness to the practical application:

1. Novelty: The geo-physical, climatic, socio-economic, and geo-political dynamics of the region are changing quickly. Access to new data is continually modifying our understanding of the possibilities for the Arctic shipping.
2. Multiple perspectives: The research context is complex, involving multiple interests and disciplines and therefore requires multiple perspectives and an openness to new vantage points.
3. Immediacy of impact and application: Because corporate actors and others are taking decisions in real time, the feedback loop between research and action is potentially very tight. In this context, research can play a significant role in creating cooperation and communication between corporate stakeholders and increasing the traction and effectiveness of regulation early in the development phase.

Fundamental assumptions

Given the sensitive nature of the research and the immediate economic motivations of the interviewees who for the most part depend on the profitability of and income from the business) this subjective dimension is impossible to avoid (Clarke & Braun, 2013).

Moreover, a specific set of skills that can be defined as a "qualitative sensibility"(Clarke & Braun, 2013) should be introduced in the process of taking and analyzing the interview. Many things fall under this umbrella term including but not limited by (1) preference to the meaning over the cause; (2) critical analysis of the received information and continuous focus on "why" question; (3) trying to regard the data from beyond and overcome our own cultural assumptions; (4) combination of both "insider and outsider positions" to generate a more comprehensive outlook on the data (Clarke & Braun, 2013).

Benefits

This research deals with matters that are time-sensitive and novel at the same time. This is complicated by the high level of uncertainty and tremendous interdisciplinarity of the research questions that need to be answered to get a holistic perspective on the issue. In the condition of a very limited number of "knowledge holders" semi-structured interviews are proposed as the main research method to best suit the research goals. This method would have enough advantages that would allow us to gather the most possible amount of high-quality information for further analysis. One of the main benefits for our research is that this method gives "voice to the participants in the research" (Howitt, 2013). This means that we can minimize the possible uncertainties on the question design stage originating from the complexity of the discussed issue by simply setting the general direction of the conversation and giving a lot of freedom to the interviewee by allowing him to elaborate o his answers and somewhat leading the discussion.

Moreover, qualitative research methods including in-depth semi-structured interviews have a serious advantage over the quantitative methods. They can provide us with a complex and multi-level explication of the particular actions based on the context (Gephart Jr, 2004) which is especially important when we are dealing with the diverse set of corporate or government stakeholders. In other words, we are more likely to see not only what is happening, but why is it happening.

Another important opportunity that becomes available for us when taking the in-person one-on-one interviews is the power of the personal connection between the interviewer and the interviewee. If the interviewer is successful in creating the safe environment for the conversation this interview might be outstandingly insightful and informative (Dodgson & Trotman, 2021). One key approach to do that is to make the interviewee the "hero" the story. In other words, to shift the attention in questions you ask from the abstract idea of the issue that your are studying, in our case sustainability implications of the trans-Arctic shipping, to the person you are talking to. In the second part of this paper, I have prepared some draft questions that are designed with the use of this approach. It was observed that people are often more involved and contributing to the discussion when they have the opportunity to speak about themselves, their contributions and achievements, etc. (Ward, 2013). So by changing the question from "*What are the consequences of the increased shipping in the Arctic region?*" to "could you please tell me more about the work that you've done on the research of the consequences of the shipping for the Arctic environment?" the interviewee in the spotlight, allowing them to speak about their own work and their successful research results proving that they did a great job. In this way might get more information and more context from their responses.

Finally, by choosing in-person interviews over the online surveys or other less personalized qualitative methods we have control over the overall "temperature" of the process, and we can make sure that the environment is friendly and safe for the interviewee to open up and speak freely. By setting up specific time bounds for the interview, for example, one hour, we can eliminate the anxiety originating from the desire to finish as fast as possible and come back to your "important" job. This all eases the mood and realises the tension which is crucial for the productive discussion. Finally, we have a complete control over the place where the interview would be taken. For example, there are examples, showing that sometimes walking interviews can be more productive. Especially, if we a specking about some place-specific issues. By putting the interviewee into that location, we initiate more in-depth answers and in-context comments (Teff-Seker et al., 2022).

Limitations

Limitations are also numerous. Firstly, interviewing is a time-consuming method that requires a lot of work both during the preparation and post-interview analysis. Moreover, most of the preparation work might be non-resultative since it might be complicated to arrange an interview with a desired person (Howitt, 2013). We are only interested in a very limited number of people who are directly included in the business process related to the sustainability activities of the companies willing or rejecting the idea to participate in the trans-Arctic Sea shipping this limitation might turn into a more serious one – insufficient pool of interviewees. Even in big logistics companies with several thousands' employees all over the world only a few are suitable to shed light or the research questions since only these few have sufficient knowledge and experience. At the same time other qualitative methods like focus groups or surveys are even less able to accommodate this concern since they are less personal and not as directly targeted to a particular person unlike the interview (Howitt, 2013).

One more important thing that would affect dramatically on the success of the interview as a whole and the quality of data received is the ability to maintain the constructive and productive "conversation flow" (Dodgson & Trotman, 2021) . This limitation can be described as the capability to make other people truly open up to you and maybe go beyond your initial question to provide you with a more detailed and context-supported understanding of the issue. This might lead to some sort of the departure from the original set of questions, but it was observed that in those supplements might contain important and insightful information (Dai et al., 2019). At the same time, it is also important to find the balance between the free "conversation flow" and our original intentions. Moreover, when dealing with sensitive topics (Leahy, 2021) the deviation from the initial course of the conversation might be initiated by the interviewee on purpose. In our case such purpose might be in the attempt to hide some information that might look the company look in a bad light because all the information even in this purely scientific interview might be available to public. And there might be some answers that might be considered as "bad publicity" which would affect the profits or business relationships of the company. Therefore, it is really important to always ask the question "why is this happening" to define the rue intentions and not be confused (Clarke & Braun, 2013). Moreover, it is always important to be able to determine the difference between the "good" interview and the "interview that is a good fit" for this particular research (Howitt, 2013). While the first one means that the interview was taken professionally, the questions were deep and some unobvious answers were revealed it doesn't obviously mean that the exiting research can benefit significantly from the data from this interview. The interview that would be a good fit for the research should be very research specific and should help us advance our understanding in the issue.

At the same time there is a number of serious limitations linked to the core assumptions and biases that might appear when conducting a qualitative interview. First one is originating from the complexity of the question and the diversity of fields it is touching on. As a sustainability researchers we are trying to embrace that complexity and build a set of research questions from a wide variety of topics to approach the studied issue from a number of perspectives. However, we should accept the fact that this might be insufficiently knowledgeable in some aspects of the research. Especially, in the practical applications. For example, if we are speaking about sustainability outcomes of the Arctic shipping, we might regard it from the perspective of the complex systems and look on the environmental issues coupled with potentially increased shipping ass well as the socio-economic outcomes. But at the same time there would be a big chunk or information that is way beyond our scope of experience since it is related to the practical applications of the shipping. And the fact that we are unaware of this information might act as a serious limitation both on the interview question design and interview conducting phases (Dodgson & Trotman, 2021). At the same time, by choosing the semi-structured interview option we might attempt to minimize the negative effect of this factor and avoid the possible limitation in the amount and quality of received information by "opening the floor" for the interviewee and just directing them with our questions rather than creating a rigid question structure where any kind of digressions are not allowed.

The question of attachment / detachment appears here as well (N. Elias, 1956). It might be a serious complication to the quality and integrity of the collected data. Firstly, there is the personality aspect to that – how the interviewer is affecting the interviewee by his character. It is hard to remain impartial and no involved in the process primarily because, as we mentioned in the advantages segment, the ability to be involved and to stimulate the interviewee to speak is one of benefits of the in-person interviews leading to a higher quality in-depth data collection. At the same time there our involvement, personal bias and pre-exiting position over the studied issue might affect the design phase of the interview development. It might lead to a way we phrase questions, the way we ask them (the tone of voice, facial expressions, etc.) it all might affect the obtained results. At the same time, without our personal interest and passion about the issue how can we make sure that we've done everything that was possible to find all the available information that is required for the conclusion. Overall, the problem of attachment and detachment has strong connections to the fight with our biases and their affection on the research and it is important to consider and acknowledge in all qualitative research.

A good example of the semi-structured interviews can be seen in (McCambridge & Mitchell, 2022) where the question of the connection between the development of science and the alcohol industry as well the involvement of the industry's employees with the scientific community. It was shown, that semi-structured approach gave the interviewees some space to customize or adjust the preliminary set of the interview questions based on the person giving the interview. The researchers explicitly showed that “there is enormous value in listening to re-searchers about the sensitive and challenging issues they face, as a fuller understanding of these issues may be attained”. One important point was made about the population size. Especially for the smaller populations the value of each individual interview might have a significant impact on the understanding of the bigger picture. Therefore, it is crucially important to make sure that the population chosen for the research is diverse and sufficiently representative to make the conclusions. In their research they noted that the vast majority of the interviews who agreed to participate were form the high-income communities. This means that there is potentially other possibly different perspective on the studied issue that is not yet revealed because some of the major participant groups have not yet participated in the research and consequently have not yet stated their position and views on the problem. Moreover, if there is some repetitive streak of refusals to participate in the research from a particular group of stakeholders we should always try to consider (1) why is this happening and (2) how does this affect our results (McCambridge & Mitchell, 2022).

After the analysis of peer-reviewed articles the following conclusions were done. Among the benefits of the semi-structured interview approach, we can highlight:

1. Semi-structured interview gives us flexibility to avoid the rigid question sequence and try direct the discussion so the interviewee would be a co-leader of the discussion and give us the insights, perspectives and answers to the questions which were unknown for us before the interview
2. Interviews just as many other qualitative methods provide us with in-depth explanation of the studied actions at the same time with providing some “real-life context”
3. By shifting the attention from the distant and non-personal aspects to the successes and contribution of the interviewee in the field of our interest we might get a more detailed and context-supported answer
4. Easy and complete control over the interview location and the “mood” of the room allows to make adjustments to increase the quality of the discussion

At the same time some serious limitations were found including but not limited by:

1. This is a time-demanding process and requires both a lot of preparation work and a lot of time resources to transcribe / translate / analyze the received results

2. The total pool of the interviewees that are potentially suits the desired interviewee profile is limited and most of them are hardly achievable
3. The success of the interview depends on the personal skills of the interviewer and his ability to “keep the discussion flowing”
4. There is a risk that the discussion might be driven away from the initial direction by the interviewee on purpose to hide some unpleasant or sensitive information
5. Pre-exiting biases an position over the studied issue and the balance between involvement and detachment might affect the data collected significantly.

Coding

As it was mentioned before preparation, conduction and the processing of the interview results takes a lot of time. Especially the last one. From every interview we might get a lot of information where only certain percentage would be directly related to our research hence could be used. However, to extract that particular information we still have to spend some time on the transcribing and analyzing the results (the recording or the detailed notes) of the interview (Dodgson & Trotman, 2021).

One issue that arises when we are dealing with huge sets of qualitative data is the attempt to overgeneralize it a turn it all into a database with numbers containing information on how often a particular thought was articulated and how many people do that and how many doesn’t. However, it is very important not to remain this data qualitative rather then turn it only quantitative. We should not only focus on the frequency of the appearing of a particular though in our data but on “how does it look like” (Dodgson & Trotman, 2021).

In order to ease the process of data processing, ensure that all data is stored safely and used correctly without any interruptions or mistakes it is really important to set up a simple but convenient coding scheme. Moreover, it was observed that it should be our assumption when we are setting up the coding scheme that the interview data might be used repetitively hence coding system should be reflective of that and should be suitable for multiple use in a long-term perspective (Dodgson & Trotman, 2021).

The first step to a successful coding should be in a proper understanding of the data that is collected and identification of the general features that should be coded and then based on the context of the data received the proper coding scheme should be developed and applied (Kenno et al., 2016). Moreover, there will be always some parts of the data that might fit hardly to the exiting coding scheme. To those chunks of information special attention should be paid. Kenno 2016 defines 5 major steps to process the data obtained from the interviews: (1) Get to know your data; (2) Code the data; (3) Connect the categories and concepts together; (4) Create tentative conclusions; (5) Corroborate those tentative conclusions. Where the last step should include identification of the data that does not fit to the created conclusion and identification of the possible explication for reasons for such a discoordination (Kenno et al., 2016).

The importance of the clear and easy-to-follow coding scheme might be justified even within one research. It was observed that continuous two-sided conversation between the researcher and the interviewees can be really impactful for both sides (Dai et al., 2019). Firstly, this is determined by the fact that sometimes the researcher might already have the vision on the exiting theory that would be a good explanation of the reality. However, until this theory is confirmed by actual data it would be wrong to consider this theory accurate. As the research goes on the sufficient confirmation might be found to prove the theory. There have been cases when researchers claimed that the set of interview questions should have looked differently if they new right from the beginning that this theory was valid, although everyone understands that this is impossible (Dodgson & Trotman, 2021). Therefore, the engagement in a conversation between to parties on the later steps of the research to continue the conversation with regards to the research finding may potentially bring some more in-depth and fact-supported contributions that can potentially explain the true origins of certain actions (Dai et al., 2019; Seale, 1999).

Moreover, it was advised to use a specific software to simplify and clarify the process of coding. One the possible apps is NVivo qualitative data analysis software (Dodgson & Trotman, 2021). Another option for increasing efficiency and quality of data analysis and coding of the recorded materials is Computer-Aided Qualitative Data Analysis Software (CAQDAS) that allows a thematic analysis of the data (Teff-Seker et al., 2022).

Coding should act as the tool to help us take the most from the interview. This means we should not only look at what was said, but also pay attention to how it was said. Was there some hesitation, was there a big pause after an uncomfortable question, did the interviewee was confused with his answer and mumbled or did they have a straight and logical story to tell. Of course, there are a lot of reasons for all the situations mentioned before, and there is no one explanation applicable for every case. For example, it would be absolutely wrong to assume if the person mumbles this means that he is hiding something and if he is speaking clean and confident, he is saying the truth, of course this is not how it works. However, those tiny moments should also be mentioned in the processing of the interview results and maybe they would be helpful contribution to the “why” part of the research. A great example of signs was shown in (Potter & Hepburn, 2012) where they create an example of code that shows all those details like the tone, the loudness, the duration of the pause, overlapping with other interviewees if there are multiple and even the exhales and inhales.

Comparison interviews vs. surveys

There potentially some other possible methods that can be a good fit for the achievement of our research goals. One of the closest would-be surveys. However, I can find some serious flaws in surveys which are making them not as fitful for the current research as in-person semi-structure individual interviews are. First complication is in the very limited population. There is only a small number of people that can provide us with the information required to make the conclusions. The response rate should be taken into consideration. Even when applying special techniques and spending a lot of effort to get responses the response rate might vary significantly and often doesn’t go higher than 50% (Zimmerman, 2003). This includes the application of special activities artificially increasing the response rate such as small money motivation in the form of 1- or 2-dollar gist certificate for the survey participants (Zimmerman, 2003). Taking in the consideration the position and status of the possible knowledge holders for our research the possibility of finding an appropriate motivation to participate in the survey is doubtable.

Another important issue is coming from the complexity of the researched subject. Since we are not professionals in this field, we might not have sufficient experience to design the survey questions properly. Poorly designed questions would lead to incorrect, fragmented, generalized or out-of-context information which would provide a mistaken understanding of the subject. Some answers might need elaboration and comments to be fully comprehended and survey does not allow that. Furthermore, some questions even if phrased in a rightful manner might still don’t cover the topic fully and part of the information might remain unrevealed.

Moreover, in the issue of the Arctic shipping there are practically no yes/no or multiple choice questions to ask. Most of the questions would require a detailed answer (Howitt, 2013). There is a high risk that survey participants would not be fully involved and would not provide the most complete and comprehensive possible answer since it takes a lot of time and efforts. This would again create the false understanding of the "big picture" and might lead to the wrong overall conclusions.

In sum, surveys have a number of limitations, that make their use for this research inappropriate. Those limitations include but not limited by:

1. Limited population and low response rate
2. No sufficient experience to generate high quality questions
3. Risk of incomplete or general answers

Trial set of questions for the interview

As can be seen from the research objectives interviews play an important role in this research since they can help us get more closer understanding of the motivations and actions undertaken by the corporate stakeholders involved in the process of the trans-Arctic shipping. In order to get the information that would create a comprehensive enough picture we should not only pay attention to the questions (how and what we ask + what answers we actually receive) but also make sure that we choose the respondents who represent the population fairly. This becomes even more crucial since we are operating in the reality of the limited population. There are several criteria that might affect the understanding of the situation and possible actions undertaken by stakeholders, therefore, we should approach and get the views from both sides. Those factors are:

1. General position about trans-Arctic shipping. There are 3 major groups of corporate stakeholders. Those who are strongly opposing, strongly supporting trans-Arctic shipping and those who are open to both tans-Arctic and non-trans-Arctic opportunities.
2. The size of the company since it correlates directly with both available funds (amount of investments to the development of the Northern Sea Route) and the potential amount of disruption. This means there should be representatives from large, medium and smaller companies.

3. Political or cultural background of the company's executive board. This includes companies from such diverse cultural regions such as North America, Europe, Russia China and other Asian counties.
4. Relation with the Arctic region. There are shipping companies from the countries that have direct access to the Arctic region, although the list of the companies that are interested in the development of the Norther Sea Route is not limited by those counties. And we can assume that the perspective and strategy plan of the company form Russia might vary from the one in Greek company, for example. Therefore, this option is to be studied further.

In preparation of those draft questions the following instructions were taken into consideration and applied int the question design:

1. We are assuming that the interviewee is the professional here, not the interviewer
2. Questions should only set the direction of the discussion and just initiate the conversation, rather than be a right structure to follow
3. By its structure the questions should avoid yes/no constructions and be as much open ended as possible to support the point number 2
4. Questions should make the interviewee the hero of the story rather than focus on the abstract distinct theoretical things

Below is the list of possible questions (in **bold**) to ask and anticipated result to receive (in *italic*):

- **What are the reasons that are pushing your company to start/increase commercial activity in the Arctic?**
  - *General understanding of the corporate motivations?*
  - *What is of the highest importance for the company?*
  - *Are environmental aspects mentioned / taken into consideration?*

- **What benefits do you see from this development (economic/environmental/etc.)?**
  - *Are economic benefits their first answer?*

- *How does the continuous economic growth (if they would highlight this benefit) complies with the environmental protection goals and sustainability targets?*

- **Are there any threats that might appear on the way?**
  - *How did they come up with the list of the threats?*
  - *How significant do they find those threats?*
  - *How realistic are those threats from the corporate view? (compare with the findings in the research)*
  - *How is the company planning to prevent or resolve possible negative consequences? Is possibility of "something going seriously wrong" even considered in the company's strategy?*

- **What environmental threats are possible from increasing the intensity of commercial shipping?**

- **Which of those threads are more and less probable to happen?**

  - *How would you rate them based on their probability?*

  - *How would you rate them based on their significance for the social, economical and natural environment?*

- **How do you evaluate the consequences of the company's activity?**

  - *direct or indirect measurements?*

  - *what are your indicators for each kind of threat?*

  - *who is conducting the evaluation process (external/internal employee; on sit/remote)?*

- **How do you address the consequences?**

  - what activities do you undertake to minimize the harm (that has already occurred and that is only expected to happen)?

- **Does your company's presence in the Arctic Region will be temporary (like the mining companies – until the mining shaft is depleted), or do you see the use of the Arctic lands as an integral part of your business in the future?**

  - *Sustainability implications?*
  - *Presence of long-term planning and "long-run" benefit corporate behavior?*

- **Have your company created a specific developmental plan for its activity in the region? If so, for how many years this plan was created (is it a 3 / 5 / 10/ etc. year plan)?**

- **What benefits do you see in the creatin of the clear long-term sustainability strategy**

- **How was this plan created? Who was in the plan development team (internal/external experts; from business/environmental backgrounds; from/out of the Arctic region)?**

  - *Who was doing the research (corporate workers / outsource researchers)? What is the level of expertise and professional field of the people who have prepares the research?*
  - *How strongly this plan is supported by scientific (from the environmental/sustainability studies) findings*

- **What are the possible environmental problems in the region and globally related to the increased shipping activity in the region (trans-Arctic)?**

- **How does the environmental aspect of the issues was or wasn't taken into consideration when deciding whether to use or not to use the Arctic region?**

  - *Is the proposed action plan is indeed supposed to initiate a positive change in the way corporate activity (business) affects the environment) or it is just a benefit-driven campaign with some "green stuff" in it to be easier to sell?*

- **What are the barriers/limits that should not be trespassed or the growth in the region might be unlimited?**

  - *What is the priority for the company - by seeing the barriers they highlight we can see in what direction their internal discussion developed and understand to what the company pays more attention?*

- **What are the methods used to define the potential environmental impact of the business activity in the region?**

  - *How scientifically supported are the proposed methods? Do those methods give a comprehensive answer to the proposed question?*

- **How does the company plan to measure and control its actual environmental impact in the region?**

  - *Shows the actual willingness to control over their activity. How much resources does the company willing to spend on monitoring of their activity?*

- **Do you see the possibility of trespassing the limits? Under what conditions it might happen? What would be the company's actions in this scenario?**

  - *See if the company has clearly defined the limits?*

- *What are the factors that contributed to the setting of the limits at a certain level? What is a major contributor "we [company] need to get X much" or "we [company] can't do more than X"*
- *What is the mechanism to make sure the limit (if one was set) is respected and not trespassed?*

- Are there any national or international agreements/pacts/pledges affecting or limiting potential activity in the region that the company recognizes and respects?

- *If so, what are those agreements? Are they voluntary or mandatory? What were the reasons for the company to recognize and respect those agreements? What aspects of business do they regulate (indigenous communities/environment/etc.)*
- *Does the company consider their activity as an individual impact, or they recognize the collective action approach?*
- *Does the company willing / is ready to comply with international regulations? What are the problematic points if the is "no"?*

- Is it important for the company to be in contact with the local community (local to the area where the business activity is undergoing – in our case – Arctic region)?

- *How do they value and estimate the degree of the impact of their activity on the communities?*
- *Is there some systemic ignorance or the relationship between their activity and community is taken into consideration?*
- *If they appreciate the influence, what does it change in their approach – are there any changes in the way they do business or it's only words?*
- *If so, what are the benefits for business from the collaboration with communities? Are there any cases of the benefits for both sides from the collaboration between business and indigenous/northern community?*

- *Are there any barriers limiting the ability of a company to connect and collaborate with those communities? If so, what are those barriers and limitations, and from the pow of the company what are the possible steps to overcome those issues?*
- *Are there any examples of problems or failures caused by the business activity undertaken without the consideration of the knowledge/interests/needs of the local communities? Have they been recognized and considered by the corporate?*