Aalto-yliopisto
Aalto-universitetet
Aalto University

Master's Programme in International Design Business Management

Geopolitics and Energy Transition in the Baltic Sea Region: A Study on Fossil Road Diesel Market Dynamics

Antti-Mikael Kaljunen

Master's thesis
2024

Aalto-yliopisto
Aalto-universitetet
Aalto University

Author Antti-Mikael Kaljunen

Title of thesis Geopolitics and Energy Transition in the Baltic Sea Region: A Study on Fossil Road Diesel Market Dynamics

Programme Master's Programme in International Design Business Management

Major International Design Business Management

Thesis supervisor Jaakko Jääskeläinen D.Sc. (Tech.)

Thesis advisor Lasse Herttuainen Ph.D.

Collaborative partner Neste Oyj

Date 25.2.2024 **Number of pages** 119 **Language** English

Abstract

This research focuses on the fossil road diesel market within the Baltic Sea Region, taking into account the ongoing global energy transition and the current geopolitical challenges, especially Russia's invasion of Ukraine.

A PESTLE analysis is utilised to explore the interconnected political, economic, societal, technological, legal, and environmental aspects affecting the diesel demand and refining operations in the region.

Key findings reveal a strategic downsizing in conventional refining capacity and a shift towards more sustainable practices within the region's diesel market. The research identifies challenges in adapting to these changes, such as the unpredictable and non-linear nature of the energy transition and policy fluctuations. Additionally, supply and demand analysis highlights the states of surplus and deficit across the region. Moreover, the research underscores the fundamental impact of the Russian invasion of Ukraine and the EU's subsequent ban on Russian crude oil and refined products, which have led to significant changes in trade flows and necessitated major adjustments in crude oil sourcing for some of the regional refiners.

The research offers insights and actionable recommendations for policymakers and industry stakeholders, underlining the need for adaptable, forward-looking strategies in an uncertain environment. The findings also pave the way for further research into the dynamics of the energy transition and diesel market evolution amid geopolitical changes.

Keywords Baltic Sea Region, EU, Crude oil, Diesel, Energy security, Energy transition, Geopolitics, Middle distillates, Oil and gas industry, Oil markets, Oil refining, PESTLE analysis, Supply and demand analysis

Aalto-yliopisto
Aalto-universitetet
Aalto University

Tekijä Antti-Mikael Kaljunen	
Työn nimi Geopolitiikka ja energiasiirtymä Itämeren alueella: tutkimus fossiilisen tieliikennedieselin markkinadynamiikasta	
Koulutusohjelma Master's Programme in International Design Business Management	
Pääaine International Design Business Management	
Vastuuopettaja/valvoja Jaakko Jääskeläinen TkT	
Työn ohjaaja Lasse Herttuainen Ph.D.	
Yhteistyötaho Neste Oyj	
Päivämäärä 25.2.2024 **Sivumäärä** 119	**Kieli** Englanti

Tiivistelmä

Tämä tutkimus keskittyy fossiilisen tieliikennedieselin markkinaan Itämeren alueella, ottaen huomioon meneillään olevan globaalin energiasiirtymän ja nykyiset geopoliittiset haasteet, erityisesti Venäjän hyökkäyksen Ukrainaan.

Tutkimuksessa käytetään PESTLE-analyysiä tutkimaan poliittisia, taloudellisia, sosiaalisia, teknologisia, oikeudellisia ja ympäristöllisiä tekijöitä, jotka vaikuttavat dieselin kysyntään ja jalostustoimintaan alueella.

Keskeisiä löydöksiä ovat fossiilisen jalostuskapasiteetin strateginen lasku ja siirtyminen kohti ympäristöystävällisempiä ratkaisuja Itämeren alueella. Tutkimus tunnistaa haasteita näihin muutoksiin sopeutumisessa, kuten energiasiirtymän ennustamattoman ja epälineaarisen luonteen sekä vaihtelun poliittisissa päätöksissä. Lisäksi kysyntä- ja tarjonta-analyysi korostaa alueen ylijäämän ja alijäämän vaihtelevuutta. Tutkimuksessa käy myös ilmi seuraamukset, kun Venäjä hyökkäsi Ukrainaan ja EU asetti kiellon venäläiselle raakaöljylle sekä jalostetuille öljytuotteille. Tämä johti merkittäviin muutoksiin valmistuotteiden kauppavirroissa ja pakotti osan Itämeren alueen jalostamoista huomattaviin muutoksiin raakaöljyn hankinnassa.

Tutkimus tarjoaa havaintoja ja suosituksia poliittisille päättäjille sekä teollisuuden toimijoille, korostaen adaptiivisten ja proaktiivisten strategioiden tärkeyttä epävarmassa ympäristössä. Löydökset avaavat myös mahdollisuuksia jatkotutkimukselle, erityisesti energiasiirtymän dynamiikan ja dieselmarkkinoiden kehityksen tutkimiselle geopoliittisten muutosten vallitessa.

Avainsanat Itämeren alue, EU, Raakaöljy, Diesel, Energiaturvallisuus, Energiasiirtymä, Geopolitiikka, Keskitisleet, Öljy- ja kaasuteollisuus, Öljymarkkinat, Öljynjalostus, PESTLE-analyysi, Kysynnän ja tarjonnan analyysi

Preface and acknowledgements

First and foremost, my appreciation goes to Neste for providing me with the chance to undertake this thesis project.

My sincere thanks to my thesis supervisor, Jaakko Jääskeläinen, for his invaluable advice and constructive criticism, which have been a source of motivation and guidance throughout this journey. Additionally, I want to recognize the continuous support and direction offered by my advisor, Lasse Hertuainen.

I am also grateful to my peers at Neste for their encouragement and the fruitful discussions that enriched my research.

Furthermore, my deepest thanks to my best friend; having you there from beginning to end meant the world to me. And to my parents, the most unselfish persons I know, who support me unconditionally, success or not. To myself, for not giving up, for making it happen.

Helsinki, 20 February 2024

Antti-Mikael Kaljunen

Table of contents

Abbreviations and acronyms

API	American Petroleum Institute
ARA	Amsterdam-Rotterdam-Antwerp
BEV	Battery Electric Vehicle
BSR	Baltic Sea Region
FAME	Fatty Acid Methyl Ester
CCS	Carbon Capture and Storage
CDU	Crude Distillation Unit
CFPP	Cold Filter Plugging Point
CP	Cloud Point
CO_2	Carbon Dioxide
EEA	European Economic Area
E-fuel	Electrofuel
EIA	Energy Information Administration
ETS	Emissions Trading System
EU	European Union
EV	Electric Vehicle
FCC	Fluid Catalytic Cracking
FCEV	Fuel Cell Electric Vehicle
FF55	Fit for 55
FQD	Fuel Quality Directive
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HDV	Heavy-Duty Vehicle
HEV	Hybrid Electric Vehicle
HICP	Harmonised Index of Consumer Prices
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
IEA	International Energy Agency
JV	Joint Venture
LFO	Light Fuel Oil
LPG	Liquefied Petroleum Gas
LWP	Liquefied Waste Plastic
MDO	Marine Diesel Oil
MK1	Miljöklass 1
Mt	Million tonnes
Mt/a	Million tonnes per year
NCI	Nelson Complexity Index
OECD	Organisation for Economic Cooperation and Development
OPEC	Organization of Petroleum Exporting Countries
PESTLE	Political, Economic, Social, Technological, Legal, and Environmental
PHEV	Plug-in Hybrid Electric Vehicle

PPS	Purchasing Power Standard
RD	Renewable Diesel
RED	Renewable Energy Directive
SAF	Sustainable Aviation Fuel
SnD	Supply and Demand
ULSD	Ultra-Low Sulphur Diesel
VGO	Vacuum Gas Oil

List of figures and tables

1 Introduction

1.1 Background

Global energy has been a journey through different eras: from the coal-dominated industrial revolution, which powered the machinery of rapid industrial growth, to the oil-centric 20th century, where oil emerged as the central pillar of global economies and geopolitical strategies (Coleman, 2012). This historical reliance on fossil fuels has not only sculpted the modern world but also led to significant environmental and geopolitical consequences. As we navigate through the 21st century, the world finds itself at a pivotal point in the history of energy consumption and environmental consciousness. The escalating concerns of global warming and the environmental crisis have triggered a profound shift towards renewable energy sources (IRENA, 2019). Indeed, the recent IPCC report "Climate change 2023" highlights the escalating challenges of climate change and emphasises the urgent necessity for the global community to transition swiftly towards a low-carbon economy (IPCC, 2023).

This transition is more than an environmental imperative; it is a geopolitical and economic recalibration, reshaping traditional energy dependencies and forging new alliances (Geels, 2014). Within this global context, the Baltic Sea Region (BSR) stands as a focal point where these historical trends, contemporary challenges, and future aspirations converge. The region's journey from a fossil fuel-based energy paradigm to a more diverse and sustainable energy portfolio mirrors the global shift but is also uniquely moulded by its geopolitical nuances, especially in light of recent events like Russia's invasion of Ukraine.

The BSR's energy sector, mirroring global trends, has historically been heavily dependent on fossil fuels. This dependency has been a cornerstone of the region's economic development, energy security, and geopolitical alignments. However, the onset of the 21st century has brought forth new challenges and opportunities. On the one hand, there is a growing realisation of the environmental costs associated with fossil fuel consumption, especially in the wake of alarming reports on global warming and climate change. On the other hand, technological advancements have made renewable energy sources more viable, thereby presenting alternatives to traditional energy sources. These global trends are reflected in the BSR's evolving energy landscape, where geopolitical events, such as Russia's invasion in Ukraine, have further complicated the energy equation. These events have not only affected the energy supply chains but have also catalysed a re-evaluation of energy policies and market dynamics within the region, highlighting the need for a comprehensive understanding of the current state and future direction of the BSR's diesel market.

Amidst these transformative changes, this study seeks to decode the complexities of the BSR's diesel market, an endeavour driven by the critical need to understand its evolving dynamics against a backdrop of global energy transition and regional geopolitical shifts. This study is motivated by an emerging discourse on the geopolitics of energy transition, which challenges traditional narratives and explores the various pathways and ramifications of this global shift.

1.2 Scope and research objectives

The scope of this study is BSR, specifically encompassing Finland, Sweden, Norway, Denmark, Estonia, Latvia, Lithuania, and Poland. This selection is distinct from traditional geographical boundaries of the BSR, uniquely including Norway, a non-Baltic Sea bordering country, while excluding Germany and Russia, despite their geographical connection to the Baltic Sea. This scope differs from both the geographical definition of the BSR and the European Commission's strategy for the BSR (European Commission, 2023b), which includes EU countries bordering the Baltic Sea, thus incorporating Germany but excluding Norway and Russia. The study's primary focus is on fossil road diesel, categorised under middle distillates in oil products, with additional insights into bio co-processed road diesel. Biodiesel and renewable diesel, while not the primary focus of the study, are briefly introduced and occasionally mentioned, particularly in the PESTLE analysis, to highlight their influence on the demand for fossil diesel.

The primary objective is to conduct a comprehensive analysis of the fossil road diesel market in the BSR. The study emphasises the impact of geopolitical developments, like Russia's invasion of Ukraine, and the global energy transition on the market. These factors are critical in understanding the changes in oil refining and market dynamics within the BSR, influenced by policies like biomandate adjustments in Sweden and Finland.

This research aims to dissect how the BSR's diesel market is navigating geopolitical pressures and energy transitions, with countries varying in their reliance on Russian energy and commitment to EU climate targets. The study will employ a PESTLE analysis to assess political, economic, social, technological, legal, and environmental factors, alongside operational shifts in refineries, such as closures and adaptations due to the energy transition.

Another key focus of the study is the supply and demand (SnD) dynamics in the BSR diesel market. This includes an in-depth exploration of how market forces, policy changes, and geopolitical events are influencing the current state and future trends of diesel consumption and distribution in the region.

Separately, the study will also delve into the potential electrification of the car fleet in the BSR and its economic implications. This aspect examines how the transition towards electric vehicles (EVs), driven by advancements in technology and environmental policies, might impact the demand for diesel. The exploration will include assessing the readiness and capacity of BSR countries for this transition, and how these changes might reshape the diesel market.

This dual approach, combining specific insights on supply and demand dynamics with a broader analysis of the transition to EVs, is designed to capture the full spectrum of influences steering the region's diesel market amidst transformative times. This methodical exploration is crucial in grasping the complex set of interconnected variables that collectively influence the market's current state and its trajectory towards an uncertain future.

The study will also look into the future outlook of the diesel market, considering the ongoing geopolitical and energy transition trends. This forecast aims to provide stakeholders with insights into potential future scenarios, thereby contributing to informed decision-making in a rapidly evolving energy landscape.

Research Objectives:

- Impact assessment of geopolitical and energy transition factors: Critically assess the impact of geopolitical events, especially Russia's invasion of Ukraine, and the global energy transition on the BSR's diesel market. This includes analysing supply chain dynamics, refinery operations, and market stability.
- Analysis of current state and future prospects: Explore the current state and future trajectory of the BSR's fossil road diesel market through refinery analysis, PESTLE assessment, and supply and demand dynamics.

Research Questions:

- How are geopolitical developments, especially Russia's invasion of Ukraine, and the ongoing energy transition impacting and currently shaping the BSR's fossil road diesel market?
- What are the future implications for the fossil road diesel market in the BSR, in light of ongoing geopolitical shifts and the energy transition?

1.3 Structure of the study

The thesis follows a sequential structure, with each chapter building upon the previous one, to provide a comprehensive insight into the fossil road diesel market in the BSR. It starts with an introduction that sets the stage by outlining the background, scope, objectives, and the central research problem. The second chapter delves into the study's methodological framework, detailing the research strategy, philosophical underpinnings, and data analysis techniques, with a specific emphasis on the PESTLE framework for a holistic market assessment. Chapters 3 and 4 introduce the theoretical foundation for geopolitics, energy transition, oil refining, and oil product markets, laying a comprehensive groundwork for understanding the market's dynamics. The narrative then expands in Chapter 5 to contextualise the BSR's market within the broader European diesel market. A detailed examination of the BSR diesel market follows in Chapter 6, where a thorough PESTLE analysis is combined with an in-depth supply and demand analysis, offering insights into the current state and potential shifts in the market. The final Chapter 7 brings together all these elements, integrating the discussions and conclusions into a synthesis of key findings, future outlook, and contributions to the field, providing a conclusive overview of the study's implications and recommendations for future research.

2 Methods and materials

The chapter outlines the research methodology, encompassing the strategy, philosophical background, data collection, and analysis methods. It details the systematic approach taken to investigate the fossil road diesel market in the BSR, amid geopolitical changes and energy transitions. This methodology section explains how the research will be conducted, providing a framework that ensures the study's findings are robust, reliable, and relevant.

2.1 Research strategy

The research strategy for this thesis is specifically designed to align with the goal of conducting a thorough analysis of the diesel market in the BSR, particularly in the context of the ongoing geopolitical changes and energy transitions. Rooted in qualitative research, this strategy is instrumental in exploring the highly context-specific and intricate issues that define this subject, as emphasised by Paivi and Anne (2008) and Yin (2009). The core of this strategy lies in an in-depth analysis of existing literature, reports, and secondary datasets, chosen for their relevance to the study's complex nature.

At the core of this strategy is thematic analysis, detailed by Braun and Clarke (2006), which serves as a methodical tool for identifying, analysing, and interpreting patterns of meaning within the qualitative data. The versatility of thematic analysis, transcending disciplinary boundaries, makes it particularly effective for energy studies where multifaceted topics are prevalent. This is evidenced in the work of Sovacool and Dworkin (2014), who adeptly utilised thematic analysis in their energy policy research, showcasing its applicability and efficacy in dissecting complex topics. In this study, thematic analysis is employed to extract and articulate coherent themes from the complex dataset, shedding light on the underlying patterns, market dynamics, and the impacts of geopolitical events and energy transitions.

Complementing this, documentary analysis will also be incorporated into the research strategy. This method, as described by Prior (2003) and (Bowen, 2009), involves a systematic examination of relevant documents and texts. It is particularly beneficial in the early stages of the research, where establishing a solid theoretical foundation is essential. By analysing existing literature, reports, and industry documents, a comprehensive overview of the field is gathered, which sets the stage for the in-depth thematic analysis that follows.

This dual approach of thematic and documentary analysis ensures a well-rounded exploration of the topic. It allows for a detailed examination of specific aspects of the diesel market, while also providing a broader understanding of the contextual factors influencing it. This strategy is designed to provide a comprehensive and insightful analysis, contributing valuable perspectives to the field and establishing a solid foundation for future research.

2.2 Philosophical background

The philosophical foundation of this study is primarily rooted in the interpretivist paradigm, which contends that reality is a subjective construct, intricately shaped by human experiences within their social contexts. This perspective is essential for understanding the complex, multifaceted world of lived experiences, particularly from the viewpoints of those immersed in it. Bryman (2016) emphasises that interpretivism prioritises the significance of viewing the world from the perspective of individuals living within it. In the context of assessing geopolitical and energy transition impacts on the BSR's diesel market, this means acknowledging that the phenomena being studied are influenced by the interpretations and meanings that individuals or societies assign to them.

Incorporating the PESTLE framework into this research aligns with the interpretivist approach, allowing for an in-depth understanding of how political, economic, social, technological, legal, and environmental factors are perceived and interpreted within specific contexts. This approach acknowledges that these macro-environmental factors are shaped by human perceptions and interactions, going beyond the view of them as mere external realities (Saunders et al., 2019).

The interpretivist paradigms synergize with the qualitative research strategy and the use of secondary data. As Creswell and Creswell (2014) suggest, the qualitative research strategy, particularly when underpinned by interpretivism, is well-suited to the use of secondary data. This approach in data collection and analysis asserts that existing literature, reports, and datasets are not just seen as sources of factual information but as representations of the various ways in which knowledge about the research topic has been constructed and interpreted. This approach allows for a deep, contextual understanding of the topic, acknowledging that the existing data is imbued with subjective meanings and interpretations.

By adopting this interpretivist lens, the study seeks to unravel the complexities of the BSR's diesel market, particularly in its navigation through geopolitical pressures and energy transitions. This exploration extends beyond objective analysis, examining the many ways in which these dynamics are perceived and reacted to by relevant stakeholders.

2.3 Data collection

The exploration of the fossil road diesel market in the BSR, amid geopolitical and energy transitions, will necessitate a multifaceted data collection strategy. The complexity and evolving nature of the diesel crisis will require gathering a broad array of secondary information. With limited academic literature on such a current issue, the study will extensively utilize diverse secondary sources, including online articles, newspapers, directive information, and political debates.

The study will adopt a desktop-based methodology, in line with the qualitative research strategy. The PESTLE framework will guide the collection of qualitative and quantitative data, enabling an in-depth understanding of the various external factors impacting the diesel market. Documentary analysis will be a key component in this phase, where a systematic examination of existing documents, including governmental publications, industry reports, and legal documents, will provide foundational insights for the study

2.4 Data analysis

This study applies PESTLE framework to analyse the collected data. This analysis offers a comprehensive view of the macro-environmental factors affecting the diesel market. Alongside PESTLE, the thesis employs thematic analysis to identify and interpret patterns within the qualitative data, particularly useful in understanding market nuances. This approach, to be discussed in Chapters 6 and 7, allows a deep exploration of the geopolitical tensions, energy transitions, and market responses. Documentary analysis complements the approach by offering a systematic and contextual examination of the secondary data sources, thereby enriching the thematic insights with a broader understanding of the historical and current market state.

The combined use of thematic, PESTLE, and documentary analyses addresses the inherent limitations in focusing solely on external factors and provide a balanced view encompassing both macro-environmental influences and specific market nuances. The variability of external factors and challenges in data accessibility are tackled through a careful and critical examination of all sources. This comprehensive approach to data handling minimises the risks associated with secondary data analysis and ensures a more robust and in-depth understanding of the diesel market.

This research strategy, which amalgamates thematic and PESTLE analyses with documentary analysis, is instrumental in capturing the multifaceted nature of the diesel market in the BSR. Despite the inherent limitations of relying on secondary data, this approach provides a holistic view of the market dynamics. It effectively synthesises diverse perspectives, facilitates a thorough understanding of the intricate interplay between geopolitical events, energy transitions, and the market's response.

The study's findings, synthesised in Chapter 7, offer valuable insights for a range of stakeholders. The political analysis clarifies how geopolitical tensions impact the market, while economic analysis provides a quantified view of supply and demand dynamics. Social, economic, technological, legal, and environmental analyses offer a multi-dimensional perspective on the factors shaping the market.

3 Geopolitics and energy transition

3.1 Geopolitics

Energy, the cornerstone of modern societies, has always been deeply intertwined with the dynamics of geopolitics. The pursuit of energy resources, their strategic value, and the necessity of guaranteeing their uninterrupted supply have influenced, and continue to influence, international relations, alliances, and at times, even conflicts. As nations steer through the complex terrain of global politics, energy stands out as a dominant theme, especially oil, due to its widespread use and essential role in various sectors.

The interdependence of energy resources and geopolitical power plays a pivotal role in shaping global politics. Energy resources, being paramount for vital functions like electricity generation and transportation, influence the strategic manoeuvres and military prowess of nations (Lehmann, 2017). It is evident that the geopolitics of energy are intertwined with national strategy and conflicts. Any shift in the prevailing political paradigm necessitates a corresponding alteration in energy systems, highlighting that alterations in political equilibrium and energy constructs are mutually inclusive and pivotal for global strategy and conflict resolutions (Lehmann, 2017).

Oil particularly has been an essential component in global geopolitics, symbolizing a cornerstone in political and economic competitions among states, given its status as the most valuable and crucial energy source. The symbiotic relationship between hydrocarbons and geopolitics arises from their essential role in modern economies and the fact that the major consumers often lack sufficient reserves, leading to a reliance on distant, often unstable sources (Painter, 1986). Consequently, to maintain continuous access, major consuming nations form robust relationships with principal foreign suppliers, even employing military intervention to safeguard these countries and the associated supply lines. The scarcity of abundant hydrocarbon sources further fuels competition among energy-importing nations, making the struggle for access to oil and gas a central theme in international relations (Painter, 1986).

In historical context, the intricate relationship between geopolitics and oil has been demonstrated on numerous occasions. Events such as the 1973 Oil Crisis and the fallout from the Iranian Revolution in 1979 among others, have highlighted the critical interplay between political events and the dynamics of the oil market (Yergin, 1991). The geopolitics of oil and gas are underscored by the universal acknowledgment of energy as a strategic commodity, integral to national security, and the geographical disparity between major hydrocarbon sources and consuming nations. Hydrocarbons, mainly comprising oil and gas, are organic compounds made up of hydrogen and carbon, serving as a primary source of energy worldwide. Oil's paramountcy arises from its role as the predominant energy source, essential for multiple sectors including transportation, industry, and warfare, comprising about 38% of total final energy consumption in 2022 (IEA, 2023f). In the transport sector specifically, oil's share was even larger at 91% (IEA, 2023f). As the Center for Strategic and International Studies report stated, oil powers not only vehicles and aircraft but also fuels military capability, national economies, and global politics (Nunn et al., 2000).

Pascual and Zambetakis (2010) also discussed the tension between securing hydrocarbon resources and transitioning to more sustainable energy consumption through efficiency and alternative sources. The financial challenges associated with funding new technologies, as well as addressing the inequities of climate change impacts, are highlighted as emerging focal points in energy geopolitics. Their book chapter also underscores the existential threat posed by volatile oil and gas prices and the imperative of addressing climate change, which paradoxically increases the allure of nuclear power. This shift towards nuclear energy, while offering a low-carbon alternative, simultaneously heightens the risk of nuclear proliferation and the potential for materials and technology to fall into the hands of terrorists. Addressing these multifaceted challenges necessitates a comprehensive understanding of the fragility of international oil and gas markets and the interconnectedness of energy security, climate change, and nuclear issues.

With the ongoing transition in global energy systems, the rise of renewables, and the imperative of decarbonization, the geopolitical dynamics are evolving in the new energy landscape. Blondeel et al. (2021) emphasizes the shift in focus from concerns about security of supply to addressing the challenges and opportunities presented by renewable energy, and the transformation of geopolitical dynamics associated with this shift in their study. The increasing role of renewables in global power generation, coupled with the rise of electrification, is presented as a transformative force reshaping the geopolitics of energy. The study also highlights the vulnerabilities introduced by the digitalization of critical energy infrastructure and stresses the importance of addressing these challenges to ensure a secure and sustainable energy future.

Russia's invasion of Ukraine

The territorial dispute between Russia and Ukraine over Crimea and Donbas escalated on February 24th, 2022, when Russia invaded Ukraine. This conflict, which began in 2014, has inflicted not only human tragedies but has also significantly influenced global financial and energy markets. Historically, military confrontations have led to market volatility due to heightened investor uncertainties. Given Russia's status as a top exporter of oil, gas, and coal, the 2022 conflict has notably disrupted energy markets (Du, Li and Wang, 2022). For the oil markets, the invasion introduced a fresh layer of unpredictability and potential disruption (Fattouh and Economou, 2022).

The International Energy Agency (IEA), founded in 1974 in the aftermath of the 1973 oil crisis, plays a pivotal role in safeguarding global energy stability, particularly during geopolitical tensions and supply challenges (IEA, 2022c). It consists of 31 countries, predominantly members of the Organisation for Economic Cooperation and Development (OECD), with many from the European Union, alongside countries from North America, Europe, Asia, and Oceania. Member nations are obligated to hold oil reserves that cover at least 90 days of their net imports, ready for potential collective deployment during critical supply deficits. Throughout its history, the IEA has initiated five collective responses to significant events, including the Gulf War, the disruption from Hurricanes Katrina and Rita, the Libyan Civil War, and the Russia-Ukraine conflict in 2022 (IEA, 2022c). This collaborative approach demonstrates the intricate relationship between geopolitics and energy security in the global oil market.

The IEA, with its extensive mandate across diverse energy resources, directly influences the diesel sector through its interventions. The agency's stipulation that member nations maintain oil reserves can, during crises, help stabilise diesel markets given that diesel is a refined product of crude oil. Furthermore, the IEA's regular market analysis reports provide crucial insights into the diesel market's health, trends, and projections, enabling policymakers and industry leaders to make informed decisions. Especially during geopolitical upheavals, the IEA's data-driven insights become pivotal in guiding the diesel market's response and ensuring its stability.

It is worth noting that before the recent conflict, the global economy had already been shaken by the 2020 COVID-19 pandemic, with the maritime and aviation industries being particularly affected (Du, Li and Wang, 2022). Consequently, there was a drop in demand and prices for oil products, such as diesel and jet fuel. However, prior to the recent war, oil prices had been steadily increasing due to tighter fundamentals, primarily driven by the recovery in oil demand following the post-pandemic shock. Along with the surge in oil prices, hydrogen and gas prices were on the rise as well, adding to the cost shock for the refining companies (Fattouh and Economou, 2022).

Following the conflict, abnormally high returns were seen for both renewable and traditional energy indexes, with the former experiencing a more significant effect. Around the time of Russia's invasion of Ukraine in February 2022, there was a significant spike in Northwest Europe diesel, North Sea Brent, and Urals prices, as illustrated in Figure 1, with diesel prices showing the most significant increase. As a response to the conflict, several Western nations have imposed sanctions and ceased trade with Russia, which inevitably impacts energy prices, affecting both consumers and governments alike. This surge in prices, particularly for diesel, underscores the volatile nature of energy markets in times of geopolitical unrest. Coordinated international efforts are needed to resolve the situation to put a stop to further damage. The rise in renewable energy indexes show that investors are favouring clean and renewable energy sources. This highlights the urgency for policy-makers and regulatory authorities to formulate strategies and guidelines that support the shift towards sustainable energy solutions (Du, Li and Wang, 2022).

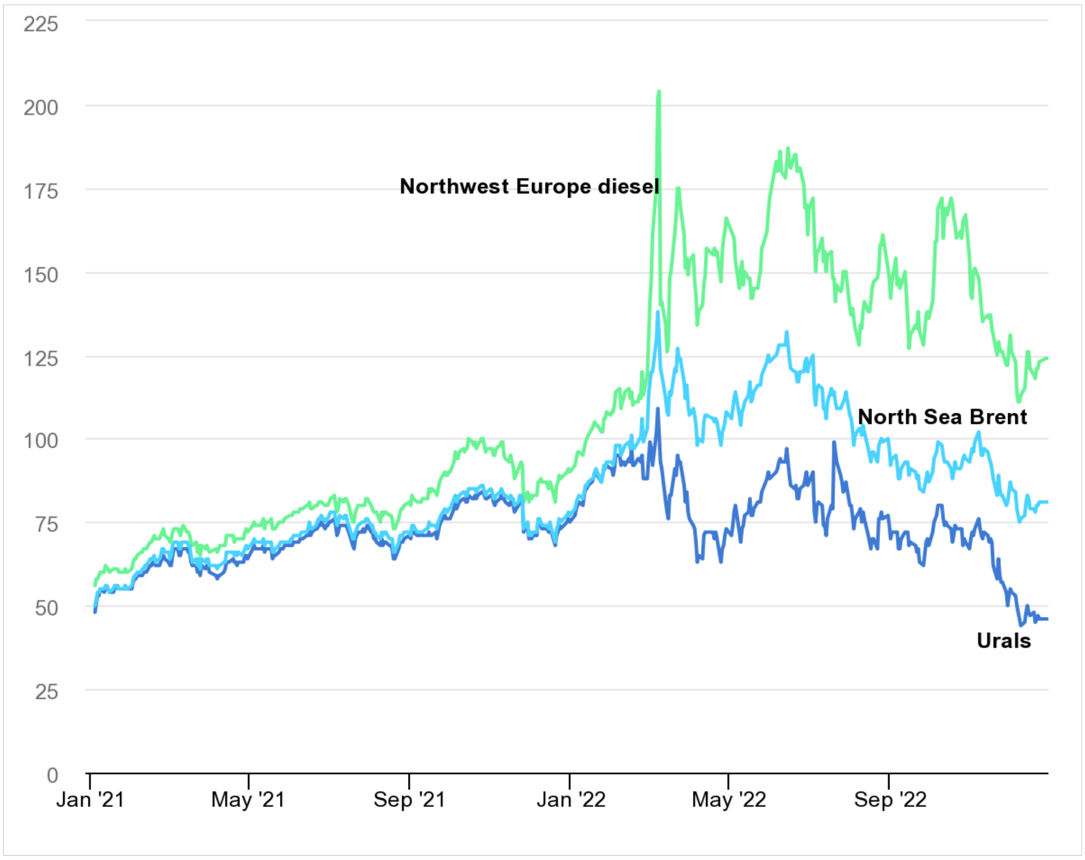


Figure 1: Prices for Brent, Urals crude and diesel in Northwest Europe, 2021-2022 (IEA, 2022b)

In response to Russia's actions, the European Union, in collaboration with global partners, implemented a series of sanctions and trade restrictions. These measures, especially those focused on the energy sector, have profoundly influenced the dynamics of the diesel market. This study will further explore the conflict's specific impacts on the diesel market in the subsequent sections.

Conclusion for geopolitics

Geopolitics, emphasizing the interplay between geographical factors and political relations, has profound implications for the dynamics of energy markets, including oil, petroleum, middle distillates, and notably, diesel. Energy geopolitics has long stood at the intersection of power, strategy, and resource allocation, playing a pivotal role in shaping global relations and national priorities. The intrinsic connection between energy and geopolitics stems from the fundamental need for energy resources to fuel economies, maintain national security, and ensure societal wellbeing. Resource distribution, geopolitical events, regulatory positions, and trade intricacies can exert substantial influence over supply, demand, and pricing in these markets. Entities like the Organization of Petroleum Exporting Countries (OPEC), with their influence over oil prices, underscore the vast control some organizations can maintain over the global market. At the same time, significant events, from the Arab Spring to the Iranian nuclear sanctions and, more recently, the Russia-Ukraine conflict, highlight the potential for rapid market changes driven by geopolitics.

In the context of the diesel market, geopolitical shifts present distinct challenges and opportunities. These challenges often arise from aspects like environmental regulations, regional disagreements, and international trade tensions, which can apply pressures on pricing, distribution, and supply chain dependability.

As the global political and geographical scenario evolves, grasping these multifaceted interactions becomes crucial. Stakeholders in the energy sector, particularly those in the diesel market, must stay adaptive, educated, and necessitate strategic foresight, collaborative approaches, and innovative solutions to address the complex challenges and harness the opportunities that lie ahead.

3.2 Energy transition

In our ever-changing world, we are confronted with challenges that demand attention in the forthcoming decades. Among these, the issue of climate change stands out. Shifting towards a low-carbon future necessitates fundamental amendments in how we generate, trade, and distribute energy (Hafner and Luciani, 2022).

The energy transition embodies a delicate balance between global and local perspectives. While climate change demands a unified international approach and collaboration to tackle its widespread challenges, it also underscores that there isn't a one-size-fits-all answer (Hafner and Luciani, 2022). Instead, a variety of tailored solutions is essential (Hafner and Luciani, 2022). The global energy system is undergoing a significant transformation and contends with considerable uncertainties. Its impact is expansive as energy profoundly influences various domains such as the economy, security, the environment, and geopolitics (Bazilian and Howells, 2019). The concept of “energy transition” is still evolving and is not fully formed. Traditionally, it has been perceived to involve changes in national energy supplies or the identification of novel energy sources, but contemporary interpretations also incorporate transformations in the markets providing energy and changes in the devices utilizing the energy (Bazilian and Howells, 2019).

The transition can take many forms, such as a swift reduction in costs of renewable energy systems like wind and solar or the development of innovative business models and contractual frameworks (Bazilian and Howells, 2019). In the context of this thesis, a relevant example is the transition to low-carbon energy. This encompasses extensive electrification and a move towards a more efficient transportation system (Kagawa et al., 2021).

Historically, renewable energy sources like wind and biomass were utilized by humans over many centuries. Yet, by the end of the 20th century, their contribution to modern industrial economies was minimal, with fossil fuels, such as oil, natural gas, and coal, making up nearly 90% of the global energy mix (Aklin and Urpelainen, 2018). In 2000, the IEA predicted that despite rapid growth, non-hydroelectric renewables would only account for 3% of global energy by 2020. However, this estimate was surpassed already by 2010, a decade earlier than forecasted, with renewables comprising 5% of global energy consumption. By 2017, the once-dismissed renewables had shown remarkable growth, particularly in the electricity sector (Aklin and Urpelainen, 2018). The history of renewable energy utilization provides context for understanding the current global landscape. However, in recent years, geopolitical events have played an equally significant role in shaping the energy narrative and influencing transitions. In Europe, the Russian invasion of Ukraine, as detailed in the previous geopolitics section, has acted as a catalyst for an accelerated energy transformation. It's evident that shifts in energy sources are influenced not just by environmental or economic factors but also by concerns of energy security, which directly impacts national security.

Despite the known issues associated with fossil fuels, modern industrial economies remain heavily reliant on them. The dominant presence of fossil fuels since the industrial era has led to a carbon lock-in (Aklin and Urpelainen, 2018). This concept describes the systemic barriers favouring fossil fuel systems despite their environmental drawbacks and when similarly priced, or even cheaper, solutions are available (Aklin and Urpelainen, 2018). However, it is important to note that the cost-effectiveness of alternatives can vary significantly across sectors. For instance, while wind and solar power have become competitively priced for electricity generation, renewable transportation fuels remain more expensive than their fossil-based counterparts. To genuinely address climate change, eliminating counterproductive subsidies and incorporating the environmental costs of fossil fuel usage into economic calculations is crucial. Moreover, energy generation is predominantly centralized, for example, in transportation, while individual vehicles consume fuel, the extraction and refining of primary fuels, notably oil, is still a centralized process controlled by major oil corporations (Aklin and Urpelainen, 2018).

Fossil fuels have historically benefited from extensive investments and technological breakthroughs, establishing them as economically competitive energy sources (Aklin and Urpelainen, 2018). In contrast, renewables face initial uncertainties in returns and technological barriers. Additionally, the environmental toll of traditional energy, such as pollution and greenhouse gas (GHG) emissions, isn't adequately factored into consumer prices, making renewables less competitive in the absence of measures like carbon taxes. Furthermore, the centralized nature of the fossil fuel industry has fostered significant political influence, creating entry barriers in the energy market and resisting policy shifts toward renewable energy (Aklin and Urpelainen, 2018). This trio of economic, environmental, and political challenges epitomizes the complexities of the carbon lock-in phenomenon (Aklin and Urpelainen, 2018).

As a result of the carbon lock-in, dependence on fossil fuels has made transitioning to renewable energy extremely challenging. Unless key stakeholders anticipate a shift away from fossil fuels, systematic change remains difficult. Given the foundational role of fossil fuels in industrialization, an external shock is likely needed to catalyse the growth of renewables. This refers to a significant, unforeseen event that arises independently of government policy interventions.

The oil price spikes in 1973 and 1979 acted as catalysts that prompted governments, previously sceptical or uninterested, to explore renewable energy. Subsequent challenges with nuclear energy, e.g., Chernobyl in 1986, increased the appeal of renewables in the eyes of many political groups. Even after renewables had started making strides, the Fukushima nuclear disaster in Japan gave the sector an additional boost (Aklin and Urpelainen, 2018). Moreover, the recent Russian invasion of Ukraine can be seen as another such external shock, emphasizing the urgency of energy transition.

While this thesis focuses primarily on the diesel market, it's important to acknowledge the broader energy landscape's dynamics. Advancements in battery technologies, improvements in grid infrastructure, and innovations in renewable energy sources are reshaping the energy market, affecting traditional fossil fuels, including diesel.

Among the sectors affected by this shift, transportation stands out prominently. Particularly, the diesel market, which is the central focus of this thesis, plays a significant role in this sector. Given the substantial contribution to global emissions, addressing transportation's carbon footprint is paramount. In developed economies, transportation is responsible for roughly 30% of CO_2 emissions (Arizcuren-Blasco, Martin-Garcia and Ruiz-Rua, 2023). Global agreements target halving CO_2 emissions by 2050. The Paris Agreement on Electro-Mobility emphasizes the need to have a fifth of all road transport vehicles electric by 2030 to keep global warming under 2°C (IEA, 2023c). The European Environment Agency highlighted in 2021 that many cities surpass the recommended air quality limits. Consequently, cities are progressively transitioning towards greener transport to adhere to regulations and environmental goals. Public transportation is viewed as a more eco-friendly urban mobility solution (Arizcuren-Blasco, Martin-Garcia and Ruiz-Rua, 2023).

Electrification of passenger cars is accelerating, and there are also emerging solutions for heavier vehicle classes. Using buses as an example, various technological alternatives to diesel buses exist, such as battery-electric buses, hydrogen fuel cell buses, and synthetic fuels. However, battery-electric buses are currently the most feasible option. Electric buses are efficient: they can be charged based on fixed routes, harness kinetic energy during braking, and consume minimal energy when stationary (Arizcuren-Blasco, Martin-Garcia and Ruiz-Rua, 2023).

Accelerating the shift towards a sustainable energy future requires effective policy and fiscal measures. Green taxation, in particular, plays a pivotal role in expediting the shift to a more sustainable economy and achieving the goals outlined in the Paris Agreement (Tomás et al., 2023). These taxes internalize the societal costs associated with the production and consumption of goods and services, prompting immediate eco-friendly actions by businesses (Tomás et al., 2023). Over time, they also stimulate innovation, steer investments towards greener technologies, and become a revenue source for governments. Leading institutions like the European Commission, OECD, and the International Monetary Fund advocate for an increased amount of environmental taxes for prevailing tax structures (Tomás et al., 2023).

Building on this, green taxation, often referred to as environmental taxes, are seen as important fiscal tools used by governments. Their goal is to factor in the costs of pollution from activities like industry and transport. By putting a price on environmental damage, these taxes encourage companies and individuals to reduce their negative impact or pay for the damage they cause. In theory, green taxes are an effective way to handle pollution. Those who can't reduce their harmful actions have to pay for them. While many praise this system for its flexibility, some environmentalists worry that richer companies might just pay and keep polluting. Looking back, green taxes became more popular during the environmental movements of the 70s and 80s (Schaffer, 2021). Over the years, global organizations have supported their wider use. When well-designed, these taxes can address many environmental issues, from climate change to waste management. However, deciding on their design and how to put them into action is often a topic of debate (Schaffer, 2021).

Building on this foundation, specific measures targeting the transportation sector have been introduced, given the significant contribution to global emissions. Numerous nations have turned to market-driven policy measures (Yoo, Koh and Yoshida, 2020). These include financial incentives, which might translate to reductions in vehicle taxes or the costs of vehicles, thereby motivating consumers to choose eco-friendlier vehicle options. Adjustments in fuel tax policies act as a disincentive, encouraging reduced driving habits. Additionally, subsidies are being offered to make vehicles running on alternative fuel sources, like hybrids and EVs, more affordable for consumers (Yoo, Koh and Yoshida, 2020).

Academic literature has started to explore the geopolitics of the energy transition. The potential variability in energy transitions underscores the criticality of strategic policy decisions in the upcoming decade, aiming to mitigate conflicts and promote equitable outcomes (Bazilian and Howells, 2019). Navigating these transitions seamlessly requires a holistic perspective that goes beyond mere technological considerations. It demands multilateral agreements, the allocation of ample funding, and the fostering of collaborative efforts (Bazilian and Howells, 2019).

Conclusion for energy transition

As the world undergoes a pivotal energy transition, the geopolitical intricacies that have long shaped the traditional energy markets are now merging with new dynamics driven by renewable and sustainable sources. This intersection is profoundly impacting the global energy landscape. The increasing global commitment to renewable energy not only offers an environmental relief but also reshapes traditional energy power structures, offering both challenges and opportunities.

The diesel market, long influenced by geopolitical factors, is now further complicated by this transition. Stakeholders navigating these waters will need to reckon with not only the legacy of past geopolitical decisions but also the emerging frameworks of a world leaning into renewable energy. As the Russia-Ukraine conflict has shown, geopolitical events can have immediate and transformative impacts on global energy markets. Similarly, as we venture deeper into an era marked by energy transition, events promoting or obstructing this shift will hold comparable influence.

For the energy sector to thrive in this dual era of geopolitical tension and transformative energy transition; adaptability, foresight, and innovation are paramount. Stakeholders must continuously refine their strategies to stay ahead of both the geopolitically-induced fluctuations and the waves of change brought about by our global commitment to a sustainable energy future.

4 Introduction to oil refining and products

This section focuses on oil refining and its associated product markets as they are crucial to comprehend the diesel market dynamics. It starts with examining the crucial role of crude oil. Next, the refining process is outlined, highlighting the transformation of raw materials into tradable commodities. The co-processing and its industry implications are also introduced. Additionally, important terminologies and products are presented for clarity. Finally, the essentials of middle distillate markets are covered, preparing for deeper analysis of the European and BSR diesel markets.

4.1 Crude oil

Introduction to petroleum and crude oil

In today's world, oil continues to be a fundamental resource. It serves dual purposes: firstly, as a source for energy and fuel production, and secondly, as a precursor for the synthesis of plastics and various other commodities. Etymologically, “petroleum” originates from the Latin words “petra” and "oleum", translating to “rock oil”. This term encapsulates hydrocarbons found abundantly in sedimentary formations, manifesting as gases, liquids, semi-solid substances, or solids (Speight, 2011).

In the realm of hydrocarbon resources, the terms “petroleum” and “crude oil” are frequently used synonymously (Gad, 2024). Both references naturally derived, combustible liquid rich in hydrocarbons. However, a more detailed understanding defines “petroleum” as the overarching category encompassing both the raw form extracted from the Earth (crude oil) and its variety of refined derivatives, such as gasoline, diesel, and other petrochemical products. Within industry-specific contexts and documentation, “petroleum” often conveys the broad spectrum of hydrocarbon-based commodities, whereas “crude oil” strictly denotes the untreated material procured from beneath the Earth's surface.

Characteristics and classification of crude oil

Crude oil characteristics vary depending on their geographical origin as seen in Figure 2 below. Two critical attributes to consider are the sulphur content and the oil's density, which offers insight into its hydrocarbon composition (Speight, 2011). Crude oils that are less dense are termed “light”, while those with greater density are labelled “heavy”. Likewise, “sweet” refers to crude oils with minimal sulphur content, whereas those rich in sulphur are categorized as “sour” (Leffler, 2020). Crude oil's density is often measured using the American Petroleum Institute (API) gravity scale. In this system, a higher API number indicates a lighter oil (Banks, 2007). Typically, lighter crude oils are more expensive because they are easier to process and yield more high-value products such as gasoline and diesel.

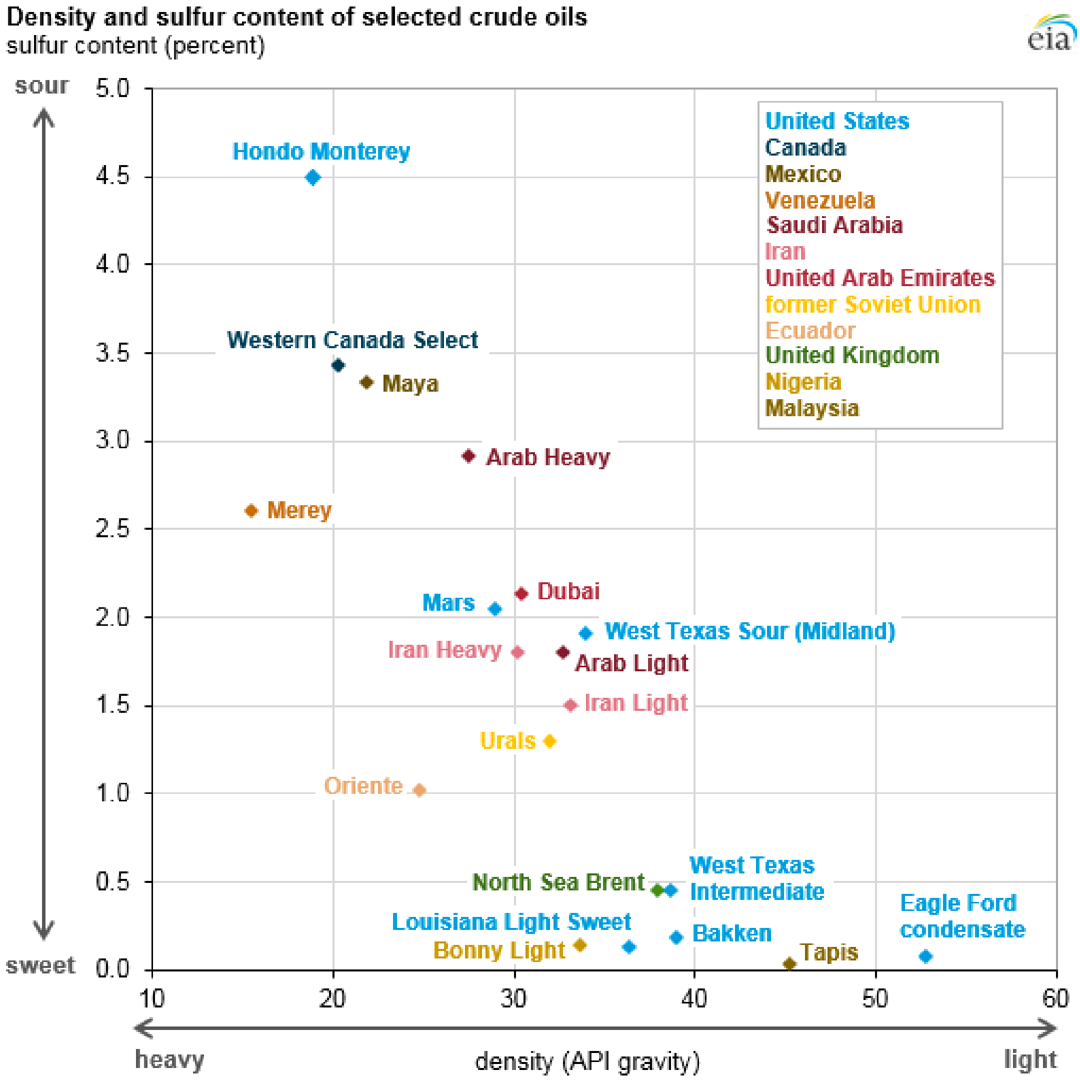


Figure 2: Density and sulphur content of selected crude oils (Ricker, Barron and Hamilton, 2017)

Crude oil pricing dynamics

To understand the diesel market, grasping the dynamics of crude oil markets is critical, as crude oil is the primary raw material for diesel fuel. The primary determinant of petroleum product prices is the cost of crude oil, frequently serving as the pivotal element influencing price fluctuations. The crude oil pricing structure mirrors the general equilibrium of the market (Speight, 2011). Specifically, when there's an oversupply leading to diminished crude oil prices, the prices of petroleum products concurrently drop. Conversely, elevated crude oil prices, indicative of undersupply or heightened demand, correlate with increased petroleum product prices. Should the crude oil price experience a consistent upward or downward shift, such a movement will invariably resonate in the product markets, assuming other variables remain constant.

History and influence of OPEC

OPEC, established in 1960, was created to provide oil-producing countries a collective voice in crude pricing, but its most influential role began in 1973 when it acted as a cartel to control prices. By the early 1970s, with the U.S.'s diminished role in crude oil production, OPEC's influence in the market grew, and in 1973, the organization significantly increased prices. Ever since, OPEC has aimed to stabilize prices by controlling the production volumes to match the market demand. One of the key reasons why OPEC continues to have significant influence over crude prices is that it is holding the majority of the world's surplus capacity (Conaway, 1999).

Historical context and global trends in oil production

Oil refining remains integral in our daily lives, even amidst energy transition. While alternative energies are gaining traction, a majority of transport vehicles still rely on processed fuels like gasoline, diesel, and aviation fuel.

Major refineries last constructed in both Europe and the U.S. date back to the mid-1970s. Since then, the focus has primarily been on shutting down or modernizing pre-existing facilities (Carollo, 2011). In contrast to the trends observed in the U.S. and Europe, Asia and the Middle East have continued with the establishment of new refineries in recent decades. This is likely driven by the anticipated growth in oil products demand in developing regions like Asia, whereas demand in Europe and the U.S. is expected to decline due to the energy transition.

Factors affecting oil prices and economy

Oil prices and their fluctuations have been integral to understanding economic developments and geopolitical events. Research has concluded that oil prices have historically been influenced by supply and demand shocks primarily stemming from geopolitical events and unexpected economic developments, reflecting and simultaneously impacting the state of the real economy (Hamilton, 1983, Mork, 1989, Kilian and Hicks, 2013).

Hamilton (1983) and Mork (1989) have illustrated the interdependent relationship between oil price growth rate and the gross national product growth rate, revealing that oil prices have a negative effect on gross national product growth when increasing, and almost zero effect in the opposite direction, emphasizing the macroeconomic ramifications of oil price movements.

Understanding the historical volatility in oil prices and its implications is crucial, as it provides insights into the multifaceted relationship between oil prices, economic growth, and geopolitical events, offering insights on the oil & gas industry's performance.

Key factors in the oil market

According to (Hosseini, Shakouri G and Peighami, 2016), the oil market is primarily influenced by three long-term factors: fundamental, technical, and political. Fundamental elements dominate the long-term market direction. They encompass oil supply and demand dynamics, futures contract volumes and prices, spare capacities, strategic oil reserve levels, the extent of oil replacement by alternatives like renewables or nuclear, and technological advances in oil exploration and extraction. Technical elements mostly affect short-term market shifts; these encompass storage capacities for oil and its derivatives in refineries and state-owned facilities, transportation limitations, and infrastructure constraints. Political elements consist of terrorism, wars, and sanctions, and the impact is typically short to medium term (Hosseini, Shakouri G and Peighami, 2016).

Various factors influence the oil production levels of both OPEC countries as well as nations outside of OPEC. One key determinant is the inherent production rates of these groups. Additionally, OPEC's available spare capacity plays a substantial role. Global economic indicators, such as the world's Gross Domestic Product (GDP), often serve as an indicator for energy demand, thereby affecting production. The volume of globally proven oil reserves can also steer production strategies. The tangible market value or real price of oil, mirroring economic situations and market perceptions, holds significant influence. Furthermore, the strategic oil inventories held by OECD nations can shape worldwide production choices based on energy security considerations and demand projections (Hosseini, Shakouri G and Peighami, 2016).

Similarly, to the factors influencing production, there are several determinants shaping the oil demand patterns in both OECD countries and those not part of the OECD. Among these are global economic metrics, notably the GDP, which can significantly influence energy needs. The energy intensity, which measures the energy consumption relative to economic output, is another critical determinant. The consumption rate of alternative energy sources to oil can also shift demand dynamics. Inventory levels of crude oil and petroleum products in refineries often reflect and respond to market demand, while the actual market value of oil provides insights into its desirability. Finally, how efficiently refineries utilize their capacity can indicate the balance between demand and supply in the market (Hosseini, Shakouri G and Peighami, 2016).

Oil companies' categorization

Oil companies can be broadly categorized based on their integration and ownership. Integrated companies operate across the entire oil value chain, from oil exploration to selling refined oil products to consumers. This vertical integration can boost value creation by combining profits from both upstream (exploration and production) and downstream (refining and distribution) activities. It also offers a buffer against market fluctuations, as one segment might perform well when other faces challenges. On the other hand, independent companies specialize in just one segment, for example, the upstream. These entities tend to be smaller and more open to exploration risks (Hafner and Luciani, 2022).

Companies can also be classified as national or international. National oil companies are often majority or solely state-owned, while international oil companies like ExxonMobil and BP are publicly traded and operate in multiple countries (Hafner and Luciani, 2022). Despite their differences, collaboration among these companies is common due to the high risks and costs of exploration. They often form Joint Ventures (JVs) to distribute risks. Within these JVs, a Joint Operating Agreement is signed, outlining roles, financing rules, and decision-making processes. The company designated as the 'operator' within the JOA manages and represents the JV in its interactions with the state and other entities (Hafner and Luciani, 2022).

Oil industry supply chain structure

The supply network, often referred to as the supply chain, embodies a cohesive system where all involved parties collaboratively ensure the delivery of goods or services. When looking at the crude oil sector, it is commonly divided into three primary segments: upstream, midstream, and downstream (Sahebi, Nickel and Ashayeri, 2014). The upstream phase encompasses the discovery, extraction, and movement of crude oil to refining facilities. Midstream focuses on the conversion of crude oil and the production of related products in refineries and petrochemical facilities. Meanwhile, the downstream phase handles post-production activities, such as warehousing and delivering products to end users. Sahebi, Nickel and Ashayeri (2014) state that each of these phases houses different entities:

- Upstream: entities like the wellhead, drilling platforms, extraction platforms, and crude collection terminals.
- Midstream: refining facilities and petrochemical processing centres.
- Downstream: storage hubs, retail outlets, and the end consumer.

Figure 3 shows the oil & gas value chain in more detail. This comprehensive visualization further emphasizes the interconnectedness of these segments and the diverse activities within each.

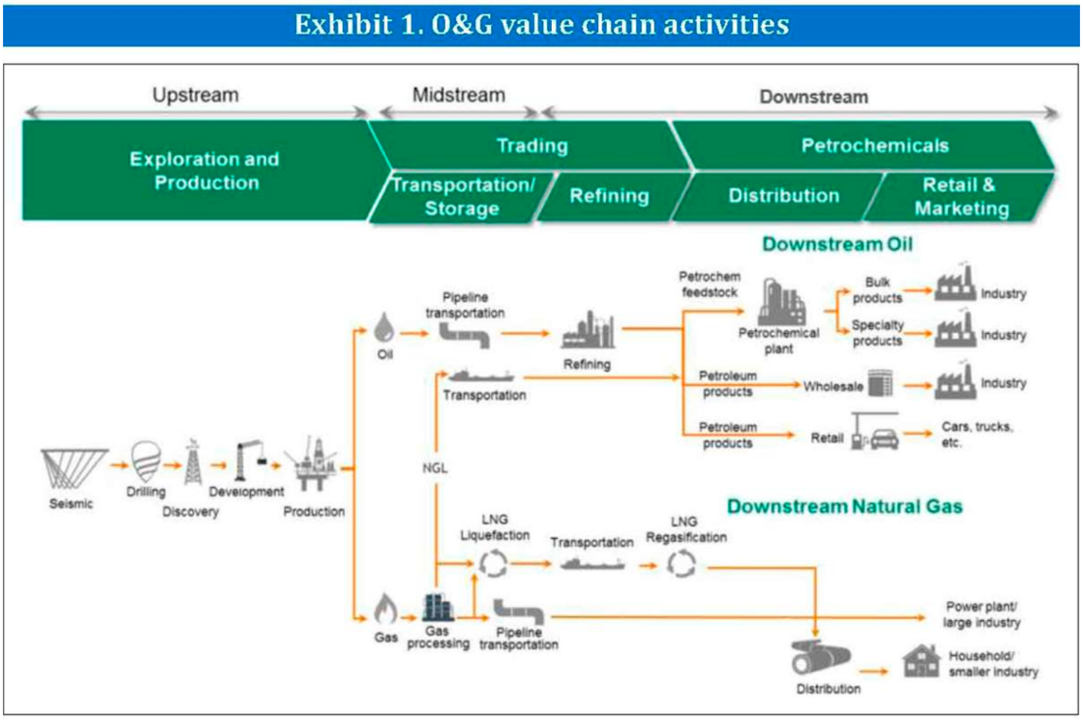


Figure 3: Oil and gas value chain activities (Álvarez et al., 2018)

However, Lima, Relvas and Barbosa-Póvoa (2016) note variations in how this division is approached. While the three-segment division is common, as outlined above, another interpretation positions the midstream segment primarily in terms of transporting crude oil to terminals and storage facilities. An alternative division simplifies the structure further by distinguishing only between upstream and downstream. In this briefer categorization, the downstream segment encompasses the tasks of refining and petrochemical operations, integrating activities traditionally associated with the midstream phase. Some companies are termed "integrated" as they merge roles from multiple segments, encompassing two or even all three of these classifications.

By identifying the distinct segments of the supply chain, one can strategically position companies within various facets of the industry's value chain. Given the emphasis on middle distillates, this thesis predominantly focuses on the midstream and downstream sectors of the oil supply chain, underscoring their roles in the processing and distribution of these products.

4.2 Crude oil refining

The petroleum refining sector transforms crude oil into an array of products. These include gasses, naphtha, gasoline, kerosene, jet fuel, diesel, various fuel oils, lubricants, wax, asphalt, and raw materials for petrochemical processing (Speight, 2011). The fundamental characteristics of petroleum-derived products are inherently determined by the attributes of the individual hydrocarbons present within the composition

Finished diesel fuel products are blended from desulphurization gas oils, encompassing desulfurized, desulfurized and dewaxed, or desulfurized, dearomatized, and dewaxed streams. Moreover, to make the products commercially viable the refiners utilize chemical reactions, blending of different components, as well as by the use of additives (Fahim, Al-Sahhaf and Elkilani, 2009). Additives are used to enhance attributes like lubricity or conductivity, depending on the requirements.

Fuels originating from petroleum contribute to over fifty percent of the global energy provision. Gasoline, diesel, and kerosene serve as primary energy sources for vehicles, such as cars, agricultural machinery, airplanes, and maritime vessels. Additionally, fuel oil and natural gas play pivotal roles in residential and commercial heating, and in electricity generation. Moreover, derivatives of petroleum are integral in the production of synthetic textiles, plastics, coatings, fertilizers, pesticides, detergents, and synthetic rubber (Speight, 2011).

Refinery operations commence with the intake and storage of crude oil, progressing to dewatering and desalting. Subsequent handling and refining steps follow these initial processes. The sector utilizes an extensive range of methodologies, with the choice of processes being influenced by the crude oil's composition and the desired array of petroleum products (Speight, 2011).

The fundamental procedure in refining is distillation, which facilitates the separation of crude oil components. Crude oil comprises a diverse array of hydrocarbons. The primary purpose of this initial refining step is to segregate these components by heating the crude oil in a distillation column. During this process, various products evaporate and are collected at distinct temperature ranges. Lighter products such as liquefied petroleum gas (LPG), naphtha, and straight run gasoline are isolated at the lowest temperatures. Following these, middle distillates like jet fuel, kerosene, home heating oil, and diesel emerge. Ultimately, the fractions with the highest molecular weights, such as residual fuel oil and residuum, are extracted. Subsequent to crude distillation, there are intricate processing stages, employing a range of sophisticated units tailored to distinct upgrading processes, aimed at generating optimal lower molecular weight derivatives (Speight, 2011). Figure 4 shows typical refinery processes.

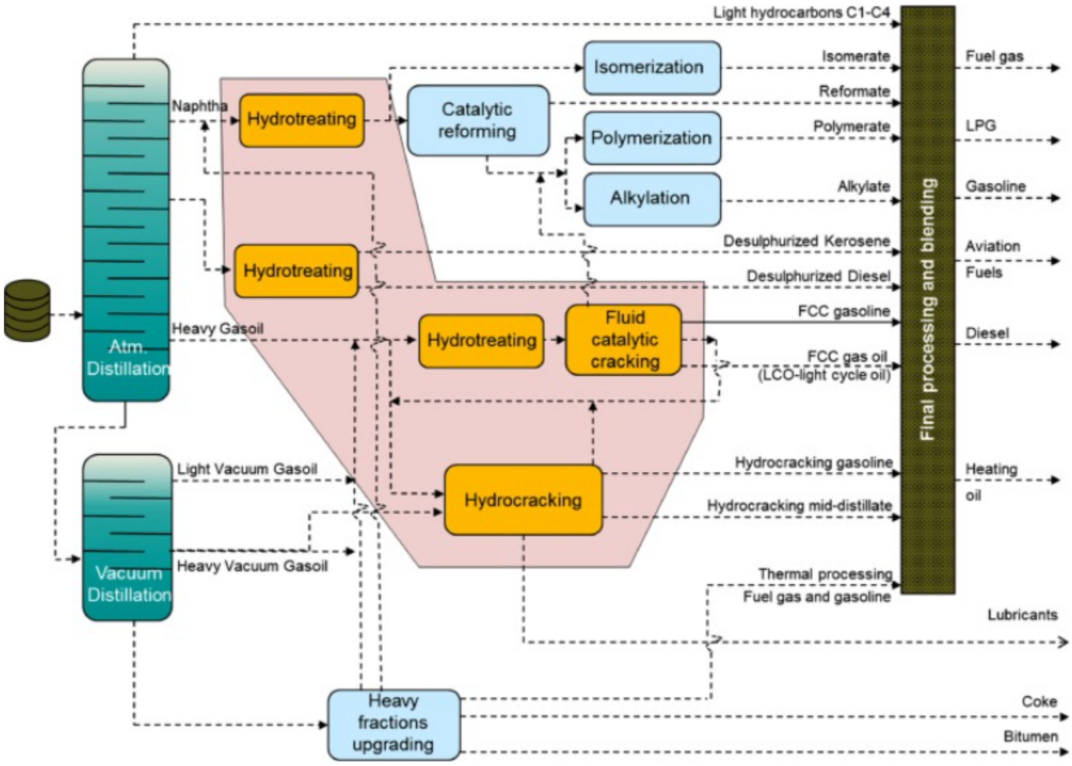


Figure 4: Typical refinery scheme (Bezergianni et al., 2018)

A refinery comprises a collection of interconnected production units, the number of which correlates with the diversity of output (Speight, 2011). These units are strategically chosen to ensure an optimal production of marketable products, aligning with the market needs and opportunities.

Speight (2011) states that the petroleum refining sector has been influenced by four primary dynamics that impact numerous industries and have expedited the evolution of novel refining methodologies:

1. The market demand for products, including gasoline, diesel, fuel oil, and aviation fuel.
2. Variabilities in feedstock supply, notably shifts in crude oil quality, geopolitical interplays among nations, and the introduction of alternative feed sources like bitumen from tar sands.
3. Evolving environmental mandates, particularly those that impose stricter limits on sulfur content in gasoline and diesel.
4. Advancements in technology, encompassing the development of innovative catalysts and processing techniques.

Refinery operations have historically evolved in response to the dynamic landscape of crude supply patterns and the demands of the product market. Modern refineries have embraced intricate configurations to amplify their yields particularly in the production of high-value fuels from low-quality fractions and residues (Speight, 2011). While the specific configuration can differ among refineries, some are mainly focused on gasoline production, emphasizing processes like reforming or catalytic cracking. In contrast, others may lean more towards producing middle distillates like jet fuel and diesel.

A modern refinery is a complex, integrated facility focused on transforming crude oil into a wide variety of products, ranging from transportation fuels and lubricants to residual fuel oils and other derivatives. Speight (2011) notes that based on their setup, refineries can be categorized as:

1. **Topping refinery:** The foundational configuration, primarily serving petrochemical feedstock preparation or industrial fuel production in secluded oil-producing regions. They predominantly yield unfinished oils, closely aligned with local market demands.
2. **Hydro skimming refinery:** Evolved from topping refineries, the addition of hydrotreating and reforming units yields a more adaptive configuration. It facilitates the production of desulphurization distillate fuels and high-octane gasoline. However, they may produce significant volumes of residual fuel oil, confronting market challenges with growing demand for low sulphur fuels.
3. **Catalytic cracking and coking refineries:** A highly versatile and modern refinery configuration. Encompassing all foundational units from the previous categories, they also integrate gas oil conversion plants (like catalytic cracking and hydrocracking units), olefin conversion plants (such as alkylation or polymerization units), and coking units to diminish residual fuel production. These refineries predominantly yield gasoline, complemented by liquefied petroleum gas, jet fuel, diesel fuel, and minimal coke amounts. They often employ solvent extraction for lubricant production and petrochemical units to extract compounds like propylene, benzene, toluene, and xylenes, facilitating their further conversion into polymers.

Fahim, Al-Sahhaf and Elkilani (2009) have also introduced a way for categorizing refineries, segregating them into three tiers: simple, complex, and ultra-complex, according to their configuration complexity. Simple refineries are typically equipped with a crude distillation unit, a reforming unit, and middle distillate hydrotreating units. Complex refineries add to this configuration, incorporating conversion units like hydrocrackers and fluid catalytic crackers, thereby broadening the range of possible refined products. The most advanced type, ultra-complex refineries, includes all units found in complex refineries plus deep conversion units that transform atmospheric or vacuum residue into lighter products, maximizing the yield of high-value refined products.

Refineries, in their quest to stay relevant and efficient, have transformed into complex systems, adapting and redefining their configurations based on the ever-evolving market demands and crude supply scenarios (Speight, 2011).

Speight (2011) explains that the economic sustainability and feasibility of a refinery operation depend on how well several pivotal components work together:

1. Crude oil slate selection: choosing different types of crude oil for processing.
2. Refinery complexity: the level of complexity and advancement in the refinery's setup.
3. Product mix: the variety and quality of products a refinery plans to produce.
4. Operational intensity: an indicator of how much of the refinery's total capacity is being utilized.
5. Environmental implications: taking into account ecological constraints and considerations.

Opting for the pricier, lighter, and sweeter variety of crude oil necessitates minimal refinery modifications. However, as the availability of this light, sweet crude oil diminishes, the price disparity with its heavier, sourer counterparts widens. The economical appeal of utilizing the more affordable heavy oil is counteracted by the needed investments in more sophisticated upgrading techniques. It's essential to compare the investment costs and payback periods for refining equipment with anticipated crude oil expenses and the emerging price differences between light and heavy crude types. In the future, the sector must increasingly upgrade its infrastructure to meet several objectives (Speight, 2011):

1. The production of ultra-low-sulphur variants of gasoline and diesel.
2. Integration of ethanol and alternate biofuels into standard gasoline and diesel.
3. Minimization of environmental impacts associated with refinery activities.

Moreover, to avoid the build-up of non-marketable products and ensure continual operation efficiency, it is crucial for refineries to maintain operational flexibility and adapt their processes according to changing circumstances.

Transactions in the oil and gas industry, such as purchasing crude oil and selling refined products, are measured in various units including metric tons, cubic meters, and especially barrels in the United States, where one barrel is approximately equal to 158 litres (Fahim, Al-Sahhaf and Elkilani, 2009).

As for the refining expenses, processing crude oil with a high sulfur content means elevated energy costs. In general, energy contributes to nearly half of the total refining expenditure (Speight, 2011). Moreover, the geographical placement of a refinery influences costs; positioning closer to both the crude source and consumption points can substantially reduce transportation costs. Additionally, the size of the refinery, its complexity, its capacity utilization, and environmental factors all affect the refining costs (Fahim, Al-Sahhaf and Elkilani, 2009).

Refining companies continuously strive to process low-cost crude oil while selling the refined products at higher prices, aiming to achieve an optimal refining margin (Banks, 2007). This refining margin is a critical indicator in the oil and gas industry, reflecting the profit earned per unit of crude oil processed.

Refining margins are categorized into three types according to Fahim, Al-Sahhaf and Elkilani (2009): gross margin, net margin, and cash margin. Gross margin is the difference between the value of refined products and the cost of crude oil. From gross margin, when variable refining costs are subtracted, we get net margin. Finally, by deducting fixed costs from net margin, the cash margin is determined. A refinery is deemed profitable with a positive cash margin. However, a low refining margin doesn't always indicate poor performance, as a refinery might produce intermediate products for further processing at another facility, showcasing the synergistic benefits of owning multiple refineries.

Interestingly, the industry-specific terminology clouds the fundamental issues related to oil allocation and product pricing, leading to uncertainty. Moreover, numerous economists struggle to clarify oil and its product pricing dynamics without advanced mathematical models. Consequently, complex equations emerge, which, to industry professionals, may not align with their hands-on understanding of oil dynamics.

4.3 Diesel fuel

In the complex landscape of oil refining and product markets, terms and definitions can vary significantly across different regions and contexts. It is important to understand the distinctions between terms such as diesel, gasoil, middle distillate, and distillate fuel. This section also introduces the main product in focus for this thesis: fossil road diesel, while also providing additional insights on bio co-processed road diesel and light fuel oil (LFO). All of these products fall under the category of middle distillates.

To begin, it is good to note that a product from one refinery can be used as an input for another, undergoing further upgrading to enhance its value. This can create ambiguity between what constitutes raw materials and finished products. However, this thesis narrows its focus to the finished products that can be used for retail and final end-use distribution.

Middle distillates are an important subgroup of the petroleum product range, positioning between lighter products like naphtha and gases and heavier products like fuel oil in the crude oil refining process. Predominantly, middle distillates encompass diesel fuels for road and marine transport, heating oils, as well as aviation fuels such as jet fuels, and kerosene, all of which are obtained from the fractionation of crude oil during the refining process. Within the spectrum of middle distillates, one term that often stands out and requires a further explanation is “gasoil”.

Gasoil, a term widely recognized in international trading and across various regions, represents a range of both intermediate and finished oil products. This name originates from the process where the fuel undergoes vaporization from its crude state, later condensing back into liquid form (Leffler, 2020). The product spectrum of gasoil is extensive, aligning mainly with distillation profiles similar to diesel or vacuum gas oil (VGO). Finished products under this classification include diesel fuel, heating oil, and marine diesel oil (MDO). In the European Union regulatory language, the terminology around gas oil also encompasses a broad range of fuels. Moreover, road fuels with low sulphur content are often designated as diesel fuels, while fuels with higher sulphur content, used for non-road machinery and marine vessels, are referred to as gas oils.

The precise definition of gasoil can shift based on its application and regional terminology, and in some areas, it might be used interchangeably with diesel. In the futures market, contracts labelled as gasoil are used to hedge a diverse range of distillate fuels, extending far beyond road diesel. Moreover, while gasoil can encompass a variety of products or a combination of products, in contexts like international trade and certain regions outside the U.S., it may also specifically refer to automotive diesel fuel (Leffler, 2020).

Another source of confusion arises from the interchangeable use of the term middle distillates and gasoil. In Germany, for instance, middle distillate directly corresponds to what many recognize as gasoil (Oiltanking, 2015). This can be very misleading, as jet fuel, for instance, is a middle distillate but does not fall under the gasoil category. It can be said that while all gasoils are middle distillates, not all middle distillates are gasoils.

The term distillate fuel oil used in the U.S. adds complexity to the already rich terminology surrounding diesel, gasoil, and middle distillates. The Energy Information Administration (EIA) uses the term distillate fuel oil to describe specific petroleum fractions stemming from conventional distillation processes. This general classification encompasses both diesel fuels and fuel oils. The categorization further breaks down into various numbered designations, such as No. 1, No. 2, and No. 4, each specifying distinct uses and properties. In addition, the terms distillate fuel oil and middle distillate are used interchangeably, as indicated by a study from the U.S. Congressional Research Service. These terms are further broken down into diesel fuel and fuel oil. Distillate fuel oil serves two primary purposes: (1) as diesel fuel, it powers trucks, buses, automobiles, and machinery for construction and farming; (2) as fuel oil, it is used for space heating and provides energy for commercial and industrial applications (Ryan, 2023).

Diesel quality requirements in the EU

Focusing on fossil road diesel, the most important product for this thesis, we will now dig deeper into the quality standards in the EU, while also accounting for the seasonality aspects that are particularly relevant in Nordic regions.

To begin with, it is good to note that both the EU and the US have progressively tightened sulphur content standards in road diesel to address environmental concerns and improve air quality. As a result, Ultra-Low Sulphur Diesel (ULSD) grades have become pivotal. With the EU setting sulphur content at 10 mg/kg (Srivastava and Hancsók, 2014) and the US at 15 mg/kg, ULSD now stands as the standard road diesel in these regions, showcasing the commitment to environmental considerations.

European Union (EU) member states are obligated to follow The Fuel Quality Directive (FQD), which is a regulatory measure implemented by the European Union to ensure the environmental and health standards of transport fuels. Established in 1998, the directive's primary goal is to guarantee fuel compatibility with engines and exhaust aftertreatment systems, promoting uniformity across EU member states. By standardizing fuel quality, the FQD also seeks to prevent trade barriers within the EU and ensure seamless cross-border vehicular movement (European Commission, 2017). The FQD applies to gasoline, diesel and biofuels used in road transport as well as gas oil used in non-road-mobile machinery. For a fuel such as diesel, the FQD can be seen as a minimum quality requirement for a diesel sold in the EU. The FQD requirements can be seen in the Table 1:

Table 1: Environmental specifications for market fuels to be used for vehicles equipped with compression ignition engines (European Commission, 2017)

Parameter (1)	Unit	Limits (2)	
		Minimum	Maximum
Cetane number		51,0	—
Density at 15 °C	kg/m (3)	—	845,0
Distillation:			
— 95 % v/v recovered at:	°C	—	360,0
Polycyclic aromatic hydrocarbons	% m/m	—	8,0
Sulphur content	mg/kg	—	10,0
FAME content — EN 14078	% v/v	—	7,0 (3)

(1) ►M6 ● ◄

(2) The values quoted in the specification are 'true values'. In the establishment of their limit values, the terms of EN ISO 4259:2006 'Petroleum products — Determination and application of precision data in relation to methods of test' have been applied and in fixing a minimum value, a minimum difference of 2R above zero has been taken into account (R = reproducibility). The results of individual measurements shall be interpreted on the basis of the criteria described in EN ISO 4259:2006.

(3) FAME shall comply with EN 14214.

▼M5 ●

The FQD mandated a reduction of at least 6% in the carbon footprint of transport fuels by 2020. Furthermore, it required suppliers to consistently monitor and report their GHGs. This directive, in conjunction with the Renewable Energy Directive (RED), governs the sustainability of biofuels (European Commission, 2020a).

In addition to the FQD, the EN590 standard, established by the European Committee for Standardization, further defines the specifications for diesel fuel used in road vehicles within the European Union and the European Economic Area (EEA). It ensures uniform diesel fuel quality by addressing specific technical parameters such as density, viscosity, lubricity, and cold properties, among others. Compared to FQD, EN590 provides more detailed technical specifics to ensure fuel compatibility with modern engines. EN590, though widely adopted, is not a binding legislation like the FQD. However, compliance with the EN590 standard is often a condition for car manufacturers to offer additional assurances or warranties for engines. In the transport fuel sector, diesel that meets EN590 standard is sometimes labelled as "EN590 diesel".

EN590 winter grade diesel

Cold temperature performance is a vital quality aspect for automotive diesel fuels. Certain heavier molecules in diesel can solidify in temperatures ranging from 0 to -20°C, a condition often seen in colder or even moderate climates (Favennec, 2001). Solidifying of diesel fuel can lead to clogged fuel lines, engine starting difficulties, reduced efficiency, and potential engine damage.

Cloud Point (CP) indicates a temperature when a cloud can be seen in the liquid diesel caused by the formation of the wax crystals. Additionally, the Cold Filter Plugging Point (CFPP) represents the temperature at which wax crystals in the diesel obstruct product flow through a filter (Favennec, 2001). In simple terms, the CP represents the lowest temperature at which diesel can be stored without forming wax crystals, while the CFPP indicates the coldest temperature at which diesel can be used to operate a vehicle without clogging the fuel filter.

The EN590 standard defines six distinct climate grades for diesel fuel (Grade A-F), each characterized by its CFPP measure. These can be seen in Table 2. For example, in Western and Central Europe, from the start of December to the end of February, winter diesel is required to meet Class F specifications (Suarez-Bertoa, 2017). In Scandinavia, the cold property requirements can be much more demanding compared to the rest of Europe (Favennec, 2001).

Table 2: Temperate climatic zones (Suarez-Bertoa, 2017)

temperate climatic zones

Characteristics	Class A	Class B	Class C	Class D	Class E	Class F	Units
CFPP	+5	0	-5	-10	-15	-20	°C
Density at 15 °C	820 - 860	820 - 860	820 - 860	820 - 860	820 - 860	820 - 860	kg/m³
Viscosity at 40 °C	2 - 4,5	2 - 4,5	2 - 4,5	2 - 4,5	2 - 4,5	2 - 4,5	mm²/s
Cetane index	46	46	46	46	46	46	
Cetane number	49	49	49	49	49	49	

Besides the six temperature climate grades, there are also five distinct Arctic Classes (Class 0-4) defined by varying attributes, as seen in Table 3.

Table 3: Arctic climatic zones (Suarez-Bertoa, 2017)

arctic climatic zones

Characteristics	Class 0	Class 1	Class 2	Class 3	Class 4	Unit
CFPP	-20	-26	-32	-38	-44	°C
Cloud point	-10	-16	-22	-28	-34	°C
Density at 15 °C	800 - 845	800 - 845	800 - 845	800 - 840	800 - 840	kg/m³
Viscosity at 40 °C	1,5 - 4,0	1,5 - 4,0	1,5 - 4,0	1,4 - 4,0	1,2 - 4,0	mm²/s
Cetane index	46	46	45	43	43	
Cetane number	47	47	46	45	45	

For these climate dependent requirements flexibility is given to allow for seasonal grades to be set nationally (Suarez-Bertoa, 2017). This flexibility results in notable variations in requirements between countries.

It is essential for those seeking information about the EN590 standard to refer to the most recent version. The standard was revised in 2023, which included, for example, a modification to the minimum density of Class E diesel, now set at 815 kg/m³ rather than the earlier 820 kg/m³, as detailed in Table 2. To access the comprehensive details of these revisions, it is typically necessary to purchase the document from the European Committee for Standardization or an authorized distributor.

With a thorough understanding of the specifications and standards for road diesel, we can now shift our attention to light fuel oil (LFO), another product under the umbrella of middle distillates. While LFO and road diesel share similar production processes and quality attributes, their applications and tax treatments differ significantly.

LFO can be produced from identical high-quality components as road diesel. For example, in Finland, LFO meets the European quality standard EN590 for diesel fuel. LFO is not used for road transportation due to its lower tax rate compared to road diesel. A red dye distinguishes LFO from road diesel to prevent misuse (Neot, 2023).

LFO has many use cases. It serves as an effective heating solution for both residential and industrial structures. Additionally, it powers off-road machinery, such as agricultural harvesters and equipment used in mining and various industries. Industrial plants and power stations often keep it on hand as a backup or emergency fuel source. Furthermore, it is utilized for fuelling ships (Neste, 2023b).

Subsequently, we will briefly introduce diesel variants such as biodiesel, renewable diesel, and bio co-processed diesel, all of which incorporate bio-based components. Although this thesis does not primarily concentrate on products such as renewable diesel, it remains an essential diesel category, as it is replacing fossil diesel demand due to environmental considerations. Additionally, it is frequently mixed with fossil diesel.

Biodiesel:

Biodiesel, often categorized as a first-generation biofuel, is predominantly made from fatty acid methyl ester (FAME). This type of biofuel is primarily derived from vegetable oils through the transesterification process, utilizing crops such as sunflower, rapeseed, soy, and jatropha. The reliance on energy crops has sparked the “food vs. fuel” debate due to potential impacts on food supply and prices (Bezergianni and Dimitriadis, 2013). Additionally, biodiesel faces quality constraints, limiting its blend in conventional diesel to 7-10% to meet B7 and B10 specifications, with the remainder being fossil diesel (Puricelli et al., 2021). The quality criteria for biodiesel are specified by the EN14214 standard (Douvartzides et al., 2019).

Renewable diesel:

Renewable diesel is a next-generation diesel fuel derived from biomass (Douvartzides et al., 2019). Unlike traditional biodiesel, it has a similar molecular structure as conventional fossil diesel (Koul, Kumar and Singh, 2022). As a result, this paraffinic drop-in biofuel can be utilized directly in existing refining and distribution systems without any modifications. Moreover, vehicles with standard engines can use these fuels in their neat form directly, without requiring any mixture with other fuels (Julio et al., 2022).

There are primarily two technological pathways utilized for producing renewable diesel: hydroprocessing and thermochemical methods, which include pyrolysis and gasification (Julio et al., 2022). In the industry, the renewable diesel derived from hydroprocessing is often referred to as hydrotreated vegetable oil (HVO), and it is common to see the terms renewable diesel and HVO used interchangeably. However, HVO is actually a specific category within the broader spectrum of renewable diesels (Julio et al., 2022).

Hydroprocessed renewable diesel does not contain aromatics and sulfur and has superior characteristics to conventional diesel, such as its elevated cetane number (Koul, Kumar and Singh, 2022). Additionally, renewable diesel offers enhanced cold weather performance compared to biodiesel (Douvartzides et al., 2019). Quality requirements for renewable diesel and other paraffinic fuels are defined in the EN15940 standard. (Douvartzides et al., 2019).

Additionally, the EN15940 standard is particularly significant in Finland, as it enables a tax reduction for paraffinic diesel. This is because paraffinic diesel meeting the EN15940 requirements is recognized as an environmentally superior, clean-burning fuel, largely due to its minimal sulfur and aromatic compounds content. Furthermore, paraffinic diesel fuel can contain both fossil and renewable components. Having a thorough understanding of standards like EN590 and EN15940, along with the associated tax incentives, can be highly profitable for the producer and provide a competitive edge, especially if they can effectively capitalise on and optimize their operations accordingly. Furthermore, this knowledge can act as an entry barrier against competition in the market.

Renewable diesel can be fully produced from waste and residues, including used cooking oils and animal fats (Bezergianni and Dimitriadis, 2013), ensuring it doesn't compete with food resources and offers a more sustainable fuel alternative. In addition to its other benefits, renewable diesel significantly reduces GHG emissions when compared to conventional fossil diesel (Grönman et al., 2019). The EU’s RED II mandates that renewable diesel, along with other bioliquids used in transportation, must meet sustainability and GHG criteria to contribute toward the EU’s renewable energy goals (EU Science Hub, 2018). Neste, the world’s largest producer of renewable diesel refined from waste and residues, states that their product can achieve a GHG emissions reduction of 75 to 95% across the fuel's life cycle, in comparison to conventional fossil diesel (Neste, 2023e).

Bio co-processed diesel

Bio co-processed diesel is another innovative approach to produce diesel fuels, integrating bio feedstocks with traditional refining processes. Unlike biodiesel and renewable diesel, which are produced through separate processing routes, bio co-processed diesel is created when bio feedstocks are co-processed in conventional fossil refinery process units (Bezergianni et al., 2018). This method allows for the direct production of diesel fuel that contains a biocomponent.

The production of bio co-processed diesel involves feeding small amounts of bio-based feedstocks, such as vegetable oils or animal fats, directly into the refinery's hydroprocessing units. This process results in a diesel fuel that has the potential to reduce GHG emissions compared to conventional diesel (Bezergianni et al., 2018). Bio co-processing will be further introduced in the next section.

4.4 Bio co-processing

Bio co-processing is an innovative method integrating bio-based feedstocks, such as vegetable oils and waste fats, into existing petroleum refinery units alongside conventional fossil feeds. While traditionally involving a small portion of bio-feedstocks, there is variability in the extent of bio-feedstock integration, with some industry players potentially reaching larger quantities. Since the 1970s, there has been a growing recognition of the need to transition away from traditional energy sources such as diesel and other crude oil-derived fuels, driven by concerns about their price volatility, and negative environmental impact (Konur, 2021). In response, this has led to the exploration of alternative, more sustainable energy solutions, among which biofuels have been identified as one viable option.

While biofuels can be produced in dedicated facilities like stand-alone biorefineries, which generate products such as renewable diesel, the bio co-processing approach offers an alternative way to incorporate bio-streams into the refinery (Bezergianni et al., 2018). This method utilizes biogenic feedstocks like oleochemicals and lipids derived from vegetable oils, animal fats, and waste oils. Lipids, broadly speaking, are organic compounds that include fats, oils, and certain vitamins. They are not only readily available commercially but are also compatible with existing conventional refinery infrastructure and processes, thereby making them an immediate solution in the transition (van Dyk et al., 2022).

Moreover, the integration of biogenic feedstocks into existing petroleum refineries through bio co-processing has potential to reduce GHG emissions (van Dyk et al., 2022) and reliance on fossil fuels. The adoption of bio co-processing is on the rise, with an increasing number of refineries now producing fuels with reduced carbon intensity, leveraging existing infrastructure to enhance the sustainability of fuel production (Bezergianni et al., 2018, van Dyk et al., 2022).The extent of GHG reductions largely depends on the choice of feedstock for biofuel production and the specific production processes used (Mellios and Gouliarou, 2021).

In Figure 5, the concept of bio co-processing is envisioned in Concawe's 'Vision 2050 for the refining system as an energy hub within an industrial cluster':

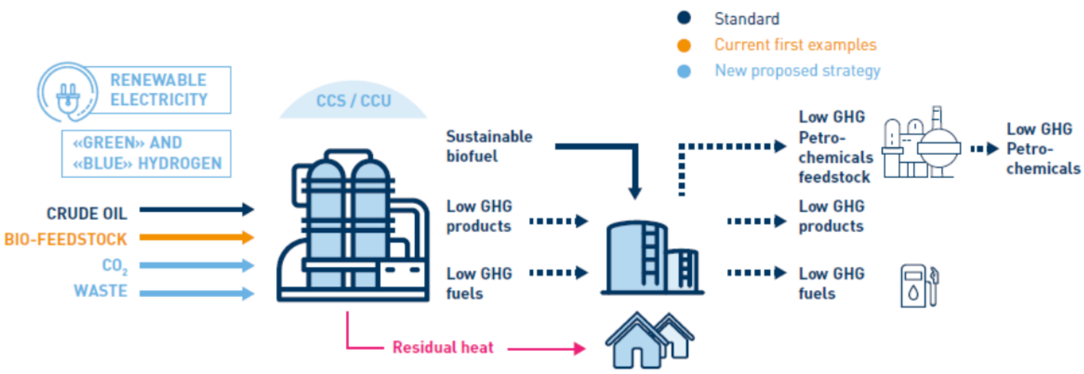


Figure 5: Vision 2050 of the refining system as an energy hub within an industrial cluster (Gudde, Larivé and Yugo, 2019).

Two primary technologies exist for co-processing biomass feedstocks with conventional petroleum fractions: catalytic hydroprocessing and fluid catalytic cracking (FCC) (Bezergianni et al., 2018). Regarding conversion technology in the bio co-processing landscape, there are a couple of approaches to note. Firstly, a dedicated lipids hydrotreater unit. This method involves either creating specific units for lipid processing or transforming an existing refinery process unit to handle 100% lipid feed. However, such conversions may pose concerns regarding capacity losses. Secondly, there's the lipid co-processing method. This strategy assumes that technically suitable hydrotreaters can co-process up to 30% lipids. The realization of this potential largely depends on economic incentives that promote bio-content, in turn driving process upgrades and technological advancements (Gudde, Larivé and Yugo, 2019).

To harness the full potential of biogenic feedstocks, refineries are adopting various strategies. Incorporating pre-treatment steps, for instance, helps in removing contaminants that might hinder the co-processing. Companies like Preem are pioneering modifications in refinery operations to optimize the co-processing of diverse biogenic feedstocks. Furthermore, while hydrotreaters currently dominate the bio co-processing landscape, FCC units may gain traction as more biocrudes become available. The flexibility of these units allows for efficient bio co-processing, adjusting to the feedstock's nature and desired output (van Dyk et al., 2022).

To further examine the potential raw materials for bio co-processing, a spectrum of triglyceride-rich substances including both edible (such as palm, rapeseed, soybean, and sunflower oils) and non-edible oils (e.g., jatropha) are considered viable for producing high-quality fuels. Importantly, residual feedstocks like used cooking oil and waste animal fats represent valuable sources (Bezergianni et al., 2018). Waste and residues are promoting resource efficiency and supporting the circular economy. Not only do they help mitigate the environmental impact by reducing the need for virgin raw materials, but they also lead to products with lower lifecycle emissions compared to those derived from virgin vegetable oils or fossil alternatives.

While oleochemicals and lipids have their advantages, there is a need for diversification in feedstock sources to achieve the long-term goal of sustainability. Biocrudes are one option, especially those derived from lignocellulosic material through technologies like thermochemical liquefaction. Although they are not yet commercially widespread, they may have potential in the future. Once challenges related to their variability and potential impacts on refineries are addressed, they can play a pivotal role in further reducing carbon intensity (van Dyk et al., 2022). In addition, while the focus of this discussion has been on bio co-processing utilizing biogenic feedstocks, it is worth noting that co-processing can also utilize feedstocks such as liquefied waste plastics (LWP).

Lastly, as the transportation industry explores sustainable alternatives to fossil fuels, there are also other options in the category of liquid transportation fuels, such as electrofuels (e-fuels). These are synthetic fuels, generated from CO2 and water using electricity, and may potentially replace some fossil and biofuel demand. The viability of e-fuels depends on the cost-efficiency of electrolysers and electricity, and currently their production costs remain high compared to most fossil and biofuels (Brynolf et al., 2018).

However, first-generation biofuels, such as biodiesel and bioethanol, derive from energy crops. This origin can restrict their environmental advantages concerning GHG emissions and also result in compatibility issues with traditional fossil fuels and combustion mechanisms (Bezergianni et al., 2018). Furthermore, their production can compete with food crops for land, leading to economic and social concerns. In contrast, advanced biofuels, derived from non-food feedstocks like agricultural residues, algae, and waste biomass, present a more sustainable solution. These biofuels do not compete with food production.

Biofuels can also be produced in “stand-alone” biorefineries like FAME biodiesel, bioethanol, and HVO (Bezergianni et al., 2018). Most capable “stand-alone” refineries can produce advanced drop-in biofuels for the aviation industry as well. Finnish Neste is an example of a company who produces renewable diesel as well as sustainable aviation fuels (SAF) (van Dyk et al., 2022).

4.5 Basics of diesel markets

In the previous sections we explored many of the major drivers of middle distillate markets. The global economy stands as a cornerstone, with its fluctuations shaping energy consumption patterns and consequently, the demand for middle distillates. OPEC and its power to influence price and supply dynamics in the oil market was also discussed.

Regarding the energy transition, it is clear that the push towards sustainable energy sources is reshaping traditional fossil fuels markets in the future, including middle distillates and diesel. Our discussions on geopolitics have underscored the inherent risks and price volatilities brought about by global tensions and events. Additionally, unexpected challenges such as pandemics, labour strikes, and supply chain disruptions can drastically disrupt the market. As we move forward, it's crucial to view the middle distillate markets through the lens of these multifaceted drivers, each interconnected with the other, shaping the market's trajectory.

Nevertheless, before diving deeper into the middle distillate market analysis, it is important to grasp the fundamental concepts and some of the key market terminology related to this industry. The forthcoming section is designed to equip readers with the foundational knowledge required to navigate the subsequent chapters.

Market types and contracts

In the oil industry, products like diesel are traded in various forms, including immediate transactions known as spot sales, future delivery agreements termed as term contracts, and bulk deals referred to as wholesale transactions. In spot sales, the product is handed over on the spot. Term contracts outline scheduled deliveries over a period of time. Wholesale transactions involve oil products being sold in large quantities at a reduced price, with the purchaser typically reselling to smaller-scale customers.

From their origins in the 1800s in the U.S., futures markets have evolved and expanded dramatically. Initially focusing on agriculture and metals, the introduction of technology, global economic shifts, and the oil crisis in the 1970s spurred rapid growth in these markets (AgEcon search, 1983). Today, futures markets span the globe, offering a wide range of opportunities for hedging and speculation. These encompass a diverse range of commodities, financial instruments, and even stock indices, reflecting the intricate and interconnected nature of the modern global economy.

Futures markets are organized platforms where instead of immediate delivery, commodities are traded for future delivery. Transactions can be canceled before the delivery date. The main instrument for trade is the futures contract, which binds a party to buy or sell a commodity at a fixed price on a specific future date. This contract can be sold before its expiration, allowing investors to lock in prices or make profits based on market movements (AgEcon search, 1983). To better understand the mechanics, let's consider a hypothetical scenario.

If one buys a futures contract in May at $80 per unit, set for November delivery, they can either take the product delivery in November or sell the contract before the delivery date. If the November price is $100.00 per unit, the contract will yield a profit of $20 per unit. Similarly, if a company buys a futures contract for a commodity in May and the market price of that commodity rises by November, the company can benefit by selling the futures contract at the higher price while procuring the actual commodity they need from the spot market (AgEcon search, 1983).

In the past, diesel did not have its own dedicated futures market. As a result, futures contracts for heating oil were used as a proxy since both are middle distillates, and their prices were closely correlated. However, with the introduction of ULSD contracts, diesel has gained more direct representation in futures markets. Today, companies can hedge directly against diesel price fluctuations using ULSD futures contracts (AgEcon search, 1983).

Though diesel's representation in futures markets has evolved, it is but one of many energy-related contracts traded globally. Today, a diverse range of energy futures contracts are traded on global exchanges. Key contracts include Brent crude oil on the ICE, WTI crude oil and ULSD on the CME Group's NYMEX, and gasoil on the London Commodity Exchange. The ULSD contract, in particular, is significant as it closely reflects modern diesel fuel standards and has a strong price correlation with diesel fuel (AgEcon search, 1983).

The dynamics of futures markets are driven by a variety of participants, each with their own objectives and strategies (AgEcon search, 1983):

- Hedgers, who seek protection against unfavourable price changes for commodities they deal with.
- Large traders, who are professional money managers.
- Speculators, who attempt to profit by taking leveraged market positions, often absorbing the risks hedgers avoid.

The spot market is where petroleum products are traded for immediate delivery. Prices in spot markets indicate the supply and demand balance (Speight, 2011). Due to its immediate nature, the spot market can be volatile, reflecting the real-time dynamics of the global oil industry. The futures markets and the spot markets are intrinsically linked. While the futures markets rely on the spot market during the finalization or execution of a contract, futures trading also influences the direct trading of crude oil.

Within these markets, various types of contracts are utilized, each serving specific purposes and offering different advantages. Term contracts represent pre-established agreements to deliver the product at a predetermined price and schedule. These contracts detail the commitment to both the price and the delivery period ahead of time (European Central Bank, 2007). With term contracts, companies may strategically secure a significant portion of their sales for the upcoming year through these yearly agreements. By doing so, they ensure a consistent revenue stream while allocating a smaller percentage of their sales for the more flexible and more opportunistic spot market.

On the other hand, spot transactions refer to immediate exchanges of a product that don't fall under any ongoing supply agreement. Such spot transactions can sometimes be less transparent in nature, as they often lack a centralized mechanism for reporting and can frequently be kept confidential between parties (European Central Bank, 2007). These transactions, however, offer flexibility, allowing traders to capitalize on short-term price fluctuations.

Commodity exchanges and pricing in Europe:

Commodity exchanges play a critical role in the financial and commodity markets, offering platforms for trading and clearing futures and options, which are essential for risk management. They also provide clearing services to guarantee transaction integrity between trading parties. The Intercontinental Exchange is an example of such a platform, known for its extensive network that enables the trading of energy futures contracts, including oil products. Another well-known exchange is the New York Mercantile Exchange, which is more closely tied to American markets and provides key benchmarks like WTI crude oil futures.

The valuation of the oil products at the wholesale level is often tied to benchmark prices. A benchmark acts as a reference price for a specific type or grade of crude oil or refined product. Platts, the world's largest price reporting agency, issues daily assessments of the current tradeable value for diesel cargoes in Europe. This collected data is aggregated into a monthly average, which is then used to settle financial derivatives, primarily cleared on the intercontinental exchange. This mechanism is integral for major producers and consumers to hedge their market exposure and assess inventory values (Quantum Commodity Intelligence, 2022). Another well-known price reporting agency in this space is Argus, which provides similar price assessments and reports that are integral to the industry. In practice, the benchmark price can be seen as a baseline. The actual transaction prices vary from this benchmark due to factors like product quality and logistics. For example, the price for a high-quality winter diesel could be benchmark plus a premium.

The diesel market is closely linked to the dynamics of the tanker and barge sector. Platts offers evaluations for the freight prices of these vessels. Dirty tankers are those that transport crude, fuel oil, or other heavier petroleum products like VGO. Conversely, clean tankers and barges transport lighter products such as gasoline, naphtha, or middle distillates like diesel and jet fuel (S&P global, 2023).

Arbitrage in the Diesel Market

Arbitrage is a fundamental concept in trading and economics. At its core, arbitrage is based on the principle that similar assets, like diesel, should have identical pricing across different markets. In simpler terms, if a commodity, like diesel, is cheaper in one market compared to another, there is an opportunity to buy it at the lower price and sell it at the higher price, thereby making risk-free profits.

For instance, geopolitical events, like Russia's invasion of Ukraine, can create price disparities in diesel across different regions. Such scenarios open up arbitrage opportunities where traders or producers in a region with lower prices, such as Asia, can export to regions with higher prices, like Europe, to take advantage of the price difference.

It is important to note that arbitrage plays a pivotal role in markets by ensuring that prices don't deviate substantially across different regions for an extended period. It acts as a balancing mechanism, bringing equilibrium to prices by addressing inconsistencies.

The dynamics of energy commodity pricing are complex, often influenced by factors such as time, geographical location, and the specific physical state of the commodity. As a result, there can be short-lived deviations from the Law of One Price. Strategic traders identify these opportunities, utilizing the interconnections between energy commodities to formulate effective trading strategies that yield positive returns. In addressing these price differences, the traders not only secure profits but also significantly contribute to achieving a stable pricing landscape in the market (Hain, Hess and Uhrig-Homburg, 2018)

The diesel market is a significant sector for such arbitrage activities. The “crack spread”, which denotes the price differential between refined products like diesel and crude oil, serves as a barometer for these arbitrage opportunities. Historically, this spread has been a focal point for commodity-trading houses, guiding their inter-commodity, location, and calendar spread strategies (Hain, Hess and Uhrig-Homburg, 2018). In the context of the oil & gas industry, an inter-commodity spread can be the price disparity between commodities, such as crude oil and diesel. If crude oil prices surge due to geopolitical tensions, but diesel prices do not rise as sharply, this spread expands. A location spread examines price variations of diesel in different geographical regions, for instance, the cost difference between diesel in Europe versus Asia, often highlighting regional demand or supply imbalances. Meanwhile, a calendar spread can be the price of crude oil for different delivery months, like the price difference between crude oil in January versus June, possibly reflecting anticipated seasonal demand changes or storage considerations. Each of these spreads provides traders with valuable insights, enabling informed decision-making in the market.

Contango and backwardation

Contango refers to a situation where the current price of a product, such as diesel, is lower than prices for delivery in subsequent months. It is a classic indicator suggesting that the market expects future prices to rise. This might occur, for example, due to anticipation of increased demand or potential supply shortages (Carollo, 2011).

In contrast, backwardation is when the current price of a product is higher than prices set for future delivery. It suggests prevailing market pessimism, where a decline in prices is anticipated. Such a situation might arise from expectations of decreased demand or increased supply in the future (Carollo, 2011).

Both contango and backwardation offer valuable insights into market sentiment and can influence decisions by producers, traders, and consumers within the diesel market.

5 European diesel market

In the following section, we will explore some of the key dynamics of the European diesel market before conducting an in-depth analysis of the BSR. We will begin by looking at some of the factors that showcase the interconnectedness between the markets:

- **Interregional trade flows:** The diesel market in the BSR is linked to the wider European market due to import and export activities. Diesel and its raw materials, such as crude oil and VGO, flow into the BSR from and to various hubs, most notably from the Amsterdam-Rotterdam-Antwerp (ARA) region, but also from farther distances such as Asia, the Middle East, and the U.S.
- **Benchmark pricing and valuation:** In the BSR, the valuation of diesel at the wholesale level is often tied to benchmark prices that originate outside the region. The North West Europe (NWE) diesel prices from Platts are a good example. These benchmarks reflect the supply and demand dynamics of a much larger market, integrating a variety of factors that go beyond the BSR's borders. Consequently, shifts in the European-wide market, including changes in stock levels, demand fluctuations, or supply interruptions, have the potential to affect local market conditions and pricing structures.
- **Supply, demand, and stocks:** The broader European diesel market's supply and demand balance, along with stock levels, plays a critical role in shaping the diesel market of the BSR. The BSR is not isolated from these larger market forces; disruptions in supply or shifts in demand within the European context are mirrored in the BSR's market dynamics.

The Amsterdam-Rotterdam-Antwerp (ARA) region has long been recognized as an important energy gateway and significant trading hub, with a substantial portion of the region's crude oil passing through it. The ARA area is a complex network consisting of interlinked ports as well as flexible and advanced infrastructure. There are terminals, large amounts of storage with blending services, refineries, and petrochemical facilities. The combination enables traders and other stakeholders to save time and money. Major ports in the area are the port of Rotterdam and the port of Antwerp (Kimani, 2023).

Additionally, the ARA region is an important transhipment hub in the global supply chain. Larger tankers such as long-range tankers or medium range tankers can bring the products from distant regions to ARA, and some of the cargo can then be transferred via smaller vessels like handy size tankers or barges to smaller ports. ARA is an important hub for the companies in the BSR.

Regarding the fundamentals of the EU's diesel market, it is essential to understand that diesel is the primary refined product consumed in Europe, primarily utilized as road transport fuel. However, the region's refining capacity is not capable of meeting the demand, leading to a significant dependence on diesel imports (Argus, 2023a). This reliance on diesel imports exposes Europe to global market fluctuations and supply chain vulnerabilities, which in turn have an impact on regional energy security and the stability of fuel pricing.

Dieselization in Europe

Certain trends and pivotal moments have defined the course of Europe's automotive industry, affecting the environment, transportation fuels, economy, and technology sectors. In recent decades, Europe has witnessed a notable shift from gasoline to diesel-powered cars, a trend termed dieselization. In contrast, the amount of diesel-powered passenger cars has remained marginal in the U.S. A fundamental reason behind the dieselization in Europe was the voluntary agreement in 1998 between the European Automobile industry and the European Commission, targeting CO2 emission reductions. However, despite the improvements in diesel engine technology, the anticipated GHG savings due to the shift towards diesel cars were overly optimistic. Ultimately, this surge in diesel car usage did not lead to the expected atmospheric cooling benefits. Furthermore, several other factors have contributed to the increase of diesel cars, fiscal measures and tax policies being particularly instrumental (Cames and Helmers, 2013).

Historically, the European Commission advocated for a fuel taxation system based on the CO2 emissions of the respective fuels. However, at the national level, many European countries had tax systems that favoured diesel over gasoline, a trend that was established before the EU's initiation of its climate policies. During the late 1980s, a time when the road haulage sector was the primary consumer of diesel, merely 15% of private vehicles ran on diesel. Stimulated by these fiscal advantages, the European automotive industry was motivated to expand its investments in diesel technology. Consequently, by the close of the 1990s, the amount of diesel vehicles had surged considerably (Cames and Helmers, 2013).

The variations in diesel adoption rates across European nations can be attributed to five key factors: diesel taxation rates as acknowledged by the European Commission, the prominence of national car/supplier industries invested in diesel technology, the rise of ecological modernization and its resulting policies, the “fuel tourism” effect in smaller states with significant transit traffic, and the characteristics of corporatist political governance (Cames and Helmers, 2013).

However, in Europe, the proportion of diesel cars began to decline in the 2010s (Rosal, 2022). Likewise, until about 2017, diesel fuel demand was surpassing gasoline in market share, but it has been on a decline thereafter (Argus, 2023). The momentum behind European dieselization began to diminish for two primary reasons: first, the emergence of the "Diesel gate scandal", and second, the growing awareness that the anticipated benefits of reduced emissions through dieselization were not being achieved as previously thought (Rosal, 2022). The Dieselgate refers to the 2015 scandal when it was disclosed that the Volkswagen Group had used cheat devices in their diesel cars sold in the US (Zachariadis, 2016).

Still, the amount of diesel cars in Europe remains high, leading to sustained diesel demand, but there are major changes coming. The proposal from the European Commission suggests a significant shift, essentially proposing a prohibition on internal combustion engines (ICE) in cars and vans by setting a 2035 deadline for zero emissions. As a result, this initiative would lead to the eventual discontinuation of traditional gasoline and diesel vehicles, "mild" hybrids, gas-driven cars, and plug-in hybrid electric vehicles (PHEVs) (Rosal, 2022).

Changing trade flows: Russia's invasion of Ukraine

As one of the world's leading producers and exporters of crude oil, Russia has a considerable role in the international oil ecosystem. In 2019 alone, the country's crude and condensate production averaged 11.25 million barrels per day, accounting for a significant 14% of worldwide production (Fattouh and Economou, 2022). European refineries were especially heavily dependent on Russian crude oil. This interdependence was evident in 2021 when Russia supplied nearly 30% of Europe's total oil imports. Furthermore, Russia was a major player in Europe's diesel sector, being responsible for nearly 40% of Europe's total diesel supply (Fattouh and Economou, 2022). Additionally, Russia plays a crucial role in providing feedstocks, such as VGO, which are used to make products such as diesel.

Russia's pivotal role in the global oil markets was further solidified in 2016 when it entered into the Declaration of Cooperation with OPEC (Fattouh and Economou, 2022). This alliance was demonstrated in a recent agreement with fellow OPEC member, Saudi Arabia, to extend output cuts, subsequently pushing oil and oil product prices higher (IEA, 2023d).

However, after Russia's invasion of Ukraine on 24th of February 2022, the EU imposed significant sanctions against Russia to cut their trade profits. The list of these actions can be seen below:

- 6th October 2022: The G7, EU, along with their partner countries, declared a prohibition on maritime services related to Russian crude oil shipments and for Russian oil products. This regulation involves an exception for oil purchased at a capped price.

- 5th December 2022: EU ban on seaborne imports of Russian crude oil, marking a significant shift in trade relations.

- 5th December 2022: Under the umbrella of the Price Cap Coalition, the G7 and Australia announced an oil price cap for Russian crude oil exports at USD 60 per barrel. This price was set notably above the then market selling price for a majority of Russian crude oil exports.
- 5th February 2023: In a unified move, The European Union, in collaboration with the international G7+ Price Cap Coalition, established two distinctive price caps based on the nature of petroleum products:
  - USD 100 per barrel for premium traded petroleum products like diesel, kerosene, and gasoline.
  - USD 45 per barrel for products traded at a discount to crude oil, encompassing fuel oil and naphtha.

(European Council, 2023a, European Commission, 2023d)

In addition, many European companies have taken the initiative to “self-sanction” by cutting their oil buying from Russia (Fattouh and Economou, 2022).

Some countries within the EU, like Bulgaria and Croatia, that have significant dependencies on Russian crude due to their geographical constraints have been granted temporary exemptions. Nonetheless, it is noteworthy that almost 90 percent of Russian crude oil delivered to Europe is transported by sea, which highlights the broad impact of the EU's sanctions (European Council, 2023).

Additionally, the goal has been to maintain global market stability and prevent inflationary spikes in oil prices. The price cap mechanism, while reducing Russian revenue, allows for the continued flow of Russian oil into the global market, thus maintaining energy market equilibrium and addressing the widespread concern over fuel costs. The price cap enables European entities to transport Russian oil to third-party nations, as long as the trade occurs under the agreed price threshold (European Council, 2023).

However, a study by CREA indicates that Russian oil molecules are still reaching Europe via so-called laundromat countries. The coalition countries that have imposed sanctions are increasingly importing refined products like diesel from nations that are major purchasers of Russian crude oil. These intermediary countries include Turkey, India, China, the United Arab Emirates, and Singapore. Among these, the port of Sikka in India is a notable export hub for oil products destined for the countries in the price cap coalition. This port also ranks as the world’s top importer of Russian seaborne crude oil, mainly to supply the Jamnagar refinery. Interestingly, the largest importer in this complex trade network was the EU (Centre for Research on Energy and Clean Air, 2023).

In response to sanctions, Russia has been redirecting its crude oil exports to more distant markets, notably India, other parts of Asia, Turkey, and the Mediterranean countries, including Italy. One of the major incentives facilitating this shift has been Russia's strategic decision to offer its Urals crude oil at considerable discounts and more favourable payment terms. Moreover, modest refining capacity utilization and domestic demand has increased the country's export volumes (Fattouh and Economou, 2022). Regarding the diesel flows out of Russia, the country has also been able to find new markets, for example, in Latin America, Northern Africa, and Asia and maintain diesel export volumes. Reduced pricing greatly incentivized nations to import more from Russia (Fattouh and Economou, 2023) and many of these suppliers have been well positioned to take advantage of the arbitrage opportunities between the regions.

As Russia was a significant exporter of diesel to Europe, there was a fear that the continent would be short on diesel. Yet, deliveries from the US, coupled with those from east of Suez areas such as Asia and the Middle East, kept Europe well-supplied. Additionally, poor economic development resulted in a decreased demand for diesel (Fattouh and Economou, 2023).

Figure 6 compares global diesel trade flows in 2019 and 2023, illustrating how the flows have changed.

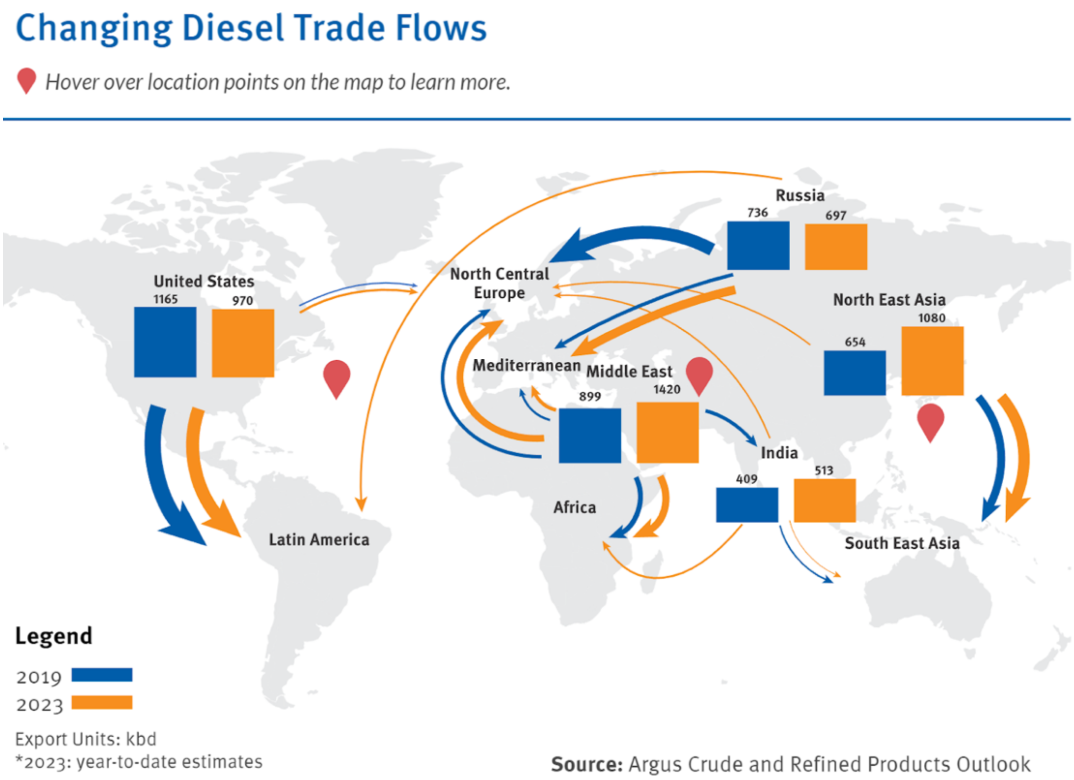


Figure 6: Changing diesel trade flows (Argus, 2023a)

The picture also shows that Europe and Latin America are significant importers of diesel within the Atlantic basin. Furthermore, it highlights that while the majority of Europe's diesel imports came from Russia in 2019, the landscape has drastically changed by 2023. Furthermore, the freight market has also undergone significant adjustments, with the impact of altered trade flows extending to transport logistics, resulting in longer transit times and elevated freight rates.

Concluding remarks

As we pivot from the broader context of the European diesel market to the specifics of the BSR, it is essential to acknowledge the prevailing uncertainties and dynamic shifts in trade flows and policies that have impacted the market. The sanctions imposed following Russia's invasion of Ukraine have catalysed significant changes in diesel trade patterns, forging new supply routes and challenging traditional market structures. The future of these sanctions remains uncertain, contingent on geopolitical developments and diplomatic resolutions, which may either ease, tighten, or completely reshape the current status quo.

The economic trajectory globally and in Europe will be a key factor influencing the demand for diesel. As the energy transition in Europe progresses, the decline in demand for fossil fuels, including diesel, is inevitable. The EU's policy-making is pushing the companies towards cleaner alternatives, such as renewable diesel and the electrification of transport, a transition accelerated by stringent CO2 tailpipe emission legislation.

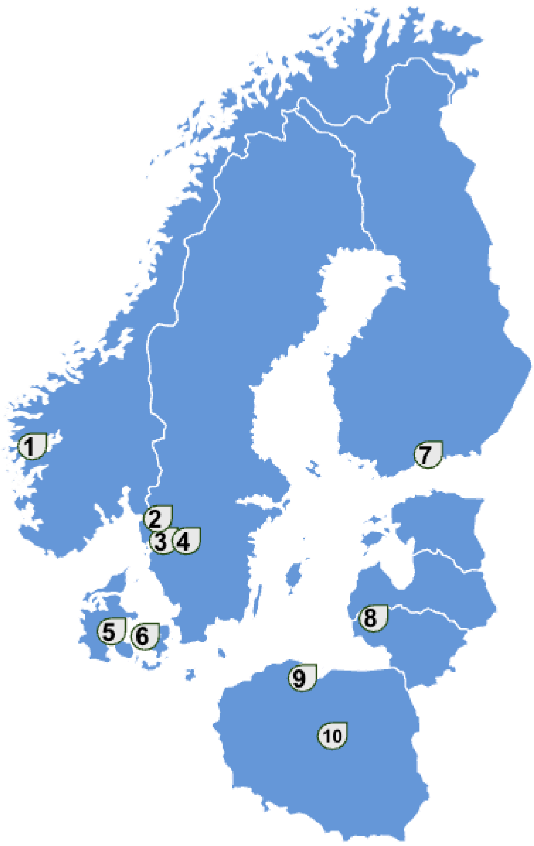
Nonetheless, the conventional refining industry in Europe and in the BSR will have to cope with a market characterized by uncertainty, increasingly stringent environmental regulations, and the unavoidable reality of declining demand for its products.

6 Baltic Sea Region diesel market

This chapter delves into the BSR diesel market, providing a multifaceted analysis of the sector's current state and future prospects. It begins with an analysis of the region's refinery capacities and technologies, laying the foundation for understanding the market's supply dynamics. This is followed by a comprehensive PESTLE analysis, scrutinising the political, economic, social, technological, legal, and environmental factors influencing the market. Subsequent sections offer an in-depth SnD analysis, assessing the balance between production and consumption. The chapter concludes with a future outlook, exploring potential trends and shifts that could impact the BSR diesel market in the coming years.

The BSR, as defined in this study, comprises Finland, Sweden, Norway, Denmark, Estonia, Latvia, Lithuania, and Poland. It is characterised by its geographical remoteness from Central Europe's larger diesel market. Additionally, the region's harsh winters necessitate diesel fuel with enhanced cold-weather performance capabilities. Moreover, fuel transportation, particularly by tankers, is impacted by these conditions, requiring vessels with suitable ice classifications to reliably navigate the region's frozen sea during winter months.

A map highlighting these countries and their refineries are included for reference.



1. Mongstad - Equinor
2. Lysekil - Preem
3. Gothenburg - Preem
4. Gothenburg - St1
5. Fredericia - Crossbridge
6. Kalundborg - Klesch
7. Porvoo - Neste
8. Mažeikiai - Orlen
9. Gdansk - Orlen
10. Plock - Orlen

Its unique geographic positioning facilitates both maritime and overland trade, supported by developed infrastructure such as ports and storage facilities. These elements are vital for the efficient sourcing, distribution, and storage of diesel and other petroleum products.

Figure 7: BSR refineries (Own illustration)

6.1 Introduction to refineries in the Baltic Sea Region

This section presents an overview of the refineries in the BSR, highlighting their capacities, technological features, and responses to recent market and environmental trends. It sheds light on the broader changes in the refining industry, particularly the notable decrease in mainstream refinery numbers and capacities across Europe, and elaborates on the unique aspects of refineries within this region. This overview aims to provide a clear picture of the refining landscape in the BSR reflecting its role in the evolving dynamics of the diesel market.

To provide a comprehensive context, we first explore the landscape of refineries across Europe. Figure 8 shows refineries as well as capacities, and also separates mainstream refineries from specialized facilities dedicated to bitumen, lubricants, or condensates (CONCAWE, 2023). From 2009 to 2022, there has been a notable decrease in the number of these mainstream refineries, from 99 to 75, a reduction of approximately 24%. Concurrently, the total refining capacity in Europe has declined from 809 million tonnes per annum (Mt/a) to 663 Mt/a.

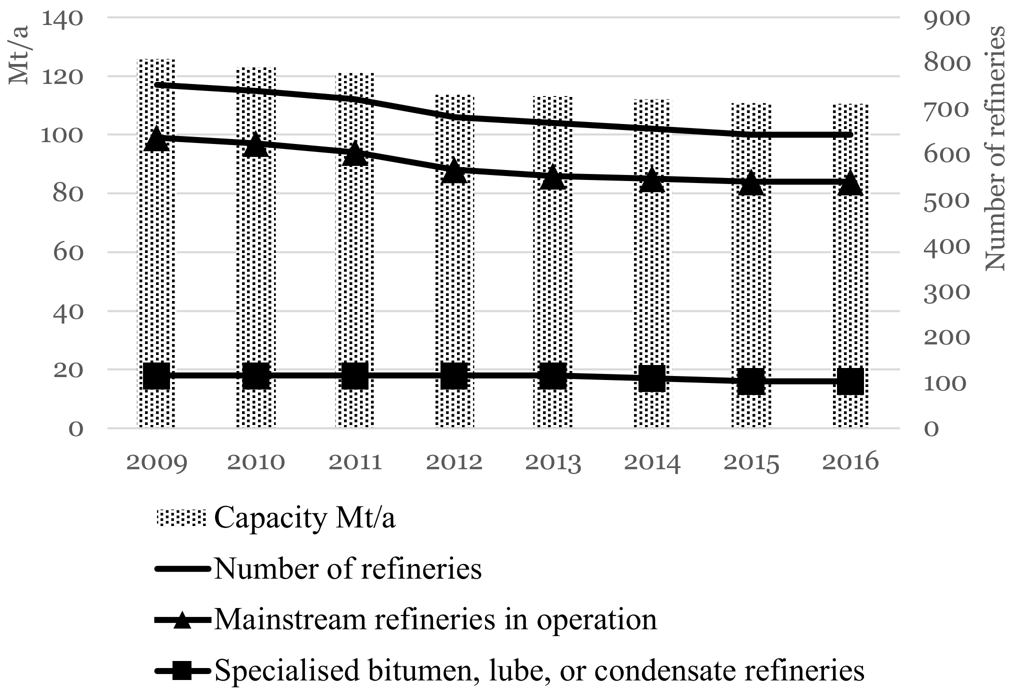


Figure 8: Refining capacity and number of refineries in Europe. (Own illustration adapted from data retrieved from CONCAWE (2023))

This contraction in numbers and capacity likely reflects a strategic downsizing within the industry, driven by the expected decline in the demand for fossil fuels and the need to comply with stricter environmental policies. The decreased number of refineries can lead to less flexibility in managing supply and demand imbalances and may influence diesel pricing and market stability. In Chapter 5, we noted that the EU is structurally short in diesel and relies on imports to satisfy demand; however, the observed trend shows no efforts from the supply side to narrow this gap.

The focus of this thesis is the BSR, which features ten refineries relevant to diesel production. Estonia and Latvia are noteworthy exceptions within this region, as they have no refineries. The Table 4 below provides basic information about these refineries such as their geographic locations, operating entities, crude distillation unit (CDU) capacities, and comments about their main characteristics. Additionally, the Nelson Complexity Index (NCI) will be included to provide an indication of each refinery's complexity level in terms of processing capability and technological advancement. A higher NCI reflects a refinery's ability to process a wider range of crude oils and produce a more diverse set of higher-value products (Herce et al., 2022). The NCI is a widely used tool for evaluating refinery complexity, but it has notable limitations. It primarily measures construction costs relative to basic distillation units, possibly failing to capture a refinery's operational efficiency or profitability. Furthermore, NCI overlooks the non-linear nature of many processes in petroleum refining, potentially missing certain complexities. Therefore, while it is a valuable metric, NCI should be used with an awareness of its limitations and not as the sole measure of a refinery's capabilities.

Table 4: CDU capacities and NCI values of refineries in the BSR (CONCAWE, 2023, NS ENERGY, 2023d, NS ENERGY, 2023b, NS ENERGY, 2023a, NS ENERGY, 2023c, Offshore Technology, 2023c, Offshore Technology, 2023g, Offshore Technology, 2023b, Offshore Technology, 2023d, Offshore Technology, 2023a, Offshore Technology, 2023e, Offshore Technology, 2023f)

Refinery	CDU Capacity Mt/a	NCI index
Porvoo, Finland (Neste)	10,4	12,1
Lysekil, Sweden (Preem)	10,6	10
Gothenburg, Sweden (Preem)	5,4	7,1
Gothenburg, Sweden (St1)	4,1	7,75
Fredericia, Denmark (Crossbridge Energy Partners)	3,4	8,18
Kalundborg, Denmark (The Klesch Group)	5,4	10,78
Mongstad, Norway (Equinor)	10,5	9,9
Mazeikiai, Lithuania (Orlen)	9,6	10,3
Gdansk, Poland (Orlen)	10,1	11,1
Plock, Poland (Orlen)	17,1	9,5

Porvoo, Finland (Neste)

One of Europe's most versatile refineries, located in the largest chemical industry consortium in the Nordics. The refinery produces more than 100 end products to customers globally, including renewable products. The facility has co-processing capability for both renewable and recycled raw materials. Additionally, the tank and underground cavern storage capacity is almost 8 million cubic meters (Neste, 2023d).

Lysekil, Sweden (Preem)

Preem, Sweden’s largest oil company, controls around 80% of the country’s total refinery capacity. Lysekil is not only the biggest oil refinery in Sweden but also in the Nordic region. It produces a range of products including LPG, gasoline, diesel, heating oil, and fuel oil (NS ENERGY, 2023d). Traditionally, these products have served both the home and Norwegian markets (Preem, 2023), with a significant amount also being exported to north-western Europe. Like Porvoo refinery in Finland, the site is notable for its underground caverns and large storage capacity (Neste, 2023d). Additionally, the refinery is equipped with bio co-processing capability (Preem, 2023).

Gothenburg, Sweden (Preem)

The refinery has renewable diesel and bio co-processing capability. Additionally, Carbon Capture and Storage (CCS) options have been studied at the site. Similar to the Lysekil refinery, its key markets include the domestic Swedish market, the Norwegian market, and north-western Europe (Preem, 2023). The Preem refineries in Lysekil and Gothenburg likely collaborate or share resources, enhancing their overall operational efficiency within Sweden's refining network.

Gothenburg, Sweden (St1)

The refinery satisfies 25% of Sweden's oil product demand and the main products are gasoline, sulphur-free MK-1 diesel and other middle distillates. The site also acts as a blending hub. Most products are distributed through the St1 and Shell network in the Nordics. Furthermore, a biorefinery dedicated to producing renewable diesel is expected to commence operations at the site in 2023 (St1, 2023).

Fredericia, Denmark (Crossbridge Energy Partners)

An energy-efficient refinery and a primary supplier of Denmark's district heating. Produces a variety of fuels, supplying about 35% of the nation's liquid fuel consumption (Crossbridge Energy Partners, 2022). Exports are directed mainly to Northern Europe. Additionally, the company indicates bio co-processing capability (Crossbridge Energy Partners, 2022).

Kalundborg, Denmark (The Klesch Group)

Denmark's largest refinery produces a range of products, including LPG, naphtha, gasoline, diesel, fuel oil, and fertilizers. Maritime transport is central to their operations, with crude oil and condensate arriving by sea and the majority of their products shipped out the same way. The refinery benefits from having its own integrated port facilities, supporting around 500 shipping operations each year (Kalundborg Refinery, 2023).

Mongstad, Norway (Equinor)

The refinery primarily produces gasoline, diesel, and aviation fuel. Its gasoline production alone is approximately four times Norway’s annual consumption. Roughly 80% of the total production is exported. The Mongstad Terminal, operated by Equinor and partly owned by the Norwegian State, is a key hub for storing and exporting Norway's oil, mainly from the Troll B, Troll C, and Johan Sverdrup fields, to various global markets (Equinor, 2023). Situated on the west coast of Norway, the refinery's export markets may differ from those of the other refineries on the list.

Mazeikiai, Lithuania (Orlen)

The only refinery in the Baltic States of Lithuania, Estonia, and Latvia. It produces a variety of refined products, mainly to Lithuania, Poland, Latvia, Estonia and Ukraine. At present, there is a comprehensive modernization project underway aimed at incorporating a new residue hydrocracker to enhance the refinery's operational efficiency and reduce its carbon footprint. The goal is to increase the profitability by increasing the yield of high-value fossil products and meet cleaner fuel requirements. The crude oil supply comes from Orlen's Butinge oil terminal in Palanga, Lithuania (NS ENERGY, 2023b).

Gdansk, Poland (Orlen)

The refinery produces a wide array of products, including gasoline, diesel, naphtha, light fuel oils, jet fuel, LPG, bitumen, heavy fuel oil, and base oils. A significant amount of the products are sold within the Polish market. Historically, the refinery has mainly processed Russian crude oil. Additionally, the refinery is strategically linked via feedstock and product pipelines to the liquid fuel handling facilities at Port Połnocny in Gdansk (NS ENERGY, 2023a).

Plock, Poland (Orlen)

The refinery is part of an integrated refining and petrochemical production complex. It is currently undergoing modernisation to raise the product yields to increase the production of high-margin products. The scope includes a new visbreaking unit as well as upgrading of the existing hydrocracking and diesel hydrotreater units (NS ENERGY, 2023c). Plock refinery has also heavily relied on Russian crude oil in the past.

As outlined previously, the refineries in the BSR do not vary only in size but also in their technological advancement and product output capabilities, which influences their ability to adapt to market demands and regulatory changes within the diesel sector. For context, a 2010 Concawe study on EU-27 refineries found that the most common NCI complexity category was category 3, indicative of a NCI ranging from 6 to 8 (Baldoni-Andrey et al., 2010).

Some companies in the region are undertaking significant shifts in their refinery operations to adapt to future needs. For instance, Preem in Sweden has indicated plans to modify its refineries to facilitate the transition from fossil crude oil to renewable raw materials. Concurrently, Neste has launched a strategic initiative aimed at transforming its Porvoo refinery to concentrate on renewable and circular solutions, with the goal of phasing out crude oil refining by the mid-2030s (Neste, 2022). Orlen appears to be the only company in the region committing substantial investment to traditional fossil fuel and fossil diesel processing, with significant upgrades at its Mazeikiai refinery in Lithuania (NS ENERGY, 2023b) and in the Plock refinery in Poland (NS ENERGY, 2023c).

In 2021, the BSR witnessed the shutdown of two oil refineries: Neste ceased operations at its Naantali refinery in Finland (Neste, 2023c), which had a crude oil processing capacity of 2,8 million tonnes per annum (CONCAWE, 2023), and ExxonMobil discontinued its Slagen refinery in Norway (Argus, 2021), with a capacity of 5,8 million tonnes per annum (CONCAWE, 2023). Furthermore, the Slagen shutdown was the fifth refinery closure in Europe since the start of the COVID-19 pandemic. It is noteworthy that two out of five European refinery closures occurred within this relatively small region (Argus, 2021). Additionally, in 2020, Preem announced the cancellation of its Residue Oil Conversion Complex project in Lysekil Refinery, which would have increased the yields of products such as fossil diesel (Woodroof, 2020).

All companies involved in the refinery closures and project cancellations mentioned the declining demand for fossil fuels as a pivotal factor in their decisions. Furthermore, economic factors, tighter environmental and regulatory requirements and increased global competition, have steered the companies towards a strategic focus on renewable solutions. Interestingly, Preem had highlighted the Swedish government's intentions to support the production of local renewable fuels and pursue high ambitions for the biofuel blending mandate. However, the policy landscape shifted dramatically after that when the new government decided to lower the mandate to the EU's minimum level this year.

6.2 PESTLE analysis

In this section, we conduct a comprehensive PESTLE analysis, focusing on the key elements that shape the diesel market in the BSR. This section systematically explores political, economic, sociocultural, technological, legal, and environmental factors, each offering unique perspectives on the complexities and evolving dynamics of this sector. From geopolitical shifts and economic trends to advancements in technology and environmental considerations, this analysis aims to provide a thorough understanding of the factors driving the BSR diesel market, highlighting both its current state and the potential trends that will shape its future.

6.2.1 Political factors

In PESTLE analysis, political and legal factors often display a significant degree of overlap, with political decisions frequently influencing legal frameworks and vice versa. Thus, these factors can be analysed in conjunction. Nevertheless, this study separates them for clarity. The political analysis will focus on higher-level policy decisions from the EU and national government trends affecting the BSR diesel market. On the other hand, the legal aspect will delve deeper into specific regulations and legislative changes. This approach, where the macro-level political climate is distinguished from the more granular legal specifics, allows for a distinct examination of how each factor uniquely impacts the diesel market.

The BSR countries are EU members with Norway as an exception, hence their energy policies are largely aligned with and influenced by EU directives. The EU energy policy is driven by three primary objectives: ensuring energy security, promoting energy efficiency and sustainability, and establishing an internal energy market (Ciucci, 2023).

Energy security and geopolitical concerns

The EU's policy on energy security, particularly after the 2009 gas crisis, emphasised reducing dependency on external energy suppliers. This focus has intensified due to recent geopolitical tensions with Russia. This situation, further intensified by the previously discussed EU's bans on Russian crude oil and refined products, has compelled countries historically reliant on Russian energy imports to make substantial efforts in diversifying their energy sources. Figure 9 illustrates these dependencies well.

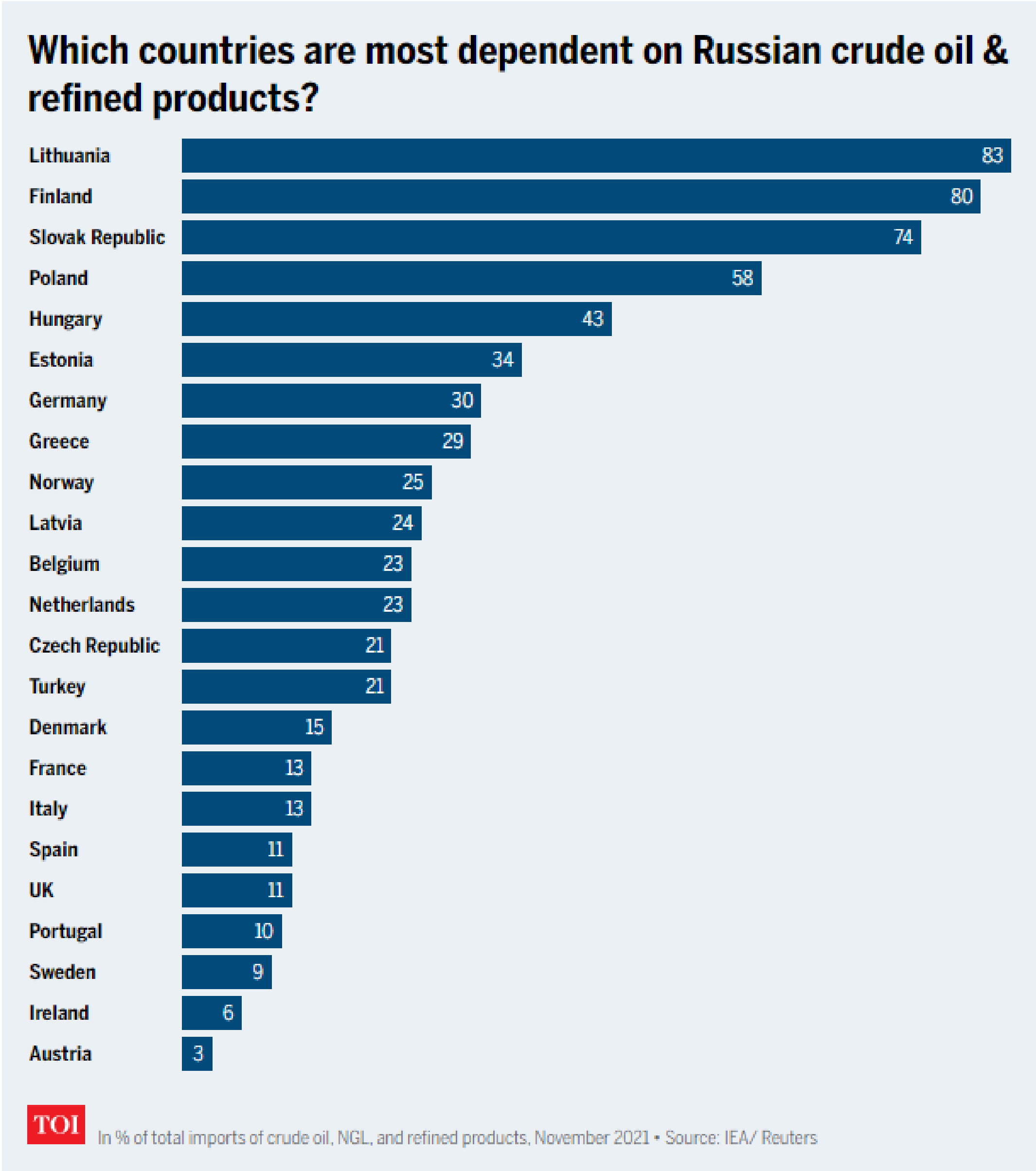


Figure 9: Russian crude oil & refined product dependencies in Europe (The Economic Times, 2022)

Based on data from the IEA and Reuters, the BSR countries most dependent on Russian crude oil and refined products were Lithuania, Finland, and Poland. As a result, the Orlen refineries in both Poland and Lithuania, along with Neste's Porvoo refinery in Finland, have had to make particularly significant adjustments to their crude oil sourcing strategies. Switching crude oils can lead to increased expenses and impact both the yield and the quality of refined products, including diesel. For instance, Neste's Porvoo refinery has shifted from Russian crude to supplies from Norway, the UK, and the US (Donovan, 2023), while Orlen Lietuva in Lithuania now largely processes crude oil from Saudi Arabia (Turner et al., 2022).

The dependency on Russia for energy supplies in some countries can be considered as a significant risk factor. Thus, countries are likely to continue diversifying their energy sources as a measure against geopolitical risks, which could decrease reliance on diesel, particularly imported from volatile regions.

Promoting energy efficiency and sustainability, and establishing an internal energy market

As part of its broader strategy to reduce reliance on imported fossil fuels and enhance energy independence, the EU has also implemented several directives that directly influence the diesel market. To enhance the EU's energy efficiency and sustainability, there are several directives that directly influence diesel markets by encouraging alternative energy sources and imposing taxes on fossil fuels such as the RED and the Energy Taxation Directive. In addition, the European Green Deal, aiming for carbon neutrality by 2050 further pressures the conventional diesel markets. The FQD and the Euro standards for vehicle emissions, as previously discussed in Chapter 4, also have direct impacts on the diesel market. These regulations necessitate the production of cleaner diesel and the development of more efficient engines, influencing both supply and demand dynamics.

Countries can affect the emissions in the transportation segment by utilising different market-based policy actions. The primary strategies include financial incentives, fuel tax regulations, and subsidies (Yoo, Koh and Yoshida, 2020). Financial incentives typically involve reductions in vehicle taxes or prices, thereby encouraging consumer purchases of more environmentally friendly vehicles. Fuel tax regulations intend to motivate drivers to reduce their driving frequency. Subsidies, on the other hand, provide financial support to lower the purchase price of alternative fuel vehicles, such as hybrids, plug-in hybrids, and EVs (Yoo, Koh and Yoshida, 2020).

In the context of promoting energy efficiency and sustainability within the European Union, a significant development lately has been the introduction of the revised RED III, which entered into force on 20 November 2023 (European Commission, 2023e). This directive, briefly mentioned alongside the FQD in Section 4,3 concerning diesel quality requirements (European Commission, 2023e), represents a pivotal step in the EU's commitment to clean energy. RED III sets an ambitious, binding target of at least 42,5% renewable energy in the EU’s energy mix by 2030, with an aspirational goal of reaching 45% (European Commission, 2023e). This legislative revision aligns with the EU's broader strategy to reduce reliance on imported fossil fuels, including diesel, and enhance energy independence. RED III introduces specific targets for renewable energy integration across various sectors, including transport, and emphasises electrification and renewable fuels, like hydrogen, in hard-to-electrify areas (European Commission, 2023e). Member states have an 18-month timeframe to transpose most of the directive's provisions into national law (European Commission, 2023e). This significant legislative development not only aligns with the goals of the European Green Deal but also directly influences the political landscape of the diesel market in the BSR, steering it towards a more sustainable and integrated energy future.

After the introduction of the first RED in 2009, the commitment to renewable energy is particularly evident in the BSR, where notable efforts have been made by countries within the scope of this study. Adhering to EU directives on renewable energy is important, as seen in the cases of Croatia, Hungary, and Portugal. These countries faced legal action and potential financial sanctions from the European Commission for failing to incorporate the RED into their national laws, underscoring the serious consequences of non-compliance (European Commission, 2023c). According to Eurostat, by 2021, Sweden, Finland, and Latvia emerged as leading examples in the EU, with Sweden achieving the highest share of renewable energy consumption at 62,6%, followed closely by Finland at 43,1% and Latvia at 42,1% (European Commission, 2023e). However, it is important to note that in Latvia, the high share of renewable energy is largely attributed to hydroelectric power in electricity production. Thus, it does not necessarily reflect the same level of advancement in renewable energy within the transportation sector, where Latvia faces unique challenges, such as an ageing vehicle fleet.

The influence of national policies

Each country in the BSR has its unique strategy for achieving energy independence and diversifying its energy sources, which significantly impacts their diesel market dynamics. While most countries align with EU directives, the speed and methods of transitioning away from fossil fuels vary, reflecting different national priorities and circumstances.

We can see some patterns for the Nordic countries as they have been at the forefront of implementing policies to reduce GHG emissions compared to the other countries in the BSR region. All four Nordic countries are committed to significantly reducing GHG emissions. This is in line with their broader goals of combating climate change and transitioning to sustainable energy sources. In addition, there is a strong emphasis on promoting EVs across these nations. Norway and Sweden, in particular, have been very successful in this regard, with Norway having one of the highest per capita rates of EV usage in the world. Furthermore, all Nordic countries use taxation as a key policy tool to discourage the use of diesel and gasoline vehicles and encourage the use of cleaner alternatives. This includes higher taxes on fossil fuels and incentives for low-emission or zero-emission vehicles. These countries also have significant investments in renewable energy, especially in wind and solar power, as part of their strategies to reduce reliance on fossil fuels.

In Finland, the national policies and political factors affecting the diesel market are closely tied to the country's broader energy and climate strategies, which aim for carbon neutrality by 2035 (IEA, 2023b). The country has been actively pursuing renewable energy sources, with a strong focus on bioenergy. The government is focusing on low-emission hydrogen and hydrogen-based fuels as solutions for heavy road transport, maritime transport, and aviation. Biomethane production for use in transport and heating is also being pushed. The country's commitment to EU's energy targets is evident in its national policies, which encourage the reduction of fossil fuel use, impacting the diesel market.

Similarly, in Sweden, the diesel market and broader transport sector are significantly influenced by policies aimed at reducing GHG emissions and promoting renewable energy use. The country's ambitious "Fossil Free Sweden" initiative demonstrates its commitment to reducing reliance on fossil fuels, including diesel (Fossilfritt Sverige, 2023). For example, the Swedish government has funded programs to support national climate investments, including charging infrastructure for EVs, public transport support, international night trains, and transport infrastructure development. The government's approach is multifaceted, focusing on both incentivizing low-emission vehicles and increasing the share of renewable fuels in the transport sector.

Norway, while not a member of the EU, aligns closely with European climate policies. A cornerstone of Norwegian climate policy is the polluter-pays principle, which includes a high registration tax for fossil fuel cars, as well as CO_2 and road use taxes on gasoline and diesel. In contrast, zero-emission vehicles, such as EVs, receive substantial subsidies including exemptions from value-added tax, registration tax, and reduced road tolls, ferry, and parking fees (Norsk elbilforening, 2023). Furthermore, Norway has set a national target that all new cars sold should be emission-free by 2025. As of 2022, battery electric vehicles had a market share of 79% in Norway (Carlier, 2023). These policies have resulted in Norway having one of the highest shares of zero-emission vehicles both in car stock and sales.

Denmark has been a pioneer in wind energy and has ambitious plans to reduce carbon emissions. Similar to Norway, Denmark also has implemented tax policies to encourage the use of EVs. In addition, Denmark plans to raise the tax on diesel starting from 2025 (The local dk, 2023). This increase is part of a broader effort to reduce CO_2 emissions, with the government estimating a potential reduction of 0,5 million tonnes due to this tax hike (The local dk, 2023).

Estonia, Latvia, and Lithuania have been working on energy independence and aligning their policies with the EU's energy directives. These countries have made investments in renewable energy and infrastructure to reduce their reliance on traditional energy sources, including diesel. However, compared to the Nordic countries, Baltic countries are not as advanced with phasing out fossil fuels in transportation.

Estonia aims to be climate neutral by 2050, but its emissions have risen since 2020, primarily due to increased shale oil use in electricity generation. To meet its climate goals, Estonia needs to accelerate its transition from oil shale to renewables (IEA, 2023e). However, the transport sector, which is one of the key areas of focus for decarbonization, is not currently on track to meet short-term emission and energy efficiency targets (Tatomir, 2022, Figure 2.19: Driving transport sector emissions down). Estonia currently does not have taxation based on GHG emissions or other environmental factors and is the only IEA member country without taxation on private vehicles, which contributes to having one of the oldest and least efficient vehicle fleets (IEA, 2023a).

Latvia's approach to the diesel market and environmental policies, shaped by its National Energy and Climate Plan for 2021-2030, faces challenges due to an ageing vehicle fleet, predominantly running on diesel, and the extensive use of older, less efficient cars. This situation is further complicated by the high import rate of used cars. In 2018, diesel was the main energy source in road transport, accounting for over 72% of energy consumption in this sector (European Commission, 2020b). The country's commitment to reducing GHG emissions in the transport sector is evident, yet the prevalence of older vehicles poses a significant issue (European Commission, 2020b). The Latvian government acknowledges these challenges and is considering a range of solutions, including support for scrapping old cars, incentives for purchasing environmentally friendly vehicles, and tax exemptions for electric and hybrid vehicles (European Commission, 2020b). However, these policy initiatives are still in the early stages of discussion and have not yet been implemented (European Commission, 2020b). The transition towards renewable energy sources in transport is gradual, with biofuels and electricity, particularly from renewable sources, playing an increasing role, although their current share remains relatively small.

The diesel market in Lithuania is influenced by several national policies and political factors, particularly in the context of environmental and energy strategies. One of the key legislative developments is the Law on Alternative Fuels (Ministry of Energy of the Republic of Lithuania, 2021), which aims to transform the transport sector by 2030. This law focuses on increasing the number of EVs and charging stations, accelerating the use of cleaner fuels in the transport sector, and promoting the use of biomethane, hydrogen gas, and stepping up biofuel blending requirements. The law introduces obligations for fuel suppliers regarding the use of biofuels and aims to transform the freight transport sector by expanding the network of alternative fueling stations and promoting the purchase of clean vehicles. Furthermore, the legislation includes provisions to ensure that by 2026, all cars and buses purchased through public procurement are environmentally friendly, and by 2029, all public road passenger transport must use alternative fuels.

Poland, although still heavily reliant on coal in electricity generation, is gradually transitioning towards renewable energy sources. The country faces challenges in this transition, but EU policies and funding are aiding in this shift, which will eventually impact its diesel market. Poland's approach to the diesel market and broader energy sector is shaped by its Energy Policy until 2040 (EPP2040), which aligns with the National Energy and Climate Plan for 2021-2030. The policy also addresses the modernization of the electricity system, the transformation of the heat and transport sectors, and the reduction of GHG emissions and pollutants in transport through the development of electromobility, hydrogen-mobility, and zero-emission public transport (Ministry of Climate and Environment Republic of Poland, 2023). On the other hand, the country has a well-established legislative and regulatory framework to ensure oil security, with a 90-day stockholding obligation for emergency situations (IEA, 2022d).

In conclusion, the influence of the EU's energy policies is evident in the way BSR countries are reshaping their energy landscapes. While the transition away from diesel and other fossil fuels is challenging, it is clear that EU directives and initiatives like the European Green Deal are guiding these countries towards more sustainable energy practices. The political analysis also highlights the individual efforts and varying paces at which each country is advancing towards a more sustainable energy future. The Nordic countries, comprising Finland, Denmark, Sweden, and Norway, are at the forefront, adopting some of the most stringent and ambitious energy policies. The Baltic countries – Estonia, Latvia, and Lithuania – are also aligning with the EU directives but are progressing at a different pace.

Poland's situation is somewhat distinct. Despite its heavy reliance on coal and a robust oil infrastructure, Poland is gradually taking the steps towards embracing renewable energy sources. Although the shift is challenging, especially given Poland's historical energy landscape, Poland's efforts signify a broader regional trend towards renewable energy, showcasing a collective move away from traditional fossil fuels like diesel. This shift, driven by the need for energy security, sustainability, and adherence to EU-wide standards, is gradually reducing the reliance on fossil diesel, shaping a future energy market that is more diverse, cleaner, and aligned with broader EU objectives.

6.2.2 Legal factors

In the BSR, many legal regulations impacting the diesel market originate from the European Union. In 1999, the EU initiated the car labelling Directive, mandating the display of a vehicle's fuel efficiency and its CO2 emissions. Concurrently, the EU started promoting voluntary CO2 emissions standards, which became obligatory by 2009. For passenger cars, the average corporate CO2 emissions standards were established at 130 grams per kilometre (g CO2/km) for the period from 2015 to 2019 (IEA, 2021). This standard was further tightened to 95 g CO_2/km for the years 2020 to 2024 (IEA, 2021). As discussed earlier in the study, as part of the ambitious FF55 program, the EU has set forth new targets for CO2 emissions reduction, aiming for a 55% decrease in passenger car emissions by 2030 relative to 2021 levels. Furthermore, by 2035, the EU's objective is for all newly manufactured light-duty vehicles to effectively have zero tailpipe emissions (IEA, 2021).

The EU's stringent emissions standards and the FF55 initiative have a profound impact on the fossil diesel market in the BSR. These regulations accelerate the shift towards more fuel-efficient and lower-emission vehicles, thereby reducing the demand for traditional fossil diesel. The 2035 target for zero tailpipe emissions particularly forces a significant push towards electrification and alternative fuels, potentially diminishing the market share and relevance of fossil diesel in the region's transportation sector.

In 2001, research indicated that there was a discrepancy of about 8% between the reported fuel consumption figures and the actual fuel consumption experienced by drivers in real-world conditions. To address this issue, the EU adopted the Worldwide Harmonized Light-Duty Vehicles Test Procedure and Test Cycle in 2017. Additionally, starting from 2021, it became mandatory for all new vehicles to be equipped with an onboard device to monitor fuel consumption. Furthermore, from 2022, vehicle manufacturers are required to submit reports on the annual average fuel consumption of their vehicles to relevant regulatory bodies (IEA, 2021).

In the BSR, Norway, Sweden, and Denmark are setting even more ambitious targets than the EU. Norway, the forerunner in ending the reign of ICE vehicles, has committed to selling only zero-emission new vehicles, including battery electric or hydrogen models, from 2025 (The Economic Times, 2023). This initiative is particularly interesting considering Norway's role as Western Europe's largest producer of fossil fuels. Yet, its commitment to EV adoption is evident, with nearly 80 percent of new cars sold in 2022 in Norway being electric, underscoring its dedication to environmental sustainability despite its fossil fuel background (The Economic Times, 2023). Similarly, Sweden has set a target of shifting to zero-emission vehicles by 2030 (The Economic Times, 2023), and Copenhagen in Denmark is also aiming to ban fossil fuel vehicles by 2030 (Wenande, 2023). These national initiatives not only complement but also significantly advance the EU's environmental objectives, showcasing a strong region-wide commitment to sustainable transportation and energy.

As previously mentioned in Section 4.3, the diesel quality requirements within the EU, including the standardisation under the EN590 norm, establish a baseline for fuel specifications across member states. However, within the BSR, certain national-specific legal frameworks further refine these standards, showcasing the varied regulatory landscape. A prime example of this is Sweden’s adoption of the miljöklass 1 (MK1) diesel specification, which imposes stricter standards than the widely accepted European EN590 norm. The MK1 specification is particularly stringent regarding the content of aromatics, aiming for a cleaner burning fuel (Danielsson and Erlandsson, 2010). This showcases Sweden's commitment to environmental protection and air quality improvement, and highlights the country's proactive stance in exceeding EU baseline requirements. Such national variations in legal regulations are crucial for understanding the diverse challenges and opportunities faced by diesel producers and distributors in the BSR.

While these general policy tools are important, specific legislative changes, such as the adjustment of biofuel mandates, can have a profound impact on the market dynamics. This is particularly evident in the recent developments in Sweden and Finland, where changes to the biofuel mandates are impacting the transportation fuel sector.

In the long term it is clear that the fossil fuel demand is expected to decline, but the energy transition is not a linear process, and sometimes steps are taken backwards. For instance, Sweden's commitment to the Paris Agreement's 2030 climate objectives is facing a significant setback with the government's recent decision to substantially reduce the mandated inclusion of biofuels in transportation fuels. As discussed earlier, this may increase the country's conventional fossil diesel demand by approximately 1,5 million tonnes annually. The move marks a retreat from the ambitious steps previously taken to blend increasing amounts of biofuel with fossil fuels, undermining a key measure in the nation's strategy to curb carbon-dioxide emissions (Pelling, 2023). This adjustment aligns the national policy with the European Union's minimum GHG reduction obligation of 6% for both gasoline and diesel, a significant change to Sweden's ambitious current standard (Chapman, 2023). The change, driven by the Sweden Democrats-backed coalition government, is expected to undergo legislative review by the Swedish Council on Legislation before facing a parliamentary decision. If passed, the new mandate is expected to be operational from January 1, 2024 (Chapman, 2023). Industry insiders, particularly from the biofuels sector, have raised alarms over the ramifications of this policy shift. A reduction to a 6% GHG reduction mandate represents a drastic decline from the present 30,5%, potentially crippling the demand for renewable diesel in Sweden (Chapman, 2023).

This policy revision emerges just as Sweden's renewable diesel production capacity is expected to increase significantly. For instance, St1 has made significant investments in a new renewable fuel production facility at its Gothenburg refinery (Pelling, 2023). Additionally, Preem is set to enhance its renewable diesel production at the Lysekil refinery in 2024 and plans further capacity upgrades in 2026 in Gothenburg (Turner, 2022). The impact is felt in Finland as well, where the revision of Sweden's biofuel mandate could result in up to 25% reduction in the anticipated sales of Neste's renewable diesel in the coming three years (MarketScreener, 2023).

Furthermore, there are concerns surrounding the supply of winter-grade diesel, which is essential due to Sweden's cold climate but not something that all refineries can produce, especially on a large scale. This could complicate the transition and potentially affect Sweden's energy security (Chapman, 2023). The resulting scarcity necessitates increased imports of winter diesel to Sweden, potentially driving up the prices and thus, costs for consumers. The potential rise in prices due to this scarcity creates an opportunity for refineries in neighbouring countries, especially those equipped to produce winter-grade diesel, to capture the value of Sweden's increased demand. Going forward, Sweden's diesel market outlook remains uncertain, affecting fossil and renewable fuel producers alike. The evolving policy environment will likely see its next major turn with the new government in 2027.

Finland, another country known for the ambitious biofuel mandates, has a current distribution obligation act that requires the share of the energy content of renewable fuels, comprising motor gasoline, diesel oil, natural gas, biofuels, biogas, and other non-biological renewable liquid and gaseous transport fuels, supplied by distributors must be at least 28 percent in 2024. The general obligation for the distribution of renewable transport fuels is set to rise from 13,5 percent to 28 percent at the beginning of 2024 and is planned to increase further to 34 percent by 2030 (FINLEX, 2023). The obligation for 2024 was raised to 28 percent through an amendment law in 2022, which aims to compensate for the GHG emissions resulting from the reduced obligations in 2022 and 2023 (FINLEX, 2023). However, the government has proposed to the parliament to maintain the 2024 distribution obligation at the current 2023 level of 13,5 percent, effectively halting the planned increase to 28 percent. The proposed changes aim to curb the rise in the prices of transport fuels (FINLEX, 2023).

The amendments to biofuel mandates in Sweden and Finland are leading to a sudden increased demand for fossil fuels, particularly fossil diesel, which goes against the anticipated long-term trend of reducing fossil fuel consumption. The volatility and uncertainty around the biofuel mandates presents considerable challenges for the refining industry. Long-term planning of capital expenditures becomes difficult. For example, many refineries might have opted not to invest in fossil diesel capabilities, anticipating a shrinking market. Scaling up production to match the new market environment may not be easy due to the capital-intensive nature of the industry and the time required to bring new capacity online.

For renewable fuel producers, this unpredictability is equally problematic. A stable and predictable policy environment is critical for these producers to make long-term investment decisions. Without assurance of demand, the financial risk of such investments may be too large.

Conversely, for some refineries and trading houses skilled at manoeuvring through market changes, these periods of instability present potential opportunities. Agile companies with the flexibility to shift between fuel types or those with strategic foresight in trading positions might seize substantial value. They can take advantage of price disparities and supply shortages, converting market turbulence into profits.

In conclusion, the legal environment in the BSR, shaped by EU directives and national policies, significantly influences the diesel market. The EU's stringent emissions standards and initiatives like FF55 are driving a shift towards greener, more efficient vehicles, reducing demand for fossil diesel. However, recent policy shifts in Sweden and Finland, particularly concerning biofuel mandates, highlight the complexities of transitioning to sustainable energy and the impact of national decisions on the market. These changes underscore the unpredictable nature of energy transitions, presenting both challenges and opportunities for the industry. The evolving legal framework in the region thus plays a critical role in shaping the current and future dynamics of the diesel market, balancing environmental objectives with economic and practical realities.

6.2.3 Economic factors

Economic factors, including inflation and gross domestic product, play a pivotal role in shaping the dynamics of the diesel market. These elements not only influence the cost of production, a crucial determinant of diesel pricing, but also impact the demand and supply equilibrium for diesel and its alternative products. In previous sections, we discussed the influence of political and legal factors, highlighting the presence of subsidies and preferential policies for renewable fuels. This section aims to explore in greater depth how these economic factors, along with macroeconomic trends and market forces, affect the dynamics of the diesel market.

Inflation

In Europe, following a period of robust post-pandemic rebound in 2021 and 2022, the current economic landscape has become challenging, marked by high interest rates and high inflation. The impact has been a rising cost of living and an increased cost of production. Part of the inflation comes from energy prices, such as diesel prices. Higher diesel prices contribute to overall inflation by increasing transportation costs, which then affects the prices of a wide array of goods and services. This is due to the critical role of diesel in logistics and transportation across many industries.

Table 5 below displays inflation rates (%) measured by the Harmonised Index of Consumer Prices (HICP) for the Euro area, EU, and specific countries in the BSR. The HICP is a standardised measure of inflation across the EU, used for assessing and comparing price stability among member states.

Table 5: Inflation rates (%) measured by the HICP for the Euro area (European Central Bank, 2023)

AREA	OCT 22	MAY 23	JUN 23	JUL 23	AUG 23	SEP 23	OCT 23
Euro area	10,6	6,1	5,5	5,3	5,2	4,3	2,9
EU	11,5	7,1	6,4	6,1	5,9	4,9	3,6
Finland	8,4	5	4,1	4,2	3,1	3	2,4
Sweden	9,8	6,7	6,3	6,3	4,5	3,7	4
Denmark	11,4	2,9	2,4	3,2	2,3	0,6	-0,4
Estonia	22,5	11,2	9	6,2	4,3	3,9	5
Latvia	21,7	12,3	8,1	6,6	5,6	3,6	2,3
Lithuania	22,1	10,7	8,2	7,2	6,4	4,1	3,1
Poland	16,4	12,5	11	10,3	9,5	7,7	6,3
Norway	8,4	7,2	6,8	5,6	4,9	2,8	3,7

The data reveals that the Euro area and EU experienced significantly high inflation rates in late 2022, which have gradually decreased over time. By October 2023, the inflation rates have come down noticeably, yet they remain above the European Central Bank's target of 2% (European Central Bank, 2023). This trend indicates a slow but steady recovery from the peak inflation experienced during the period. Estonia and Poland still show relatively high inflation rates compared to other countries in the region, suggesting that these economies are facing more persistent inflationary pressures. The overall trend of decreasing inflation rates across the board, however, is a positive sign, indicating a gradual stabilisation of the economic environment in the Euro area and the BSR.

In the BSR, these broader economic challenges are influencing both consumer behaviour and government policies. As diesel prices climb, there is a growing concern among consumers and businesses alike about the affordability of transport and the cost of goods. This situation is further complicated by the energy transition goals of various countries in the region. While the move towards cleaner energy sources is a long-term objective, the immediate economic pressures are prompting governments, such as those in Sweden and Finland, to reconsider their biofuel mandates (Squadrin, 2023). The decision to reduce biofuel blending requirements can be seen as a response to the economic hardship faced by consumers, aiming to alleviate the immediate financial burden by potentially reducing diesel prices.

Inflation is showing signs of easing and predictions indicate a continued downward trend. The EU is expected to see a reduction in headline inflation from 6,5% in 2023 to 3,5% in 2024, and 2,4% in 2025. This decline is primarily driven by the decrease in consumer energy prices and is expected to be sustained by monetary policies and easing inflationary pressures across various sectors (European Commission, 2023a).

Conversely, in times of economic downturn, the demand for diesel may decrease as commercial activities slow down and consumers and businesses seek to reduce expenses. This reduced demand can subsequently lead to lower diesel prices. Moreover, the broader economic downturn is likely to impact investments in the diesel market. High interest rates can dampen investment in new technologies and infrastructure, essential for the transition to cleaner fuels. This could slow down the advancement and adoption of alternative fuels, including EVs, especially in regions with relatively lower economic resilience.

Gross domestic product and investment capability

To examine the economic capabilities of each country in the BSR, the following Table 6 provides key economic indicators such as nominal GDP and GDP per head in Purchasing Power Standard (PPS). This data not only reflects their economic status but also highlights their potential to invest in transitioning to cleaner energy technologies, essential for moving away from fossil diesel.

Table 6: Nominal GDP and GDP per head in PPS in BSR (European Commission, 2022)

Country	Population (on 1/1/2021)	Nominal GDP (billion eur, 2020)	GDP PER HEAD IN PPS (EU-27=100, 2020)
Finland	5539	239	114
Sweden	10347	478,9	129
Denmark	5831	306,1	129
Estonia	1332	26,8	84
Latvia	1837	27,9	70
Lithuania	2796	47,6	88
Poland	37926	529,1	76
Norway	5455	331,8	146

Nominal GDP measures a country's annual economic production in euros. GDP per head in PPS is an average economic output per person, adjusted for cost-of-living differences, with the EU average set to 100. PPS is a unit that accounts for different price levels between countries.

Looking at the future, despite the current challenges, there is an expectation of mild recovery in growth as consumer spending rebounds, supported by rising real wages and stable investment levels. The GDP growth in the EU is forecasted to rise to 1,3% in 2024 and further to 1,7% in 2025, with the euro area showing slightly lower growth rates (European Commission, 2023a).

Nominal GDP and GDP per capita can indicate a country's capacity to invest in new technologies like EVs for modernising its vehicle fleet. Thus, Norway, Sweden, Denmark, and Finland, with their higher GDP per capita, may be better positioned financially to move from fossil diesel to cleaner energy sources than Baltics and Poland, potentially leading to a more rapid decrease in fossil diesel usage. However, it is noteworthy that the energy transition is influenced by many factors such as policy, public support, and infrastructure, not just economic indicators alone.

Diesel and oil price

An overview of diesel and oil prices, especially in light of recent events and economic shifts, reveals significant fluctuations. Initially, the COVID-19 pandemic in 2020 led to a substantial drop in economic activity, which correspondingly reduced the demand for gasoline and diesel. This resulted in lower fuel prices. However, as vaccination rates increased and pandemic restrictions were eased in 2021, the economy started to recover. This recovery spurred a rise in demand for oil, while the supply remained constrained. Such dynamics in the global oil market led to consistent withdrawals from petroleum and liquid fuels inventories, pushing the prices upwards.

The situation escalated with the Russian invasion of Ukraine in February 2022. This geopolitical event caused a significant spike in gasoline and diesel prices, reaching their peak during this period. This is illustrated in Figure 10. In response to these surging prices, several European Union countries opted to reduce fuel taxes, aiming to mitigate the financial burden on consumers. In a strategic move, the European Union imposed a ban on the import of diesel fuel and other oil products from Russia in February 2023. Despite this ban, there was a slight decrease in prices, attributed to the increased imports of refined oil products from the Middle East and Asia.

Figure 10: EU-27 Gasoline and diesel untaxed price development 2020-2023. Source: FuelsEurope (2023) adapted from Oil Bulettin, European Comission

Looking at a broader historical perspective, oil prices have been relatively low over the past decade, except for a peak just before the 2008 financial crisis. The pandemic and the subsequent price war between Riyadh and Moscow in April 2020 caused a dramatic plunge in demand, reaching levels last seen in 1995. However, as the global economy reopened, oil prices rebounded. The Russian-Ukrainian conflict in 2022 further escalated the prices, driving them to around $120 per barrel. This level, however, did not sustain, and by early 2023, prices had moderated to around $80 per barrel FuelsEurope (2023).

Tax incentives for biofuels

As highlighted in the political analysis, the countries within the scope of this study have adopted varying tax incentives to encourage biofuel consumption in the transportation sector. However, the implementation of these incentives is predominantly observed in the higher-income Nordic countries. Specifically, Denmark and Finland have structured their tax incentives for biofuels based on their energy content (calorific value) and average CO_2 emissions, thereby promoting more environmentally friendly fuel options. On the other hand, Norway and Sweden offer reduced tax rates even for lower biofuel blends. Conversely, the Baltic countries and Poland exhibit a more restrained approach to biofuel incentivization. In these regions, tax benefits are either limited to high biofuel blends, typically around 30% and up, or there are no distinct tax advantages for biofuels when compared to traditional fossil fuels. This variation in tax policies reflects the differing economic capacities and environmental priorities of these countries, with the Nordic nations taking a more proactive stance in fostering biofuel usage through tax policies.

In conclusion, the economic analysis of the diesel market within the BSR reveals a complex interplay of inflation, GDP, diesel and oil price fluctuations, and varying tax incentives for biofuels. High inflation and the rising cost of living have directly impacted diesel production and consumption, with countries responding through varied fiscal policies. The post-pandemic recovery, though promising, is uneven across the region, with Estonia and Poland facing persistent inflationary pressures compared to their Nordic counterparts.

The fluctuating diesel and oil prices, influenced heavily by geopolitical events like the Russian-Ukrainian conflict, have led to significant shifts in market dynamics, with EU countries adapting through policy changes like tax reductions and import bans. The divergent approaches to biofuel incentivization reflect not just economic capabilities but also environmental priorities, with Nordic countries leading in promoting greener fuel alternatives.

As the region moves towards a mild economic recovery with anticipated decreases in inflation and steady GDP growth, the diesel market is expected to evolve. This evolution will likely be shaped by continued global economic shifts, policy adaptations, and the increasing focus on transitioning to cleaner energy sources. The analysis underscores the importance of strategic planning and adaptability in navigating the volatile diesel market, with an emphasis on balancing immediate economic challenges with long-term sustainability goals.

6.2.4 Social factors

In the BSR and globally, consumer behaviour and societal trends are pivotal in driving the energy transition towards cleaner and more sustainable solutions. Consumers, motivated by environmental concerns and the potential for lower energy bills, are increasingly gravitating towards clean energy technologies. However, financial barriers remain a significant hurdle, especially for lower-income consumers. Products like EVs and energy-efficiency retrofits in buildings, are often out of reach due to their high upfront costs. This economic disparity is evident in the United States, where higher-income households are ten times more likely to own an EV compared to the lowest income groups (Davis, 2023). These wealthier households also tend to have more solar panels and use more efficient appliances and lighting technologies (Davis, 2023). To address this, one approach is leveraging energy taxation to incentivize cleaner and more efficient consumer choices, particularly targeting lower income households.

In some countries, the affordability of clean energy technologies is less of a concern. For instance, in China, smaller models of EVs and two-wheelers are already priced competitively with, and sometimes even lower than, gasoline or diesel vehicles. This contrasts with the situation in the BSR and other parts of Europe, where ownership of technologies like heat pumps is lower among low-income households due to the initial cost barriers, despite these technologies being cost-competitive with fossil fuel alternatives in some markets, such as Sweden.

Consumers' increased awareness is translating into a growing preference for cleaner and more environmentally friendly transportation alternatives. Governments and organisations are implementing measures to address environmental concerns, and consumers are responding by favouring vehicles that align with their sustainability values. This shift in social attitudes is not only affecting individual buying choices but also influencing the regulatory landscape. As environmental awareness continues to gain traction, policies promoting cleaner fuels, emission reductions, and stricter regulations are emerging.

In the BSR, the case of Preem in Sweden offers insight into how companies are responding. Preem, Sweden's largest refining company, made a significant decision in 2020 to cancel the expansion of the country's biggest oil refinery, a project valued at 15 billion Swedish crowns ($1,65 billion) (Ringstrom, 2020). This decision is a noteworthy example of the complex interplay of economic and social factors influencing the fossil fuel industry. Preem cited economic challenges, particularly those exacerbated by the COVID-19 pandemic, as a key reason for halting the expansion (Ringstrom, 2020). However, the decision was also influenced by social dynamics, including substantial environmental concerns and activism. The proposed expansion had faced considerable opposition from climate activists, who argued that it would significantly increase Sweden's CO_2 emissions, potentially making the refinery the country's largest polluter (Ringstrom, 2020). This opposition, which included actions by groups like Greenpeace and statements from activists like Greta Thunberg (Ringstrom, 2020), reflects a growing societal awareness and activism around environmental issues. The combination of these economic and social factors underscores the multifaceted challenges facing companies in the fossil road diesel market, where decisions are shaped by both financial viability and societal expectations regarding environmental responsibility.

Similarly, in Finland, the Teboil situation shows the significant impact of societal factors on market dynamics, particularly when intertwined with geopolitical events. Teboil, known for its extensive network of service stations providing diesel and other fuels, faced a public boycott due to its Russian ownership following Russia's invasion of Ukraine (Räisänen and Pitkänen, 2022). This politically and ethically motivated boycott had profound repercussions for local Finnish entrepreneurs operating Teboil franchises. Their challenges highlight the complex relationship between consumer behaviour, societal attitudes, and global political developments, emphasising the need for businesses in the diesel market to be acutely aware of not just local societal sentiments but also the broader geopolitical landscape.

This sensitivity to public sentiment and economic pressures is also evident in policy-making, as seen in the adjustments to biofuel mandates in Sweden and Finland. The previously discussed reduction of biofuel mandates by Sweden and Finland can be viewed as a direct response to societal pressures emerging from the rising costs of fuel such as diesel. This action reflects a government's sensitivity to public sentiment and economic burdens faced by its citizens. This decision highlights the significant influence that public opinion and societal well-being have on policy-making, especially in sectors directly affecting daily life, such as energy and fuel. Governments, in trying to balance environmental objectives with immediate economic realities, often must adjust their policies to reflect the prevailing public mood and economic conditions.

On an even broader scale, societal and ethical considerations also play a crucial role in decisions about energy sourcing, as demonstrated by the regional response to geopolitical conflicts. The response to Russia's invasion of Ukraine has had significant repercussions on the fossil diesel market, particularly concerning Russian crude oil. Prior to the EU's official ban on Russian crude, there was considerable social pressure on refiners and governments to reduce dependence on Russian oil. This movement was driven by a combination of ethical considerations and geopolitical concerns. As a result, several companies and countries in the region began to phase out their reliance on Russian crude more swiftly than others, demonstrating a proactive response to public sentiment. This shift was not merely a compliance with forthcoming regulations but also a reflection of societal values and political stance. The decision by these entities to reduce or eliminate Russian crude oil ahead of official mandates illustrates the powerful role of societal influence and ethical considerations in shaping business practices and energy policies. For the fossil diesel market, this example underscores the importance of being responsive to societal trends and geopolitical events, as they can lead to significant shifts in sourcing and supply chain strategies, impacting market dynamics profoundly.

In conclusion, this social analysis reveals that the clean energy transition in the BSR is profoundly influenced by a dynamic mix of consumer choices, societal trends, environmental activism, and ethical considerations. These factors shape both individual purchasing decisions and broader policy directions, highlighting the evolving nature of the market. The move towards cleaner energy is thus not only a technological or economic shift but also a societal one, where public sentiment and ethical considerations play a crucial role. Industry stakeholders must therefore closely monitor and adapt to these changing social dynamics to navigate this evolving landscape successfully.

6.2.5 Technological factors

Technology plays a key role in the pursuit of environmentally sustainable transportation. This section of the PESTLE analysis explores the multifaceted technological advancements and regional trends that are shaping the future of road transport in the EU and BSR.

To achieve a road transport system with zero net GHG emissions (well-to-wheel) by 2050, significant transformations are necessary in three areas: the generation of energy and energy carriers, including electricity, hydrogen, and renewable fuels; the vehicle fleet and the efficiency of the vehicle fleet; and the supportive infrastructure, such as charging networks (Dauphin et al., 2022). The "well-to-wheel" approach considers emissions from the entire fuel lifecycle, including extraction, production, and use in vehicles, providing a comprehensive assessment of a fuel's environmental impact.

Technologically, while electrification is important, a broad spectrum of vehicle technologies is required. This includes battery electric vehicles (BEVs) for direct electric propulsion, fuel cell electric vehicles (FCEVs) that utilize hydrogen as a fuel, and advanced hybrid powertrains, particularly PHEVs. The latter are predominantly operated in electric mode and can switch to a highly efficient auxiliary drive system powered by GHG-neutral fuels for longer trips (Dauphin et al., 2022). Collectively, these technologies drive the sector toward reduced GHG emissions, affecting the demand for traditional diesel fuels.

Hydrogen has the ability to play a versatile threefold role, acting as a direct fuel in vehicles like FCEVs, as a key component in manufacturing e-fuels and chemicals including fertilisers, and as an energy storage to balance seasonality in the electricity grid (Dauphin et al., 2022). This underscores the multidimensional role of hydrogen in the broader context of energy transition and its potential to complement electrification in the transportation sector.

The IEA emphasises that currently, EVs represent the most promising technology for replacing ICE vehicles, and it is projected that by 2023, they will constitute over 60% of global vehicle sales (IEA, 2022a). However, the organisation also underscores the importance of regulatory support, not only for EVs themselves but also for the necessary charging infrastructure (IEA, 2022a). The anticipated rise in EV sales has direct implications for the diesel market, signalling a shift in the industry's focus towards these emerging technologies.

Technological advancements in fuel efficiency can affect the consumption of diesel. However, as there is a large shift away from fossil fuels, the vehicle manufacturers are likely allocating their research and development efforts to EVs and other alternative technologies, but improvements in diesel engine technology can still play a role.

Biofuels, including biodiesel and renewable diesel, are well-established technological options in the energy sector, playing a key role in the transition towards more sustainable fuel sources. As discussed earlier, the BSR, in particular, has seen significant growth in renewable diesel production. However, while biofuels are likely to remain important, especially in vehicle classes where electrification is difficult, their wider adoption is currently hindered by factors such as higher prices compared to fossil diesel and limited availability of feedstocks. The amount of waste and residue feedstocks, which don't compete with food production or contribute to land use issues, is particularly limited. This scarcity underlines the need for continuous technological advancements, not only in production processes to lower costs but also in the development of novel feedstocks like algae or lignocellulosic biomass.

To address the stricter emission requirements in fossil diesel and other fuel refining, technologies like CCS are emerging as possible solutions. CCS has the potential to extend the viability of fossil fuel refining by significantly reducing the carbon footprint associated with production processes. Additionally, the integration of renewable energy sources, such as electricity and hydrogen into the refining process presents another promising avenue for lowering emissions. These technological advancements could help traditional fossil fuel refiners prolong the lifetime of their assets and operations.

In the BSR, Preem's CCS project, which was a Swedish-Norwegian collaborative effort from early 2019 to the beginning of 2022, focused on CO2 capture at Preem refineries in Sweden and its transportation for storage under the sea floor off the coast of Norway (Biermann et al., 2022). Funded by the Norwegian CLIMIT-Demo program, the Swedish Energy Agency, and industry and research partners, the project aimed at contributing to Preem's goal of net-zero CO2 emissions across its value chain by 2035. Following the project's insights, Preem plans to implement full-scale CCS at its refineries, starting with the Lysekil hydrogen production unit by 2026-2027 (Biermann et al., 2022). Regarding renewable electricity and hydrogen, Neste is proceeding with both solutions in their Porvoo refinery in Finland (Neste, 2023a, Sieppi, 2023).

In the transition away from fossil diesel, retrofitting existing infrastructure for alternative fuel production and distribution is a viable option. This leverages current assets and accelerates the shift towards more sustainable energy sources. Co-processing, where renewable or recycled feedstocks are blended with traditional fossil fuels in existing refinery setups, is one such approach. It allows for a gradual transition by incrementally increasing the proportion of sustainable feedstocks in the fuel production process. Particularly in the BSR, as noted in this study, there is active involvement in co-processing, illustrating its practical implementation in the region. Another option is the complete conversion of existing conventional assets to handle purely alternative feedstocks.

Another technological approach previously mentioned are the synthetic fuels, or e-fuels, which are generated from CO2 and water using electricity. In a significant development for the e-fuels sector in Europe, the EU plans to allow new cars that use e-fuels, which are carbon-neutral, to be sold after 2035 (Wacket, 2023). This move is an exception to the broader EU law that aims to stop the sale of new ICE cars by 2035 (Wacket, 2023). This decision paves the way for potential market opportunities for e-fuels that encompass a range of products, including e-diesel, e-gasoline, and e-kerosene, demonstrating their applicability across various transport modes. Companies in the BSR, including Norway's Norsk e-Fuel, are involved in this evolving landscape. While some industry players view this as a major opportunity for e-fuels in the automotive sector, others, such as Norsk e-Fuel, are directing their efforts towards sectors where electrification poses greater challenges, like aviation (Mundell, 2023). However, it is good to note that the production of e-fuels is currently energy-intensive and costly (Mundell, 2023). Yet, the industry, which includes both start-ups and established firms in the Nordics and beyond, faces the challenge of scaling up technology and production to meet the growing market demand for these sustainable fuels (Mundell, 2023).

Transitioning from the analysis of technological factors influencing the EU and BSR road transport sector, the distribution of passenger cars by fuel type in 2021 is shown in Table 7, while Table 8 illustrates the new registrations in 2022. This data offers valuable insights into the evolving preferences and trends in vehicle fuel types, reflecting the impact of the technological advancements and policy shifts discussed earlier.

Table 7: Passenger car in use by fuel type in 2021. Source: Koster, Simone and Saint-Supéry (2023) adapted from ACEA, 2023

Country	Gasoline (%)	Diesel (%)	Alternative (%)	BEV (%)	PHEV (%)	HEV (%)	Natural Gas (%)	LPG (%)	Other (%)
Finland	68,4	27,3	4,3	0,8	2,8		0,5		0,2
Sweden	51,8	34,6	13,6	2,2	3,8	3,1	0,8		3,7
Norway	31	41,8		16	6,3	4,9			
Denmark	64,9	28,6	6,5	2,4	2,8	1,3			
Estonia	56	40,9	3,1	0,3		2,4	0,3		0,1
Latvia	32,9	65	2,1	0,3		0,7		0,1	0,9
Lithuania	25,2	67,8	7	0,3	0,1	3	0,2	0,4	3
Poland	44,7	39,9	15,4	1,7				13,4	
EU	51,1	41,9	7	0,8	0,7	2,3	0,6	2,5	0,1

Table 8: Passenger car registrations by fuel type in 2022. Source: Koster, Simone and Saint-Supéry (2023) adapted from ACEA, 2023

Country	Gasoline (%)	Diesel (%)	Alternative %	BEV (%)	PHEV (%)	HEV (%)	LPG + NG + Other + unknown
Finland	23,6	6,6	69,8	17,8	19,8	31,5	1
Sweden	21,9	11,5	66,6	33	23,1	8,9	1,7
Norway							
Denmark	36	6,8	57,7	20,8	17,8	19	
Estonia	44	16,2	40	3,4	2	33,3	1
Latvia	47	17	36	6,4	2	25,9	2
Lithuania	58	14,5	27,9	5,3	2,6	18,5	1
Poland	48,4	11,1	40,5	2,7	2,3	32,6	3
EU	36,4	16,4	47,1	12,1	9,4	22,6	3

Based on the data, there are clear differences in the composition of the passenger car fleet by fuel type across the countries in the BSR, including both the Nordic and Baltic countries, as well as Poland, when compared to EU totals.

In the Nordic countries, there is a significant emphasis on alternative fuel vehicles, with Sweden demonstrating a particularly high percentage of alternative fuel cars in use at 13,6% and an even more substantial figure for new registrations at 66,6% in 2022. This reflects a strong move towards cleaner technologies in the Nordic region, driven by government incentives and environmental policies. Finland follows with a 4,3% share of alternative fuel vehicles in use, and 69,8% in new registrations. Denmark's numbers are comparatively lower but still reflect a commitment to alternative fuel vehicles, with a 6,5% share in use. Norway, while not included in this dataset, is recognized as a forerunner in the electrification of private cars, with around 20% being EVs in 2022 (Statistics Norway, 2023).

On the other hand, the Baltic countries show a lower adoption rate of alternative fuel passenger vehicles. Latvia and Lithuania have a significantly higher reliance on diesel cars, with 65% and 67,8% respectively, compared to the EU average of 41,9%. This could be attributed to economic factors, existing vehicle fleets, and potentially less ambitious environmental policy frameworks. New registrations for alternative fuel vehicles are increasing, but not at the pace observed in the Nordic countries.

Poland, a much larger market, stands out with a substantial 15,4% share of alternative fuel vehicles in use, and 40,5% in new registrations. While this is a significant move towards cleaner technologies, it is still lower than the drastic shifts seen in the Nordic countries. Moreover, within Poland's alternative fuel market, LPG vehicles constitute a considerable segment, accounting for a significant portion of its current car fleet.

When comparing to EU totals, the BSR countries, particularly the Nordic ones, are ahead in terms of adopting alternative fuel vehicles. The EU's average for alternative fuel vehicles in use is 7%, while new registrations are at 47,1%. This indicates that while the EU as a whole is moving towards a greener fleet, the BSR, led by the Nordics, is progressing at a faster rate.

The trends in the BSR indicate a decline in fossil road diesel demand, particularly in the Nordics, where alternative fuel adoption is accelerating. In the Baltic states, diesel remains more prevalent, possibly extending the market's lifespan for fossil diesel. Poland's significant LPG usage also indicates a more gradual shift from diesel, maintaining a notable market for fossil fuels.

In light of the uncertainties and complex, unpredictable systemic effects inherent in this transition, it would be risky to rely solely on one technology. The journey towards achieving the sustainability targets for the transport sector calls for a diversified technology strategy, particularly during the phases of research, development, and the transition phase, where actual developments may diverge significantly from initial plans. Furthermore, when establishing infrastructure such as public or dynamic charging systems, it is crucial to ensure harmonisation across EU member states, to prevent a fragmented market and facilitate a smoother transition (Dauphin et al., 2022).

6.2.6 Environmental factors

The section focuses on the ecological aspects that directly or indirectly affect the production, distribution, and consumption of diesel in BSR. Factors such as emission norms, climate change policies, and the global shift towards sustainable energy sources significantly influence the market dynamics. As also mentioned in the social factors section, the growing public awareness about environmental protection and the push for greener alternatives pose challenges and opportunities for refineries.

Diesel engines have been considered more fuel-efficient and emit less CO2 than gasoline engines. However, due to their significantly higher emissions of nitrogen oxide and particulate matter which are harmful to the environment and human health, they have considerable impact on air pollution (European Environment Agency, 2016). However, it is noteworthy that these impacts vary depending on whether the engine uses fossil diesel or renewable diesel, the latter offering a more environmentally friendly option. Stricter emission standards globally, such as Euro VI (EUR-Lex, 2022) in Europe, has been pushing manufacturers to invest in cleaner, more advanced diesel engine technology. This has implications for research and development costs and the overall price of diesel vehicles which indirectly affect the demand for diesel. Additionally, incidents like the Volkswagen emissions scandal (Hotten, 2015) have somewhat altered public perception of diesel vehicles. This shift, along with a growing awareness of environmental issues, could potentially lead to a reduced demand for diesel-powered vehicles.

On the other hand, with the global focus on reducing carbon emissions to combat climate change, alternative fuels and technologies as mentioned in the previous section are becoming more viable and popular due to significant lower environmental impact. For instance, biodiesel and renewable diesel could reduce the GHG emissions up to around 80% compared to fossil diesel (Xu et al., 2022). As previously discussed, EU and national policies also pave the way for green transition.

The EU's Emissions Trading System (ETS) is a central component of the EU's climate change policy and important in reducing GHG emissions cost-effectively. As the world's first and largest carbon market, it encompasses all EU countries, including EEA-EFTA states like Norway. It covers around 10,000 installations in energy and manufacturing, along with aircraft operators, and will include maritime transport from 2024 (European Commission, 2023f).

The EU ETS operates on a "cap and trade" principle, which sets a cap on carbon emissions and allows for trading of emission allowances, thereby directly influencing industries by affecting production costs and, consequently, market prices (European Commission, 2023f). This system affects the diesel market by encouraging cleaner production methods and potentially increasing costs for industries reliant on fossil fuels.

The European Green Deal is the EU's strategic plan to achieve a sustainable economy by achieving climate neutrality by 2050. Introduced by the European Commission in December 2019 and acknowledged by the European Council, it aims to integrate environmental, economic, and social sustainability across all sectors, including climate action, energy, transport, industry, and agriculture (European Council, 2023b). The plan encompasses various initiatives targeting climate neutrality, but for the fossil road diesel market, the FF55 package is possibly the most significant element. FF55 seeks to reduce GHG emissions by 55% by 2030 (European Council, 2023b), thus having a large impact on the fossil diesel sector. While FF55 is central, other initiatives like the EU Strategy on Adaptation to Climate Change, the Biodiversity Strategy, and the Farm to Fork Strategy (European Council, 2023b), though not detailed here, are also relevant as they indirectly influence fuel markets and consumption patterns.

The FF55 includes CO_2 emissions reduction targets for new cars and vans. Under the new rules adopted in March 2023, all new cars and vans sold in the EU from 2035 have to be zero-emission (European Council, 2023b). This regulatory update aims to drive innovation in the automotive sector, protect the environment, and deliver long-term benefits to consumers (European Council, 2023b). In practice, this means that post-2035, the sales of new cars and vans running on fossil diesel will be prohibited within the EU. Although the transition to an entirely zero-emission fleet will happen over a longer period, such a regulation marks a substantial shift for the fossil diesel market.

As for the heavy-duty vehicles (HDVs) such as trucks and buses, the European Commission has set progressive targets in the 2023 revision of the CO_2 emission standards. By 2040, new HDVs must achieve a 90% reduction in CO_2 emissions per kilometre, relative to 2019-2020 levels, with interim targets of a 45% reduction by 2030 and a 65% reduction by 2035 (European Council, 2023b). Additionally, the Commission mandates zero-emission city buses from 2030 (European Council, 2023b). These targets align with the EU's 2050 climate neutrality goal and are intended to diminish reliance on imported fossil fuels, improve air quality, reduce operational costs for transport operators, and drive industry investment in clean technologies. Adoption by the European Parliament and the Council of the EU is pending to bring these regulations into effect (European Council, 2023b).

In conclusion, fossil diesel is highly influenced by environmental factors, including stringent emission regulations, climate change policies, the rise of alternatives, and changing public perceptions. These elements collectively signal a challenging future for the fossil diesel market. As discussed earlier, the demand for fossil diesel is expected to diminish, prompting a significant transformation in both the energy and automotive sectors. This shift represents not only a challenge but also a catalyst for innovation and adaptation within the industry.

6.3 Supply and demand analysis

In this section, we integrate the insights gathered from the PESTLE analysis to explore the SnD dynamics of the fossil diesel market in the BSR. By examining individual countries, as well as various regional groupings, we will uncover the intricate balance between diesel production and consumption across this diverse area.

Table 9 shows the fossil road diesel consumption in the BSR per country between 2013 and 2021.

Table 9: Final energy consumption in road transport by type of fuel in million tonnes of oil equivalent (Eurostat, 2023)

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
EU - 27 countries	163,4	166,7	170,8	176,4	179,9	179,6	179,9	158,0	172,1
Denmark	2,1	2,2	2,3	2,3	2,4	2,5	2,4	2,2	2,3
Estonia	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5
Latvia	0,6	0,6	0,7	0,7	0,8	0,8	0,8	0,8	0,8
Lithuania	1,0	1,2	1,3	1,4	1,5	1,6	1,6	1,6	1,6
Poland	8,8	9,1	9,7	11,6	13,8	14,2	14,3	13,9	15,0
Finland	2,3	2,0	2,0	2,4	2,2	2,3	2,2	2,1	1,9
Sweden	3,3	3,3	3,4	3,2	3,2	3,0	3,1	3,0	3,0
Norway	2,3	2,4	2,5	2,4	2,2	2,3	2,1	2,1	2,2

In 2021, the total consumption of fossil road diesel in the BSR is approximately 27 million tonnes of oil equivalent, which is roughly 16% of the EU-27's total consumption of 172 million tonnes. Tonnes of oil equivalent is a standardised unit that represents the energy released by burning one tonne of crude oil, allowing for comparisons across different energy sources.

In the Nordic countries, Sweden has the highest consumption, at approximately 3 million tonnes of oil equivalent. This positions Sweden as the second-largest consumer after Poland within the selected group of countries. The Baltic states had the smallest markets, with their combined consumption still less than that of Sweden alone. Poland stands out with the consumption of 15 million tonnes, surpassing the combined consumption of the Nordic countries (Sweden, Norway, Finland) and the Baltic States (Estonia, Latvia, Lithuania).

Focusing on the growth rates, fossil diesel demand in the Nordic countries has remained relatively stable, with observed reductions in 2020 and 2021 potentially influenced by the COVID-19 pandemic. On the other hand, the Baltic states have experienced a consistent increase in diesel consumption, and Poland has had substantial growth in demand.

The following graphs and analysis aim to provide an understanding of the market's self-sufficiency and dependencies, highlighting the regions and countries that are net exporters or importers of fossil diesel.

For supply/production estimates, the calculation logic involves the CDU capacities (as outlined in Section 6.1) multiplied by a 90% annual utilisation rate and an average diesel yield of 40% (Office of Energy Efficiency & Renewable Energy, 2020) for all refineries. It is important to note that this supply data represents production only, excluding imports, and focuses exclusively on fossil diesel.

For more detailed understanding, it is acknowledged that more advanced refineries focusing on middle distillates may have diesel yields exceeding 40%, while less complex ones might have lower yields. However, for simplicity, a standard yield of 40% is used here. Specific cases like Preem's refineries in Sweden, where the smaller Gothenburg refinery likely supports the larger Lysekil refinery, might result in varied yields. Moreover, Orlen's refineries in Lithuania and Plock are expected to have higher yields, especially upon the completion of the ongoing upgrade projects, as previously mentioned in the Section 6.1.

Next, Figure 11 shows the fossil road diesel SnD balance for Nordic countries.

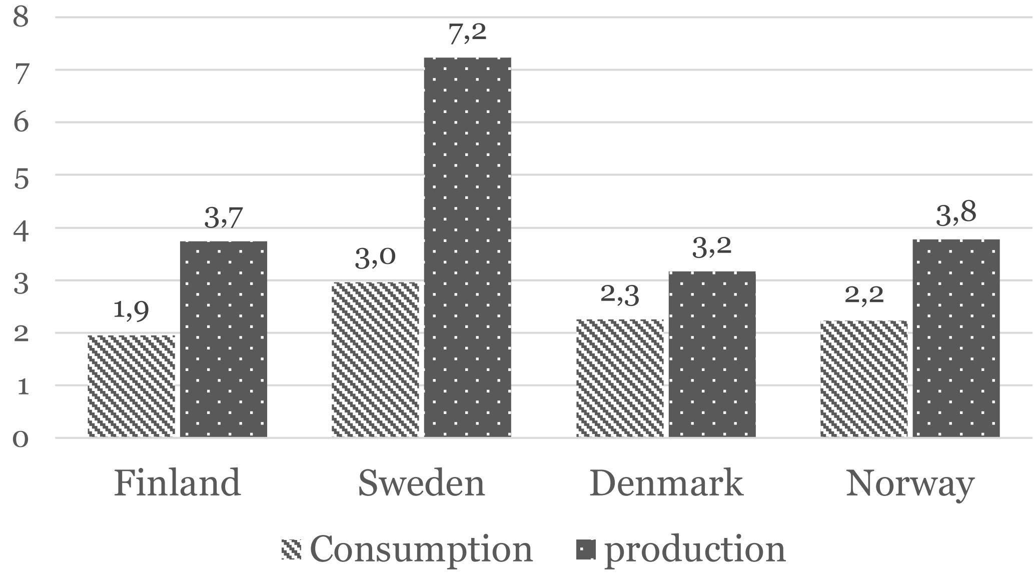


Figure 11: Nordics (Finland, Sweden, Norway, Denmark) fossil road diesel SnD in Mt. Source: Own calculations, adapted data from Eurostat (2023)

The analysis of the Nordics reveals that each country within this region, including Finland, Sweden, Norway, and Denmark, individually exhibits a surplus in diesel production relative to their domestic consumption. This collective surplus across all these Nordic nations not only implies a strong self-sufficiency but also positions them as potential diesel exporters. However, the recent change in Sweden's biofuel blending mandate to 6% could lead to an increased demand for fossil diesel, which might alter the surplus dynamics and influence the region's diesel market. Moreover, the balance for winter diesel, which requires better cold properties, is likely tighter.

In the Nordic region, refineries typically produce less winter-grade diesel compared to their overall diesel output, and outside the Nordics, the capability to produce such fuel is even scarcer. To meet the Nordic winter grade specifications, refiners can blend kerosene, which has good cold properties, into the diesel pool but the price of the kerosene type of products can be high.

In Sweden, the previously mentioned adoption of the MK1 specification, which is stricter than the standard EN590 diesel, complicates the situation further. In addition, the recent decrease in Sweden's biofuel mandate, leading to less renewable diesel (which has good cold properties) in the market, also impacts the balance of fossil winter diesel. Consequently, the diesel market, particularly in Sweden, faces more complexity and potentially tighter supply during winter months.

Industry insights from Argus Media align with these findings. They highlight Sweden's potential struggle to replace the missing renewable diesel volumes with MK1 diesel, given its limited production in northwest Europe. If the mandate drops to 6%, Sweden might need around 1,5 Mt/a of additional diesel. Due to Sweden's climate requirements for winter diesel and the EU ban on Russian-origin diesel, experts from Argus Media speculate a possible shortage of winter diesel in Sweden, especially considering the rapid timeline of these changes (Argus, 2023b).

Following the examination of the Nordic countries, Figure 12 provides an overview of the fossil road diesel SnD balance in Estonia, Latvia, Lithuania, and Poland.

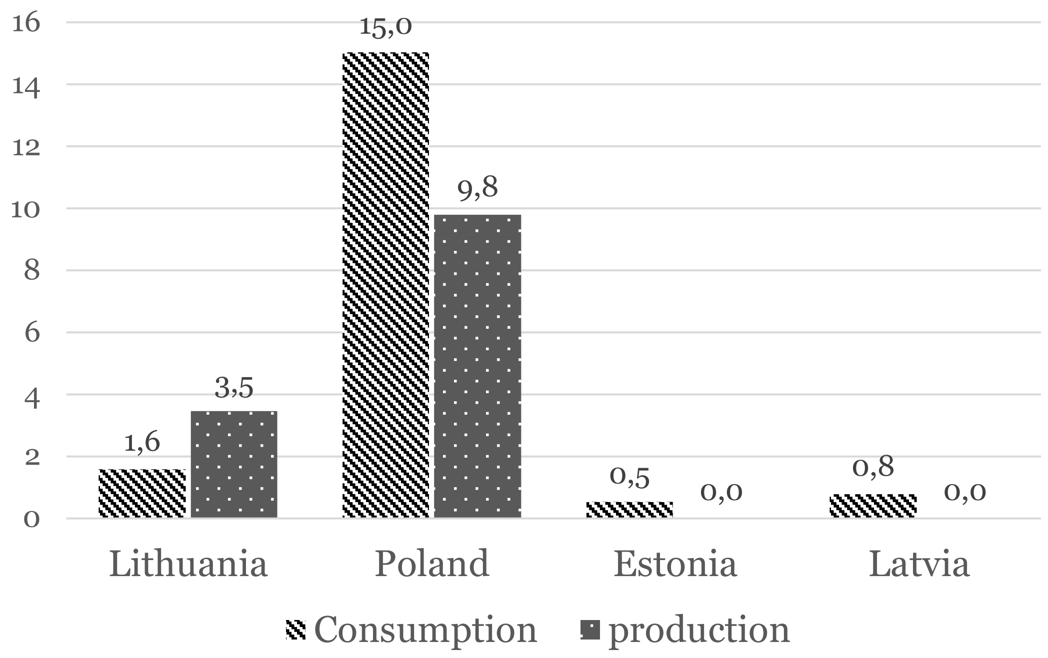


Figure 12: Baltics (Estonia, Latvia, Lithuania) and Poland fossil road diesel SnD in Mt. Source: Own calculations, adapted data from Eurostat (2023)

In the Baltic states, the dynamics of the diesel market are influenced by the limited refinery capacity. As previously mentioned in this study, only Lithuania has a refinery, which positions it uniquely in the region. Despite this, the diesel production capacity in Lithuania is sufficient to theoretically meet the combined diesel needs of all three Baltic countries. This indicates a relatively balanced market within the Baltics, albeit on a smaller scale compared to the Nordics. The market dynamics here underscore the interplay between regional production capabilities and the reliance on imports, especially for Estonia and Latvia which lack domestic refineries. However, the winter diesel balance in the Baltics is potentially tighter. Although their winter diesel requirements are less stringent than those in the Nordics, they are still more demanding than in Central Europe.

Based on the analysis, Poland stands out with a significant mismatch, roughly 5 Mt/a, between its domestic diesel production and consumption, indicating a heavy reliance on imports to meet its diesel needs. This is further validated by statements from Marek Wocial of PKN Orlen's Wholesale Price Coordination Office, confirming a shortfall of about 5 million tons of diesel in Poland, necessitating imports. This shortage, coupled with limited global fuel availability, has been contributing to rising diesel prices in the country despite falling oil prices (Słowińska, 2023).

This detailed analysis underscores the varied nature of diesel markets in the BSR, highlighting the self-sufficiency of some areas and the reliance on imports in others, particularly in Poland.

7 Discussions and conclusions

7.1 Discussion

Geopolitical and energy transition impact

Chapter 3's examination of geopolitical dynamics emphasises the profound impact on the diesel market, particularly highlighted by Russia's invasion of Ukraine. This geopolitical disruption, involving a major energy exporter, has introduced significant volatility into the global energy markets, directly influencing the diesel sector. The role of international organisations, like the IEA in maintaining energy stability, has become increasingly crucial in light of these events. The historical context of energy geopolitics, including pivotal events like the 1973 Oil Crisis, is acknowledged for its role in shaping current market perceptions. However, the primary focus remains on contemporary issues, including the geopolitical shifts that directly impact energy security and market dynamics today.

In parallel, the energy transition is redefining the diesel market. The shift towards low-carbon energy sources, including the increasing role of renewables, is transforming the energy landscape. This transition, though beneficial for environmental sustainability, introduces new challenges. The study particularly notes the impact of policy shifts, like the biomandate changes in Sweden and Finland, on the diesel market. These changes illustrate the non-linear and unpredictable nature of the energy transition, often influenced by political decisions and economic factors.

The analysis of geopolitical and energy transition impact recognizes that the energy market, particularly the diesel sector, is at a transformative phase. Geopolitical events, such as the Russia-Ukraine conflict, and the global energy transition are intricately interlinked, shaping the market's current state and future trajectory. The diesel market's stakeholders are thus required to navigate these complex geopolitical landscapes and adapt to the evolving energy transition dynamics. The ability to anticipate and respond to these changes will be crucial for maintaining market stability and moving towards a more sustainable energy future.

Refinery analysis and operational shifts

The analysis of refineries in the BSR and their operational shifts is a crucial aspect of understanding the dynamics of the diesel market. The refineries in the region showcase a range of capacities and technological advancements, as evidenced by the varying NCI values. These differences influence their ability to adapt to market demands and regulatory changes. The notable decrease in the number of mainstream refineries across Europe, including the BSR, from 99 to 75 between 2009 and 2022, reflects a strategic downsizing driven by the anticipated decline in demand for fossil fuels and stricter environmental policies. This contraction in refinery numbers could lead to less flexibility in managing supply and demand imbalances, potentially impacting diesel pricing and market stability.

Several refineries in the BSR are making significant operational shifts to adapt to future market needs. For instance, Preem in Sweden and Neste in Finland have announced initiatives to transition from fossil crude oil to renewable raw materials. Alongside this, there is also notable bio co-processing activity in the region, reflecting a growing trend in integrating renewable resources into traditional refining processes. These initiatives underscore a broader shift in the refining industry towards more sustainable practices. In contrast, Orlen in Lithuania and Poland is still investing significantly in traditional fossil fuel processing.

The closure of two refineries in the region, Neste's Naantali refinery in Finland and ExxonMobil's Slagen refinery in Norway, further underscores the shift away from fossil fuels. These closures, accounting for a significant portion of refinery shutdowns in Europe since the COVID-19 pandemic, were influenced by declining demand for fossil fuels, economic factors, and environmental regulations.

In conclusion, the refinery analysis and operational shifts in the BSR reflect the region's response to changing market demands, environmental regulations, and the global shift towards renewable energy sources. The study's findings indicate a strategic move towards sustainability within the refining sector, aligning with broader environmental goals and market trends. This transition, while necessary for environmental sustainability, poses challenges for refineries in adapting their operations and maintaining market stability. The insights gained from this analysis are vital for understanding the future trajectory of the diesel market in the BSR and for informing strategic decisions by policymakers and industry stakeholders.

PESTLE analysis integration

In the BSR, the interplay of political, economic, social, technological, legal, and environmental factors creates a dynamic and multifaceted landscape. The PESTLE analysis highlights several key trends and interrelations, illustrating the complex nature of the market in this region.

- **Political and legal influences**

The BSR is heavily influenced by EU directives, particularly in terms of energy security, efficiency, and sustainability. Recent policy shifts, like the adjusted biofuel mandates in Sweden and Finland, underscore the fluctuating nature of energy policy and its direct impact on the diesel market. These changes, while addressing short-term economic concerns, have led to an increased reliance on fossil diesel, revealing the intricate balance policymakers must find between immediate economic realities and long-term environmental goals. Legal frameworks, notably the EU ETS and CO2 emission standards, drive the market towards cleaner production methods, further influencing diesel demand dynamics.

- **Economic context**

The economic landscape, marked by post-pandemic recovery, fluctuating inflation and interest rates, and varied GDP growth, directly impacts consumer behaviour and government policies. High crude oil and diesel prices, influenced by global events and geopolitical tensions, have increased transportation costs, affecting a wide range of goods and services. The differing economic capabilities of BSR countries, as reflected in their GDP, influence their potential to invest in transitioning to cleaner energy technologies, thereby affecting fossil diesel usage.

- **Social dynamics**

Consumer behaviour and societal trends play a critical role in shaping the diesel market. Increasing environmental awareness is driving a preference for cleaner transportation options. Decisions like Preem's cancellation of conventional refinery expansion in Sweden highlight the power of societal influence and environmental activism in shaping market decisions. Similarly, the response to geopolitical events, such as the Russian invasion of Ukraine, demonstrates how ethical considerations and societal values can lead to significant shifts in energy sourcing strategies and consumer choices.

- **Technological progress**

Technological advancements are key to achieving sustainable transportation. The development of EVs, hydrogen fuel cells, and advanced hybrid powertrains is rapidly changing the automotive landscape. The rise of EVs, in particular, signifies a significant shift away from transportation fuels, especially fossil fuels. In parallel, enhancements in diesel engine technology, along with the growing adoption of biofuels and synthetic fuels, are contributing to a reduction in fossil fuel demand, offering cleaner alternatives and aligning with the global move towards sustainability.

CCS technologies represent a vital approach for fossil fuel refiners to extend the use of their conventional refining assets under tighter sustainability regulations. By adopting CCS, refiners can mitigate the environmental impact of fossil fuel refining. Additionally, integrating renewable electricity and hydrogen into refining processes provides another pathway to lower carbon emissions. This strategy involves using renewable energy sources to power refining operations, thereby reducing the carbon footprint. Furthermore, incorporating bio co-processing and lower-carbon feedstocks like LWPs can further decrease the carbon intensity of fuel products, aligning refinery operations with evolving market demands for cleaner energy solutions.

- **Environmental considerations**

Environmental factors, including emission norms and climate change policies, significantly affect diesel production and consumption. While diesel engines are more fuel-efficient, they contribute notably to air pollution, particularly when using fossil diesel. This has prompted the development of cleaner and more advanced technologies. Renewable and synthetic diesels represent more environmentally friendly alternatives, as they typically result in lower emissions compared to their fossil-based counterparts. EU initiatives like the FF55 package, which aims for climate neutrality, are reshaping the diesel market, with profound implications for supply and demand dynamics. This shift reflects a growing emphasis on reducing the environmental impact of diesel fuels, aligning market trends with sustainability goals.

In summary, the PESTLE analysis of the diesel market in the BSR reveals a complex interplay of factors, each influencing and interacting with the others. Political and legal decisions are closely tied to economic conditions, while social trends and technological progress drive market adaptations. Environmental considerations overlay all these factors, pushing the market towards cleaner and more sustainable solutions. This complex network of influences underscores the need for a comprehensive and adaptive approach to navigate the future of the diesel market in the BSR.

Market dynamics

The dynamics of the diesel market in BSR and Europe are shaped by a range of interrelated factors, from geopolitical events to policy shifts and changing trade flows. The diesel market's interconnectedness with the broader European context is evident through import and export activities, often linked to major hubs like the ARA region. The valuation of diesel at the wholesale level in the BSR is often tied to benchmark prices that originate outside the region, reflecting the broader European SnD dynamics. This interconnectedness means that shifts in the European-wide market, whether due to changes in stock levels, demand fluctuations, or supply interruptions, have the potential to impact local market conditions and pricing structures within the BSR.

Russia's role as a major supplier of crude oil and diesel to Europe has been a critical factor in the region's energy dynamics. The Russian invasion of Ukraine and the subsequent EU sanctions have led to a significant restructuring of trade relations and diesel supply routes. The sanctions included a ban on Russian crude oil and refined products, which forced European refineries, particularly in the BSR, to adapt their sourcing strategies. This realignment has seen an increased reliance on imports from other regions like the

Middle East, Asia, and the U.S., thus exposing the BSR to global market fluctuations and supply chain vulnerabilities.

In terms of SnD dynamics within the BSR, countries demonstrate varied levels of self-sufficiency and dependence on diesel imports. The Nordic countries generally show a surplus in diesel production relative to their consumption, positioning them as potential exporters. However, recent policy changes, like the adjustment in Sweden's biofuel mandate, likely increases the demand for fossil diesel, altering the surplus dynamics. In contrast, Estonia, Latvia, and Poland demonstrate a significant mismatch between domestic diesel production and consumption, indicating a heavy reliance on imports to meet its diesel needs. These findings underscore the diversity of market dynamics within the BSR.

The market dynamics in the BSR highlight the complexities of transitioning to sustainable energy and the impact of national decisions on the diesel market. The legal environment, shaped by EU directives and national policies, influences the diesel market by driving a shift towards greener, more efficient vehicles, thereby reducing the demand for traditional fossil diesel. However, recent policy shifts in Sweden and Finland concerning biofuel mandates illustrate the non-linear nature of energy transitions, presenting challenges and opportunities for the industry.

In conclusion, the BSR diesel market is in a period of transformation driven by a mix of trade, geopolitical, policy, and market changes. The need for adaptability and foresight among stakeholders is paramount in this evolving landscape. The ongoing shift to sustainable energy, influenced by environmental, technological, and policy factors, is reshaping the future of the diesel market in the region.

Reliability and limitations

This thesis's reliability is strengthened by its reliance on authoritative sources, including academic and scientific reports, and its application of comprehensive analytical methods, such as the PESTLE framework and SnD analysis.

Initially, the study extensively relies on academic literature and reputable industry publications, particularly in the chapters discussing geopolitics, energy transition, and the basics of oil refining. To address the limited availability of up-to-date academic sources in later chapters, particularly chapter 6, the research incorporates data from credible sources like the European Union, the IEA, and national government websites. In addition, validated data sources such as Eurostat are integrated into the SnD analysis. Reputable oil market media such as S&P Global Commodity Insights and Argus Media provide further insights. Other media sources are referenced when necessary, ensuring a balance between academic rigour and the practical relevance of current market conditions.

While the conclusions drawn align with the prevailing understanding of the market, there are inherent limitations due to the market's dynamic nature. Rapid geopolitical and economic shifts can quickly make the findings outdated, and the reliance on publicly accessible data may constrain the depth of insights gained. The study's complexity, which involves merging oil market dynamics with energy transition and geopolitical factors, presents unique analytical challenges. Despite employing robust methodologies and credible sources, this complexity might impact the precision of the findings. This situation underscores the need for ongoing and flexible analysis in this dynamic and multifaceted field.

7.2 Conclusions

Synthesis of key findings

Diesel's significant role in the European Union, particularly when compared to regions like the U.S., underscores the dieselization trend, as discussed in Chapter 5. Despite the decline in diesel car proportions due to the diesel scandal and less effective emission reductions, diesel vehicles remain a substantial market segment. The EU's structural shortage of diesel, reliant on imports, contrasts with the BSR's varied landscape: Nordic countries and Lithuania are long on diesel, while Estonia, Latvia, and Poland, particularly due to the absence of refineries, show a deficit. Additionally, Nordic countries may face tighter supply and demand balance for winter diesel.

Despite the SnD balance, the refinery analysis revealed that there has been no significant effort towards bridging the diesel supply gap or adding refining capacity in Europe or BSR. In fact, the BSR has seen a decrease in refining capacity, particularly notable since the start of the COVID-19 pandemic, with two refineries closing in the region, representing a significant portion of the closures across Europe. This trend is strongly linked to the anticipated decline in fossil fuel demand as part of the energy transition.

The geopolitical landscape, especially post-2022, has dramatically altered the EU and BSR markets. The Russian invasion of Ukraine and the EU's ban on Russian crude oil and refined oil products have reshaped trade flows and dependencies. This has notably affected BSR refiners like Neste and Orlen, which previously relied heavily on Russian crude oil.

The study also reveals unexpected shifts in energy transition, such as the biomandate changes in Sweden and Finland, which have unpredictably increased demand for fossil diesel. This indicates the non-linear nature of the energy transition, where political changes and governmental decisions can lead to fluctuations in fossil fuel demand. While the closures of refineries in the BSR might align with long-term expectations of reduced fossil fuel demand, they present immediate challenges in the face of sudden increases in fossil diesel demand.

The economic environment, characterised by high inflation and interest rates, has also impacted diesel demand. Interestingly, this economic downturn which decreased the diesel demand initially helped Europe cope with the ban on Russian diesel, along with diesel imports from the East or Suez, such as China and India. The future outlook for refining and the fossil diesel market remains uncertain, with key questions about the reintegration of Russian oil products into the EU market, potential new geopolitical challenges, the overall economic development, and the pace and direction of the energy transition. In the long run, the decline in fossil fuel demand seems evident, with projections from McKinsey and the IEA indicating a significant portion of the EU's refining capacity at risk and an anticipated decline in demand.

A crucial driver in the market is the European Commission's proposal to effectively end the sale of ICE cars and vans by 2035, aiming for zero emissions. While stopping the sale of ICE cars is one aspect, the transition of the car fleet will take time, representing another dimension of market dynamics. The discussion highlights the need for agility and preparedness in companies to navigate these complex, multifaceted changes. The future of the fossil road diesel market in the BSR is thus shaped by a confluence of factors, including geopolitical developments, non-linear energy transition progress, economic conditions, and significant policy shifts. This scenario presents a landscape marked by uncertainty, demanding adaptability and strategic foresight from market participants.

Future outlook of the refining sector

Following the detailed PESTLE and SnD analysis, we will next examine the future landscape of the EU refining sector through 2040 and the trends shaping the global refining industry. This outlook is affected by several critical factors, for example, anticipated fossil diesel demand reduction, increasing energy costs, and the implications of CO2 pricing under the EU ETS.

- **Decline in fossil fuel demand and refining capacity reduction**

The McKinsey & Company report suggests a significant portion of European refining capacity may struggle with profitability by 2040, particularly under scenarios involving rapid technological advancements and strict regulatory policies.

This trend is evident in the BSR, where closures and announcements of substantial transformations in refineries reflect a shift away from fossil fuels, aligning with the anticipated decline in demand. Industry stakeholders must navigate this changing landscape, potentially exploring diversification into biofuels or other sustainable energy sources (Ding et al., 2022).

- **Geopolitical shifts and trade flow changes**

The Russian invasion of Ukraine has drastically altered the EU and BSR's oil product markets. This shift necessitates a revaluation of supply chain strategies and an increased focus on energy security. Policymakers should strengthen regional collaboration and diversify energy sources to mitigate geopolitical risks.

- **Policy fluctuations and non-linear energy transition**

Biomandate changes in Sweden and Finland illustrate the unpredictable nature of the energy transition, causing fluctuations in diesel demand. Policymakers need to consider the implications of these changes and ensure that transitional policies are adaptable to market needs. For the industry, flexibility in response to policy shifts is vital, not only to maintain market stability but also to secure profitability and ensure reliable deliveries to customers.

- **Economic influences and market dynamics**

Economic factors such as inflation and fluctuating interest rates affect diesel demand. The IEA report indicates stagnant growth in transport fuel demand post-2030, suggesting a shift in refining strategies towards new markets and products. The industry needs to anticipate these changes and adjust their business models accordingly (IEA, 2023f).

- **Transition to cleaner energy sources and regulatory impacts**

The EU's Green Deal and FF55 initiatives are pushing the refining sector towards sustainability. This transition may involve closures, conversions, or significant transformations in the refining industry. Policymakers must balance environmental objectives with industry needs, providing support and incentives for sustainable transitions.

- **Future uncertainty and need for agility**

The unpredictability of geopolitical developments and the energy transition poses significant challenges for the refining sector in the BSR. Companies must remain agile and adaptable to rapidly changing market conditions. The reintegration of Russian oil into Europe's energy system, the development of new technologies, and further policy changes could significantly impact market dynamics. Policymakers should focus on creating frameworks that can accommodate such uncertainties, while industry players must be prepared to pivot in response to new developments.

To navigate these trends, actionable recommendations for policymakers and industry stakeholders include:

- **Diversification and sustainability**: Encourage refineries to diversify their product portfolios, especially towards sustainable energy sources. Policymakers can support this through incentives and clear as well as predictable regulatory frameworks.
- **Strengthening energy security:** Enhance energy security by diversifying supply sources and strengthening regional energy collaborations. This includes investing in infrastructure that supports alternative energy sources.
- **Adaptable policy frameworks:** Develop energy policies that are flexible enough to adapt to market and geopolitical changes. This includes policies that support the gradual transition from fossil fuels to more sustainable energy sources.
- **Industry adaptability:** Refining companies should focus on agility and resilience, preparing for potential market shifts, and capitalising on opportunities in emerging energy markets.
- **Investment in innovation:** Both policymakers and industry players should invest in technological innovation that aligns with the energy transition, such as renewable fuels and energy-efficient processes.
- **Monitoring global trends:** Continuously monitor global economic and geopolitical trends to anticipate their impacts on the diesel market and adjust strategies accordingly.

The future of the BSR's diesel market and refining sector is indeed complex, characterised by evolving geopolitical landscapes, policy shifts, and the transition towards sustainability. Navigating this terrain requires a strategic, adaptable approach from both policymakers and industry stakeholders.

Contribution to the field

This thesis on the fossil road diesel market in the BSR has made academic and practical contributions to the understanding of energy markets amidst geopolitical and environmental shifts. By providing a comprehensive analysis of the diesel market in the BSR, a region that is often underrepresented in energy market studies, this research has expanded the academic knowledge in this field. The examination of geopolitical events, notably Russia's invasion of Ukraine, offers new insights into their profound impact on regional energy markets, enriching the understanding of how such events can reshape market dynamics.

Integrating the PESTLE framework into the study has not only added depth to the academic discourse but also presented a comprehensive view of the market, considering a wide range of influencing factors. This multifaceted approach emphasises the importance of a holistic view in understanding energy markets, potentially serving as a model for future studies in similar contexts. The study has also advanced the understanding of geopolitical impacts on energy markets, providing empirical evidence of how international relations and policy decisions can directly affect regional markets.

In the context of the global energy transition, this research contributes to an understanding of the non-linear nature of this transition, particularly in the BSR. The study's findings on the fluctuating demand for diesel in response to policy and technological changes add valuable insights to energy transition studies, highlighting the complexities and challenges in shifting from fossil fuels to sustainable energy sources.

From a practical standpoint, the study offers a holistic overview and actionable recommendations for policymakers and industry stakeholders. For policymakers, the findings emphasise the importance of creating adaptable yet predictable regulatory frameworks, essential for enabling informed decision-making on large-scale investments, typical in the industry due to substantial capital expenditures, extended lead times, and long asset lifespans. Industry stakeholders, particularly in the refining sector, can use these insights to strategize and adapt to the evolving energy landscape.

In conclusion, the study contributes significantly to both academic and practical understanding, providing a new and detailed perspective on the challenges and opportunities in the fossil road diesel market in BSR during a time of significant geopolitical and environmental change.

Recommendations for future research

Given the complex and multifaceted nature of the fossil diesel market in the BSR, the potential for further research is vast. This study opens up numerous avenues for exploration, whether delving deeper into the intricacies of energy transition, examining the nuances of geopolitical shifts, focusing on technological advancements, understanding consumer behaviour, or exploring specific aspects of the oil and diesel market. Each of these areas offers rich opportunities for detailed investigation, highlighting the dynamic and evolving landscape of the energy sector.

Building on this foundation, for future research on the fossil diesel market, it would be interesting to explore categories like HDVs, marine transport, and LFO applications, particularly in regions like the Nordics where LFO is used in home heating. While these sectors are also actively pursuing decarbonization, with the EU targeting significant reductions in CO_2 emissions from HDVs by 2040, there is still a substantial reliance on diesel. Understanding the unique challenges and pace of transition in these sectors can provide a comprehensive view of where fossil diesel demand might persist. This approach acknowledges ongoing decarbonization efforts while identifying potential areas of continued diesel use.

Future research building on this study could also focus on more detailed forecasting and scenario building for the fossil diesel market. This could involve extended SnD analyses predicting further into the future, incorporating anticipated changes in supply and demand. Factors to consider might include policy shifts like biofuel mandates, the reintegration of Russian supplies, technological advancements, and evolving consumer preferences. Additionally, such analyses could estimate the necessary adjustments in refining capacity to meet future demand and further assess the competitiveness of the 10 refineries in the region, identifying those at risk of closure or requiring modification. This comprehensive approach would offer a dynamic, forward-looking perspective, providing valuable insights into market evolution under various scenarios and guiding strategic decisions on capacity and operational efficiency.

Author's reflection

This study has uncovered distinctive aspects of the BSR diesel market, particularly highlighting how geopolitical turbulence and the energy transition uniquely influence this market. By exploring the complexities of policy and market interplay, the research offers new insights into the BSR diesel dynamics, challenging predetermined assumptions and enriching the broader discourse in energy market studies. Initially focusing on the multifaceted problems related to geopolitical impacts, refinery operations, and market dynamics, the study navigates through these intricate layers, offering a detailed PESTLE analysis that connects macro-level factors to specific market outcomes. In doing so, it not only addresses the primary research questions but also raises further queries regarding the nonlinear aspects of energy transitions and their implications. This research serves as a foundation for future investigations into policy shifts, technological advancements, and the evolving societal attitudes shaping the energy markets, both regionally and globally. It signifies a step towards understanding the broader implications of energy market dynamics and their impact on regional economies and global environmental strategies. This extended understanding is crucial for policymakers, market analysts, and academics alike, as it lays the groundwork for more targeted, effective, and sustainable energy policies and market strategies in the future.

References

AGECON SEARCH. Proceedings - Twenty-fourth Annual meeting. 1983.

AKLIN, M. & URPELAINEN, J. 2018. *Renewables : The Politics of a Global Energy Transition,* Cambridge, UNITED STATES, MIT Press.

ÁLVAREZ, E., BRAVO, M., JIMÉNEZ, B., MOURÃO, A. & SCHULTES, R. 2018. The Oil and Gas value chain: a focus on oil refining. *Boston Consulting Group in collaboration with Orkestra*.

ARGUS. 2021. *ExxonMobil shut Norway Slagen refinery in June* [Online]. Argus. Available: https://www.argusmedia.com/en/news/2237347-exxonmobil-shut-norway-slagen-refinery-in-june [Accessed Sep 5 2023].

ARGUS. 2023a. *European Diesel* [Online]. Argus. Available: https://www.argusmedia.com/en/hubs/european-diesel [Accessed Oct 2023].

ARGUS. 2023b. *Q&A: HVO blend in Swedish diesel could drop below 1pc* [Online]. Argus. Available: https://www.argusmedia.com/en/news/2466871-qa-hvo-blend-in-swedish-diesel-could-drop-below-1pc [Accessed Nov 1 2023].

ARIZCUREN-BLASCO, J., MARTIN-GARCIA, R. & RUIZ-RUA, A. 2023. Is unsubsidised energy transition possible? Feasibility of replacing diesel buses with electric ones. *Transport Policy,* 137**,** 67-89.

BALDONI-ANDREY, P., GIRLING, A., STRUIJK, K., BORMAN, F. D., SMITH, R., CAPUANO, M. & HAAN , K. D. 2010. Refinery BREF related environmental parameters for aqueous discharges from refineries in Europe. Brussels: CONCAWE,.

BANKS, F. 2007. The Political Economy of World Energy: An Introductory Textbook.

BAZILIAN, M. D. & HOWELLS, M. 2019. Preface to the special issue on “The geopolitics of the energy transition”. *Energy Strategy Reviews,* 26**,** 100413.

BEZERGIANNI, S. & DIMITRIADIS, A. 2013. Comparison between different types of renewable diesel. *Renewable and Sustainable Energy Reviews,* 21**,** 110-116.

BEZERGIANNI, S., DIMITRIADIS, A., KIKHTYANIN, O. & KUBIČKA, D. 2018. Refinery co-processing of renewable feeds. *Progress in Energy and Combustion Science,* 68**,** 29-64.

BIERMANN, M., HARVEY, S., KJÄRSTAD, J., ANANTHARAMAN, R., FU, C., JORDAL, K., LÚA, A. R., ROUSSANALY, S., LUNDQVIST, K., GORSET, O., HOBALLAH, R., WANDERLEY, R. & SEGLEM, H. E. 2022. Preem CCS Synthesis of main project findings and insights.

BLONDEEL, M., BRADSHAW, M. J., BRIDGE, G. & KUZEMKO, C. 2021. The geopolitics of energy system transformation: A review. *Geography Compass,* 15**,** e12580.

BOWEN, G. A. 2009. Document Analysis as a Qualitative Research Method. *Qualitative Research Journal,* 9**,** 27-40.

BRAUN, V. & CLARKE, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology,* 3**,** 77-101.

BRYMAN, A. 2016. *Social Research Methods*, Oxford University Press.

BRYNOLF, S., TALJEGARD, M., GRAHN, M. & HANSSON, J. 2018. Electrofuels for the transport sector: A review of production costs. *Renewable and Sustainable Energy Reviews,* 81**,** 1887-1905.

CAMES, M. & HELMERS, E. 2013. Critical evaluation of the European diesel car boom - global comparison, environmental effects and various national strategies. *Environmental Sciences Europe,* 25**,** 15.

CARLIER, M. 2023. *Market share of battery electric cars (BEV) in Norway from 2018 to 2022* [Online]. Statista. Available: https://www.statista.com/statistics/1029936/market-share-of-battery-electric-cars-in-norway/#:~:text=The%20majority%20of%20cars%20sold,to%2064.5%20percent%20in%202021. [Accessed Nov 5 2023].

CAROLLO, S. 2011. *Understanding Oil Prices : A Guide to What Drives the Price of Oil in Today's Markets,* Newark, UNITED KINGDOM, John Wiley & Sons, Incorporated.

CENTRE FOR RESEARCH ON ENERGY AND CLEAN AIR 2023. The Laundromat: How the price cap coalition whitewashes Russian oil in third countries.

CHAPMAN, A. 2023. *Sweden slashes biofuels mandate to increase diesel demand by 1.5m tonnes per year* [Online]. Fastmarkets. Available: https://www.fastmarkets.com/insights/sweden-slashes-biofuels-mandate-to-increase-diesel-demand/ [Accessed Aug 28 2023].

CIUCCI, M. 2023. *Energy policy: general principles* [Online]. European Parliament. Available: https://www.europarl.europa.eu/factsheets/en/sheet/68/energy-policy-general-principles [Accessed Sep 5 2023].

COLEMAN, L. 2012. Explaining crude oil prices using fundamental measures. *Energy Policy,* 40**,** 318-324.

CONAWAY, C. F. 1999. 14.1 Crude Oil Marketing. *Petroleum Industry - A Nontechnical Guide*. PennWell.

CONCAWE. 2023. *Refinery Sites in Europe* [Online]. CONCAWE. Available: https://www.concawe.eu/refineries-map/ [Accessed Dec 16 2023].

CRESWELL, J. W. & CRESWELL, J. W. 2014. *Research design : qualitative, quantitative, and mixed methods approaches,* Los Angeles, SAGE.

CROSSBRIDGE ENERGY PARTNERS. 2022. *Crossbridge Energy A/S and Everfuel Finalize Phase 2a Green Hydrogen Agreement* [Online]. Crossbridge Energy Partners. Available: https://crossbridgepartners.com/crossbridge-energy-a-s-and-everfuel-finalize-phase-2a-green-hydrogen-agreement/ [Accessed Aug 23 2023].

DANIELSSON, D. & ERLANDSSON, L. 2010. Comparing exhaust emissions from heavy duty diesel engines using EN 590 vs. MK1 diesel fuel.

DAUPHIN, R., EDWARDS, S., JARASSE, A. & WEISSNE, M. 2022. A Mapping of Technology Options for Sustainable Energies and Powertrains for Road Transport.

DAVIS, L. W. 2023. The Economic Determinants of Heat Pump Adoption.

DING, C., FERRO, A., FITZGIBBON, T. & SZABAT, P. 2022. *Refining in the energy transition through 2040* [Online]. McKinsey & Company. Available: https://www.mckinsey.com/industries/oil-and-gas/our-insights/refining-in-the-energy-transition-through-2040 [Accessed Aug 1 2023].

DONOVAN, K. 2023. *Finland replaces Russian Urals with oil from Norway, UK and US* [Online]. Reuters. Available: https://www.reuters.com/business/energy/finland-replaces-russian-urals-with-oil-norway-uk-us-2023-03-15/ [Accessed Sep 5 2023].

DOUVARTZIDES, S. L., CHARISIOU, N. D., PAPAGERIDIS, K. N. & GOULA, M. A. 2019. Green Diesel: Biomass Feedstocks, Production Technologies, Catalytic Research, Fuel Properties and Performance in Compression Ignition Internal Combustion Engines. *Energies,* 12**,** 809.

DU, J., LI, Z. & WANG, J. 2022. The reaction of energy markets to regional conflict: evidence from event study approach. *Procedia Computer Science,* 214**,** 935-942.

EQUINOR. 2023. *Onshore facilities* [Online]. Equinor,. Available: https://www.equinor.com/energy/onshore-facilities [Accessed Nov 10 2023].

EU SCIENCE HUB. 2018. *Renewable Energy – Recast to 2030 (RED II)* [Online]. Available: https://joint-research-centre.ec.europa.eu/welcome-jec-website/reference-regulatory-framework/renewable-energy-recast-2030-red-ii_en [Accessed Oct 15th 2023].

EUR-LEX. 2022. *Emissions from heavy-duty vehicles (Euro VI): certification rules* [Online]. EUR-Lex. Available: https://eur-lex.europa.eu/EN/legal-content/summary/emissions-from-heavy-duty-vehicles-euro-vi-certification-rules.html [Accessed Nov 1 2023].

EUROPEAN CENTRAL BANK 2007. Oil market structure, network effects and the choice of currency for oil invoicing.

EUROPEAN CENTRAL BANK. 2023. *Two per cent inflation target* [Online]. European Central Bank. Available: https://www.ecb.europa.eu/mopo/strategy/pricestab/html/index.en.html [Accessed Nov 5 2023].

EUROPEAN COMMISSION 2017. Evaluation of Directive 98/70/EC of the European Parliament and of the Council

relating to the quality of petrol and diesel fuels ('Fuel Quality Directive').

EUROPEAN COMMISSION. 2020a. *Fuel Quality* [Online]. European Comission. Available: https://climate.ec.europa.eu/eu-action/transport/fuel-quality_en#:~:text=The%20Fuel%20Quality%20DirectiveEN,6%25%20after%20the%20year%202020. [Accessed Sep 30th 2023].

EUROPEAN COMMISSION 2020b. Latvia's national energy and climate plan 2021–2030. Riga.

EUROPEAN COMMISSION. 2022. *EU transport in figures, statistical pocketbook 2022* [Online]. European Commission. Available: https://op.europa.eu/en/publication-detail/-/publication/f656ef8e-3e0e-11ed-92ed-01aa75ed71a1/language-en/format-PDF/source-277192062 [Accessed Nov 5 2023].

EUROPEAN COMMISSION. 2023a. *Autumn 2023 Economic Forecast: A modest recovery ahead after a challenging year* [Online]. European Commission. Available: https://economy-finance.ec.europa.eu/economic-forecast-and-surveys/economic-forecasts/autumn-2023-economic-forecast-modest-recovery-ahead-after-challenging-year_en#:~:text=EU%20GDP%20growth%20is%20forecast,to%201.7%25%2C%20in%202025. [Accessed Nov 9 2023].

EUROPEAN COMMISSION. 2023b. *EU Strategy for the Baltic Sea Region* [Online]. European Commission. Available: https://ec.europa.eu/regional_policy/policy/cooperation/macro-regional-strategies/baltic-sea_en [Accessed Nov 1 2023].

EUROPEAN COMMISSION 2023c. The European Commission decides to refer CROATIA, HUNGARY and PORTUGAL to the Court of Justice of the European Union for failing to enact EU rules promoting more renewable energy in Europe. European Commission.

EUROPEAN COMMISSION 2023d. Guidance on Russian oil price cap.

EUROPEAN COMMISSION. 2023e. *Renewable Energy Directive* [Online]. European Commission. Available: https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en [Accessed Nov 1 2023].

EUROPEAN COMMISSION. 2023f. *What is the EU ETS?* [Online]. European Commission. Available: https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/what-eu-ets_en [Accessed Nov 15 2023].

EUROPEAN COUNCIL. 2023a. *EU sanctions against Russia explained* [Online]. Available: https://www.consilium.europa.eu/en/policies/sanctions/restrictive-measures-against-russia-over-ukraine/sanctions-against-russia-explained/ [Accessed].

EUROPEAN COUNCIL. 2023b. *European Green Deal* [Online]. European Council. Available: https://www.consilium.europa.eu/en/policies/green-deal/ [Accessed December 20 2023].

EUROPEAN ENVIRONMENT AGENCY 2016. Explaining road transport emissions.

EUROSTAT. 2023. *Final energy consumption in road transport by type of fuel* [Online]. Eurostat. Available: https://ec.europa.eu/eurostat/databrowser/view/TEN00127/default/table [Accessed Aug 10 2023].

FAHIM, M. A., AL-SAHHAF, T. A. & ELKILANI, A. 2009. *Fundamentals of Petroleum Refining,* San Diego, NETHERLANDS, THE, Elsevier Science & Technology.

FATTOUH, B. & ECONOMOU, A. 2022. Russia's Invasion of Ukraine and Oil Market Dynamics.

FATTOUH, B. & ECONOMOU, A. 2023. Global Oil Market Update: H2 2023. Oxford Institute for Energy Studies.

FAVENNEC, J.-P. 2001. 2.5.2 Cold Temperature Performance. *Petroleum Refining, Volume 5 - Refinery Operation and Management.* Editions Technip.

FINLEX 2023. Hallituksen esitys eduskunnalle laiksi uusiutuvien polttoaineiden käytön edistämisestä liikenteessä annetun lain 5 §:n muuttamisesta.

FOSSILFRITT SVERIGE. 2023. *Fossilfritt Sverige* [Online]. Fossilfritt Sverige. Available: https://fossilfrittsverige.se/ [Accessed Nov 5 2023].

FUELSEUROPE 2023. FuelsEurope Statistical Report 2023.

GAD, S. C. 2024. Petroleum hydrocarbons. *In:* WEXLER, P. J. (ed.) *Encyclopedia of Toxicology (Fourth Edition).* Oxford: Academic Press.

GEELS, W. F. 2014. Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society,* 31**,** 21-40.

GRÖNMAN, K., PAJULA, T., SILLMAN, J., LEINO, M., VATANEN, S., KASURINEN, H., SOININEN, A. & SOUKKA, R. 2019. Carbon handprint – An approach to assess the positive climate impacts of products demonstrated via renewable diesel case. *Journal of Cleaner Production,* 206**,** 1059-1072.

GUDDE, N., LARIVÉ, J. & YUGO, M. 2019. Refinery 2050: Conceptual Assessment. Exploring opportunities and challenges for the EU refining industry to transition towards a low-CO2 intensive economy. *Concawe Special Task Force Refinery 2050.* Brussels: Concawe: Environmental Science for European Refining.

HAFNER, M. & LUCIANI, G. 2022. *The palgrave handbook of international energy economics,* Cham, Switzerland, Springer Nature.

HAIN, M., HESS, J. & UHRIG-HOMBURG, M. 2018. Relative value arbitrage in European commodity markets. *Energy Economics,* 69**,** 140-154.

HAMILTON, J. 1983. Oil and the Macroeconomy since World War II. *Journal of Political Economy,* 91**,** 228-48.

HERCE, C., MARTINI, C., SALVIO, M. & TORO, C. 2022. Energy Performance of Italian Oil Refineries Based on Mandatory Energy Audits. *Energies* [Online], 15.

HOSSEINI, S., SHAKOURI G, H. & PEIGHAMI, A. 2016. A conceptual framework for the oil market dynamics: A systems approach. *Energy Exploration & Exploitation,* 34**,** 171-198.

HOTTEN, R. 2015. *Volkswagen: The scandal explained* [Online]. BBC. Available: https://www.bbc.com/news/business-34324772 [Accessed Nov 1 2023].

IEA. 2021. *Fuel economy in the European Union* [Online]. IEA. Available: https://www.iea.org/articles/fuel-economy-in-the-european-union [Accessed Sep 6 2023].

IEA. 2022a. *By 2030 EVs represent more than 60% of vehicles sold globally, and require an adequate surge in chargers installed in buildings* [Online]. IEA. Available: https://www.iea.org/reports/by-2030-evs-represent-more-than-60-of-vehicles-sold-globally-and-require-an-adequate-surge-in-chargers-installed-in-buildings [Accessed Oct 23 2023].

IEA 2022b. IEA, Prices for Brent, Urals crude and diesel in Northwest Europe, 2021-2022. Paris: IEA.

IEA 2022c. Oil Security Policy. Paris.

IEA. 2022d. *Poland Oil Security Policy* [Online]. IEA. Available: https://www.iea.org/articles/poland-oil-security-policy [Accessed Sep 6 2023].

IEA. 2023a. *Estonia 2023* [Online]. IEA. Available: https://prod.iea.org/reports/estonia-2023/executive-summary [Accessed Nov 5 2023].

IEA. 2023b. *Finland 2023* [Online]. IEA. Available: https://www.iea.org/reports/finland-2023/executive-summary [Accessed Nov 5 2023].

IEA 2023c. Global EV Outlook 2023. Paris: IEA.

IEA 2023d. Oil Market Report - September 2023. Paris: International Energy Agency IEA.

IEA. 2023e. *Replacing oil shale with renewables in the power system can help Estonia achieve its energy and climate ambitions* [Online]. IEA. Available: https://www.iea.org/news/replacing-oil-shale-with-renewables-in-the-power-system-can-help-estonia-achieve-its-energy-and-climate-ambitions [Accessed Nov5 2023].

IEA 2023f. World Energy Outlook 2023.

IPCC 2023. IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland.

IRENA 2019. A New World: The Geopolitics of the Energy Transformation.

JULIO, A. A. V., MILESSI, T. S., OCAMPO BATLLE, E. A., SILVA LORA, E. E., YEPES MAYA, D. M. & ESCOBAR PALACIO, J. C. 2022. Techno-economic and environmental potential of Renewable Diesel as complementation for diesel and biodiesel in Brazil: A comprehensive review and perspectives. *Journal of Cleaner Production,* 371**,** 133431.

KAGAWA, S., KAGAWA, S., FUJII, H., KAGAWA, S. & FUJII, H. 2021. *Advances in Low Carbon Technologies and Transition,* Basel, Switzerland, MDPI - Multidisciplinary Digital Publishing Institute.

KALUNDBORG REFINERY. 2023. *About us* [Online]. Kalundborg Refinery. Available: https://www.kalundborgrefinery.com/about [Accessed Nov 10 2023].

KILIAN, L. & HICKS, B. 2013. Did unexpectedly strong economic growth cause the oil price shock of 2003-2008? *J. Forecast.,* 32**,** 385-394.

KIMANI, A. 2023. *Oil Trade Is Moving Away From Europe* [Online]. Oilprice.com. Available: https://oilprice.com/Energy/Crude-Oil/Oil-Trade-Is-Moving-Away-From-Europe.html [Accessed Sep 23rd 2023].

KONUR, O. 2021. Petrodiesel fuels: A scientometric review of the research. *Petrodiesel Fuels*, 951-975.

KOSTER, M., SIMONE, F. D. & SAINT-SUPÉRY, M. V. 2023. Overview of biofuels policies and markets across the EU.

KOUL, R., KUMAR, N. & SINGH, R. C. 2022. Comparative analysis of renewable diesel and biodiesel produced from Jatropha oil. *Environmental Progress & Sustainable Energy,* 41, e13832.

LEFFLER, W. L. 2020. 4.1 The Simple Still. *Petroleum Refining in Nontechnical Language (5th Edition).* PennWell.

LEHMANN, T. C. 2017. *The geopolitics of global energy : the new cost of plenty,* Boulder, Colorado ;, Lynne Rienner Publishers, Inc.

LIMA, C., RELVAS, S. & BARBOSA-PÓVOA, A. P. F. D. 2016. Downstream oil supply chain management: A critical review and future directions. *Computers & Chemical Engineering,* 92, 78-92.

MARKETSCREENER. 2023. *Neste to Take 25% Sales Hit From Sweden's Biofuel Pull-Back -- OPIS* [Online]. MarketScreener. Available: https://www.marketscreener.com/quote/stock/NESTE-OYJ-1412495/news/Neste-to-Take-25-Sales-Hit-From-Sweden-s-Biofuel-Pull-Back-OPIS-43924867/ [Accessed Sep 7 2023].

MELLIOS, G. & GOULIAROU, E. 2021. Fuel quality monitoring in the EU in 2020. Belgium: European Topic Centre on Climate change mitigation and energy.

MINISTRY OF CLIMATE AND ENVIRONMENT REPUBLIC OF POLAND. 2023. *Energy Policy of Poland until 2040 (EPP2040)* [Online]. Ministry of Climate and Environment Republic of Poland. Available: https://www.gov.pl/web/climate/energy-policy-of-poland-until-2040-epp2040 [Accessed Sep 6 2023].

MINISTRY OF ENERGY OF THE REPUBLIC OF LITHUANIA. 2021. *The Law on Alternative Fuels has been passed: How the transport sector will change over the next decade* [Online]. LIETUVOS RESPUBLIKOS ENERGETIKOS MINISTERIJA. Available: https://enmin.lrv.lt/en/news/the-law-on-alternative-fuels-has-been-passed-how-the-transport-sector-will-change-over-the-next-decade/ [Accessed Sep 5 2023].

MORK, K. A. 1989. Oil and the Macroeconomy When Prices Go Up and Down: An Extension of Hamilton's Results. *Journal of Political Economy,* 97, 740-744.

MUNDELL, I. 2023. *The Ecosystem: Europe's electrofuel companies prepare for life on the road* [Online]. ScienceBusiness. Available: https://sciencebusiness.net/news/Mobility/ecosystem-europes-electrofuel-companies-prepare-life-road [Accessed Sep 13 2023].

NEOT. 2023. *Fuel oils* [Online]. Neot. Available: https://www.neot.fi/en/supply/products/fuel-oils/ [Accessed Oct 10th 2023].

NESTE. 2022. *Neste launches a strategic study on transitioning its Porvoo refinery to a renewable and circular site and ending crude oil refining in the mid-2030s* [Online]. Neste. Available: https://www.neste.com/releases-and-news/renewable-solutions/neste-launches-strategic-study-transitioning-its-porvoo-refinery-renewable-and-circular-site-and#:~:text=19%20September%202022-,Neste%20launches%20a%20strategic%20study%20on%20transitioning%20its%20Porvoo%20refinery,refining%20in%20the%20mid%2D2030s [Accessed Sep 5 2023].

NESTE. 2023a. *Energy efficiency* [Online]. Neste. Available: https://www.neste.com/sustainability/climate/energy-efficiency#3e87cfe6 [Accessed Oct 3 2023].

NESTE. 2023b. *Fuel oils* [Online]. Neste. Available: https://www.neste.com/products/all-products/fossil-products/fuel-oils#9998997a [Accessed Oct 10th 2023].

NESTE. 2023c. *Neste's refining operations in Naantali have ended – Naantali terminal to start operations* [Online]. Neste. Available: https://www.neste.com/about-neste/who-we-are/production/porvoo-and-naantali/naantali-refining-operations-have-ended#3e87cfe6 [Accessed Sep 5 2023].

NESTE. 2023d. *Porvoo* [Online]. Neste. Available: https://www.neste.com/about-neste/who-we-are/production/porvoo#3e87cfe6 [Accessed Nov 11 2023].

NESTE. 2023e. *Renewable Road Transport - Reduced emissions* [Online]. Available: https://www.neste.com/products/all-products/renewable-road-transport/reduced-emissions#ac1fd98e [Accessed Oct 23rd 2023].

NORSK ELBILFORENING. 2023. *Norwegian EV policy* [Online]. Norsk elbilforening. Available: https://elbil.no/english/norwegian-ev-policy/ [Accessed Nov 5 2023].

NS ENERGY. 2023a. *Grupa Lotos Oil Refinery Upgrade* [Online]. NS ENERGY. Available: https://www.nsenergybusiness.com/projects/grupa-lotos-oil-refinery-upgrade/ [Accessed Nov 10 2023].

NS ENERGY. 2023b. *Mazeikiai Refinery Expansion and Upgrade* [Online]. NS ENERGY. Available: https://www.nsenergybusiness.com/projects/mazeikiai-refinery-expansion-and-upgrade/ [Accessed Nov 10 2023].

NS ENERGY. 2023c. *Plock Refinery Upgrade* [Online]. NS ENERGY. Available: https://www.nsenergybusiness.com/projects/plock-refinery-upgrade/ [Accessed Nov 11 2023].

NS ENERGY. 2023d. *Preemraff Lysekil Refinery* [Online]. NS ENERGY. Available: https://www.nsenergybusiness.com/projects/preemraff-lysekil-refinery/#:~:text=Preemraff%20Lysekil%20refinery%20performance&text=The%20refinery%20has%20a%20Nelson%20Complexity%20Index%20(NCI)%20of%2010. [Accessed Nov 11 2023].

NUNN, S., SCHLESINGER, J. R., EBEL, R. E., CENTER FOR, S. & INTERNATIONAL, S. 2000. *The geopolitics of energy into the 21st century : a report of the CSIS Strategic Energy Initiative,* Washington, D.C, CSIS Press.

OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY. 2020. *FOTW #1142, July 13, 2020: Refineries in the Americas Produce a Greater Share of Gasoline per Barrel of Crude Oil than Refineries in other World Regions* [Online]. Office of Energy Efficiency & Renewable Energy. Available: https://www.energy.gov/eere/vehicles/articles/fotw-1142-july-13-2020-refineries-americas-produce-greater-share-gasoline [Accessed August 15 2023].

OFFSHORE TECHNOLOGY. 2023a. *Refinery profile: Fredericia coking refinery, Denmark* [Online]. Offshore Technology. Available: https://www.offshore-technology.com/marketdata/fredericia-refinery-coking-denmark/ [Accessed Nov 12 2023].

OFFSHORE TECHNOLOGY. 2023b. *Refinery profile: Gothenburg I coking refinery, Sweden* [Online]. Offshore Technology. Available: https://www.offshore-technology.com/marketdata/gothenburg-i-refinery-coking-sweden/ [Accessed Nov 11 2023].

OFFSHORE TECHNOLOGY. 2023c. *Refinery profile: Gothenburg I coking refinery, Sweden* [Online]. Offshore Technology,. Available: https://www.offshore-technology.com/marketdata/gothenburg-i-refinery-coking-sweden/?cf-view [Accessed Dec 24 2023].

OFFSHORE TECHNOLOGY. 2023d. *Refinery profile: Gothenburg III hydroskimming refinery, Sweden* [Online]. Offshore Technology. Available: https://www.offshore-technology.com/marketdata/gothenburg-iii-refinery-hydroskimming-sweden/?cf-view [Accessed Nov 11 2023].

OFFSHORE TECHNOLOGY. 2023e. *Refinery profile: Kalundborg coking refinery, Denmark* [Online]. Offshore Technology. Available: https://www.offshore-technology.com/marketdata/kalundborg-refinery-coking-denmark/ [Accessed Nov 12 2023].

OFFSHORE TECHNOLOGY. 2023f. *Refinery profile: Mongstad* [Online]. Offshore Technology. Available: https://www.offshore-technology.com/marketdata/mongstad-refinery-coking-norway/?cf-view [Accessed Nov 12 2023].

OFFSHORE TECHNOLOGY. 2023g. *Refinery profile: Porvoo cracking refinery, Finland* [Online]. Offshore Technology. Available: https://www.offshore-technology.com/marketdata/porvoo-refinery-cracking-finland/?cf-view&cf-closed [Accessed Nov 11 2023].

OILTANKING. 2015. *Glossary/ Middle Distillates / Gasoil* [Online]. Oiltanking. Available: https://www.oiltanking.com/en/news-info/glossary/middle-distillates-gasoil.html [Accessed Sep 24th 2023].

PAINTER, D. S. 1986. *Oil and the American Century: The Political Economy of U.S. Foreign Oil Policy, 1941-1954,* Baltimore, Johns Hopkins University Press.

PAIVI, E. & ANNE, K. 2008. Qualitative Methods in Business Research. London: Sage Research Methods.

PASCUAL, C. & ZAMBETAKIS, E. 2010. The geopolitics of energy. *Energy Security: Economics, Politics, Strategies, and Implications*, 9-35.

PELLING, L. 2023. *Sweden's climate policy is off the rails* [Online]. IPS. Available: https://www.ips-journal.eu/topics/economy-and-ecology/swedens-climate-policy-is-off-the-rails-7029/ [Accessed Nov 7 2023].

PREEM 2023. Sustainability Report 2022.

PRIOR, L. 2003. *Using Documents in Social Research*, SAGE Publications.

PURICELLI, S., CARDELLINI, G., CASADEI, S., FAEDO, D., VAN DEN OEVER, A. E. M. & GROSSO, M. 2021. A review on biofuels for light-duty vehicles in Europe. *Renewable and Sustainable Energy Reviews,* 137, 110398.

QUANTUM COMMODITY INTELLIGENCE. 2022. *Analysis: European diesel benchmarks under spotlight amid war* [Online]. Available: https://www.qcintel.com/article/analysis-european-diesel-benchmarks-under-spotlight-amid-war-5083.html [Accessed].

RÄISÄNEN, O. & PITKÄNEN, L. 2022. *MobilePay ei enää kelpaa Teboililla – boikotti on ajanut Teboil-yrittäjät ahdinkoon: "Minun yritystoimintani ei Teboilia rikastuta"* [Online]. Yle. Available: https://yle.fi/a/74-20000663 [Accessed Oct 24 2023].

RICKER, C., BARRON, J. & HAMILTON, M. 2017. *Changing quality mix is affecting crude oil price differentials and refining decisions* [Online]. U.S. Energy Information Administration. Available: https://www.eia.gov/todayinenergy/detail.php?id=33012 [Accessed October 22nd 2022].

RINGSTROM, A. 2020. *Preem drops $1.65 bln Swedish refinery expansion plan* [Online]. Reuters. Available: https://www.reuters.com/article/sweden-preem-refinery-idUSL8N2GP31J/ [Accessed Oct 24 2023].

ROSAL, I. D. 2022. European dieselization: Policy insights from EU car trade. *Transport Policy,* 115**,** 181-194.

RYAN, L. 2023. Diesel and Fuel Oil: Distillate Supply Issues. Congressional Research Service (CRS).

S&P GLOBAL 2023. Specifications Guide - Global Freight.

SAHEBI, H., NICKEL, S. & ASHAYERI, J. 2014. Strategic and tactical mathematical programming models within the crude oil supply chain context—A review. *Computers & Chemical Engineering,* 68**,** 56-77.

SAUNDERS, M., LEWIS, P., THORNHILL, A. & BRISTOW, A. 2019. "Research Methods for Business Students" Chapter 4: Understanding research philosophy and approaches to theory development.

SCHAFFER, L. M. 2021. The politics of green taxation. *Handbook on the Politics of Taxation.* Edward Elgar Publishing.

SIEPPI, S. 2023. Neste moves forward in its renewable hydrogen project in Porvoo, Finland. Neste.

SŁOWIŃSKA, J. 2023. *Polish Briefing: Poland is 5 million tons of diesel short I KGHM's small reactor project I Orlen and Synthos inch towards an SMR near Oświęcim* [Online]. Biznes Alert. Available: https://biznesalert.com/polish-briefing-poland-is-5-million-tons-of-diesel-short-i-kghms-small-reactor-project-i-orlen-and-synthos-inch-towards-an-smr-near-oswiecim/ [Accessed Nov 1 2023].

SOVACOOL, B. & DWORKIN, M. 2014. *Global Energy Justice: Problems, Principles, and Practices.*

SPEIGHT, J. G. 2011. *An Introduction to Petroleum Technology, Economics, and Politics,* Newark, UNITED STATES, John Wiley & Sons, Incorporated.

SQUADRIN, G. 2023. *Bio-mandates cuts to worsen oil supply security: IEA* [Online]. Argus. Available: https://www.argusmedia.com/ja/news/2321581-biomandates-cuts-to-worsen-oil-supply-security-iea [Accessed Nov 9 2023].

SRIVASTAVA, S. P. & HANCSÓK, J. 2014. *Fuels and Fuel-Additives,* Newark, UNITED STATES, John Wiley & Sons, Incorporated.

ST1. 2023. *Refinery* [Online]. St1. Available: https://www.st1.com/about-st1/company-information/areas-operations/st1-refinery [Accessed Nov 10 2023].

STATISTICS NORWAY. 2023. *Registered vehicles* [Online]. Statistics Norway. Available: https://www.ssb.no/en/transport-og-reiseliv/landtransport/statistikk/bilparken [Accessed Nov 1 2023].

SUAREZ-BERTOA, R. 2017. Reference fuels. European Comission.

TATOMIR, S. 2022. *Estonia's climate policy: challenges and opportunities* [Online]. OECDilibrary. Available: https://www.oecd-ilibrary.org/sites/25d93653-en/index.html?itemId=/content/component/25d93653-en [Accessed Nov 5 2023].

THE ECONOMIC TIMES. 2022. *Explained: How much crude oil does the EU still import from Russia* [Online]. The Economic Times,. Available: https://energy.economictimes.indiatimes.com/news/oil-and-gas/explained-how-much-crude-oil-does-the-eu-still-import-from-russia/94338324 [Accessed Sep 5 2023].

THE ECONOMIC TIMES. 2023. *The countries phasing out internal combustion engines* [Online]. The economic times. Available: https://energy.economictimes.indiatimes.com/news/oil-and-gas/the-countries-phasing-out-internal-combustion-engines/99055832 [Accessed Sep 7 2023].

THE LOCAL DK. 2023. *Denmark confirms plan to raise diesel tax from 2025* [Online]. The local dk. Available: https://www.thelocal.dk/20231013/denmark-confirms-plan-to-raise-diesel-tax-from-2025 [Accessed Nov 5 2023].

TOMÁS, M., GARCÍA-MUROS, X., ALONSO-EPELDE, E., ARTO, I., RODRÍGUEZ-ZÚÑIGA, A., MONGE, C. & GONZÁLEZ-EGUINO, M. 2023. Ensuring a just energy transition: A distributional analysis of diesel tax reform in Spain with stakeholder engagement. *Energy Policy,* 177, 113558.

TURNER, E. 2022. *Refinery news roundup: Renewables projects in Europe* [Online]. S&P Global Commodity Insights. Available: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/petrochemicals/072622-refinery-news-roundup-renewables-projects-in-europe [Accessed Sep 4 2023].

TURNER, E., BALDWIN, N., KETTLEY, E., ANGELL, S. & JOHNSTONE , C. 2022. *European refiners acting fast to replace Russian crude* [Online]. S&P Global Commodity Insights. Available: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/petrochemicals/053122-european-refiners-acting-fast-to-replace-russian-crude [Accessed Sep 6 2023].

VAN DYK, S., SU, J., EBADIAN, M. & SADDLER, J. 2022. Production of lower carbon-intensity fuels by co-processing biogenic feedstocks: Potential and challenges for refineries. *Fuel,* 324**,** 124636.

WACKET, M. 2023. *Exclusive: EU drafts plan to allow e-fuel combustion engine cars* [Online]. Reuters. Available: https://www.reuters.com/business/autos-transportation/eu-proposes-exception-e-fuel-combustion-engines-2035-2023-03-21/ [Accessed Sep 17 2023].

WENANDE, C. 2023. *Copenhagen looking to ban fossil fuel vehicles by 2030* [Online]. The Copenhagen Post. Available: https://cphpost.dk/2023-05-08/news/copenhagen-looking-to-ban-fossil-fuel-vehicles-by-2030/ [Accessed Aug 28 2023].

WOODROOF, N. 2020. *Preem withdraws expansion plans for Lysekil Refinery* [Online]. Hydrocarbon Engineering. Available: https://www.hydrocarbonengineering.com/refining/28092020/preem-withdraws-expansion-plans-for-lysekil-refinery/ [Accessed Sep 5 2023].

XU, H., OU, L., LI, Y., HAWKINS, T. R. & WANG, M. 2022. Life Cycle Greenhouse Gas Emissions of Biodiesel and Renewable Diesel Production in the United States. *Environmental Science & Technology,* 56**,** 7512-7521.

YERGIN, D. 1991. *The prize : the epic quest for oil, money and power,* New York, Simon & Schuster.

YIN, R. K. 2009. *Case Study Research: Design and Methods*, SAGE Publications.

YOO, S., KOH, K. W. & YOSHIDA, Y. 2020. Are consumers abandoning diesel automobiles because of contrasting diesel policies? Evidence from the Korean automobile market. *Energy Economics,* 92**,** 104969.

ZACHARIADIS, T. 2016. After 'dieselgate': Regulations or economic incentives for a successful environmental policy? *Atmospheric Environment,* 138**,** 1-3.