11-3-2019

Decarbonising the global supply chain: which fuel alternative should shipping companies turn to? : a feasibility study of the implementation of biofuels

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DECARBONISING THE GLOBAL SUPPLY CHAIN: WHICH FUEL ALTERNATIVE SHOULD SHIPPING COMPANIES TURN TO?

A Feasibility Study of the Implementation of Biofuels

By

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A dissertation submitted to the World Maritime University in partial fulfilment of the requirement for the award of the degree of

MASTER OF SCIENCE
In
MARITIME AFFAIRS

(SHIPPING MANAGEMENT AND LOGISTICS)

2019

DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: ……....…...………………...

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ACKNOWLEDGEMENTS

The journey towards the completion of this dissertation has been an unforgettable roller coaster. I would like to dedicate this accomplishment to everyone mentioned below. Foremost, I would like to thank God who has continuously armed me with strength and perseverance. Throughout my academic journey, I have learned that His plan for us all is to live a thriving life, a plan to give us hope and a future.

Then, I would like to thank the Government of Norway for the generous full funding of my studies at the World Maritime University. Similarly, I would also like to thank the Women's International Shipping & Trading Association Norway (WISTA) for awarding me with the WISTA Norway Research Grant.

I would like to express my sincere gratitude to my supervisor Professor Aykut Ölcer, Head of Maritime Energy Management (MEM) Specialization, for sharing his knowledge with me, for his patience, motivation, enthusiasm and immense guidance throughout my entire research. I would also like to express my deepest thankfulness to Professor Dong-Wook Song, our Head of Specialization for Shipping Management and Logistics (SML), who constantly has a positive approach to life. He displayed a spirit of adventure with regards to learning and convincingly conveyed an excitement for teaching. Likewise, thank you to the entire WMU faculty, who gave their support in so many ways by delivering an outstanding learning environment. In addition, I would like to thank the professional experts who were involved in the interviews for this dissertation. Without their passionate participation and input, this dissertation would not have been possible.

I must express my very profound appreciation to my parents and to my sister for their unconditional love and unfailing support. Thank you for being my source of inspiration and for always whole-heartedly encouraging me to pursue my dreams. Last but not least, I am grateful to my remarkable friends who have made this experience more thrilling than I expected. Thank you for challenging me to become a better version of myself and for making amazing memories with me that will last a lifetime. With all the gratitude to everyone who made all the difference, I am ready and excited to embark on the next journey!

ABSTRACT

Title of Dissertation: **Decarbonising the global supply chain: which fuel alternative should shipping companies turn to? A feasibility study of the implementation of biofuels.**

Degree: **Master of Science**

The dissertation assesses the feasibility of the potential future uptake of biofuels by shipping companies. In the era of global supply chains and "just-in-time" logistics, the fast delivery of goods is an economic competitive advantage for shipping companies. Seaborne trade has played a significant role in driving the global economy and is expected to increase in the coming years. However, expected ship traffic growth will contribute considerably to the existing air pollution problems and climate-change risks worldwide. This dissertation focuses on CO_2 emissions generated by ships on the global level.

To date, developments in ship environmental performance have not grown at the same pace as the increase in shipping activity. Several energy efficiency and CO_2 emissions reduction technologies have been identified in the shipping industry. However, their global implementation remains undetermined. This dissertation identified the perception of the shipping industry towards biofuels, compared the levels of costs and price associated with the production of biofuels with other marine fuels, investigated the amount of R&D initiatives dedicated to biofuels for the shipping industry, measured the extent to which regulations leads to achieving emission reduction targets and finally evaluated the level of contribution of biofuels to long-term and environmental sustainability.

In the framework of the following research, qualitative data was collected. Primary data was collected through semi-structured in-depth interviews (20 to 45 minutes) with individuals with different backgrounds including shipping, engineering, logistics as well as academics. Secondary data was gathered from peer-reviewed journals, scientific publications (e.g. European Union, International Energy Agency) as well as other websites (e.g. Clarksons Shipping Intelligence Network). In addition, a PESTLE Analysis was conducted to identify risks and influential factors under different sub-categories including Political, Economic, Social, Technological, Legal and Environmental. The commonalities between the findings of the literature review, the PESTLE Analysis and the interviews were compiled into themes and served as input for scenario planning. The concluding chapters examine the scenarios where shipping companies currently stand with regards to biofuels, and discuss the desirable scenarios that would facilitate the effective implementation of biofuels.

KEYWORDS: Biofuels, Shipping CO_2 Emissions, Climate change, PESTLE Analysis, Scenario Planning

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List of Abbreviations

CO_2	Carbon dioxide
ECA	Emission Control Areas
EEDI	Energy Efficiency and Design Index
GHG	Greenhouse Gas
HFO	Heavy Fuel Oil
IMO	International Maritime Organization
LCA	Life-cycle assessment
MARPOL	International Convention for the Prevention of Pollution from Ships
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
NO_x	Nitrogen Oxide
N_2O	Nitrous Oxide
PESTLE	Political, Economic, Social, Technological, Legal, Environmental Analysis
RED	Renewable Energy Directive
SEEMP	Ship Energy Efficiency and Management Plan
SO_x	Sulphur Oxide

1. INTRODUCTION

1.1.Background of the study

Maritime transport carries 90% of global trade, because it is the most fuel-efficient mode of transport (Lister, Poulsen, & Ponte, 2015). It amounts up to 70% of the revenues of global trade (The Blue Economy Conference, 2018). In other words, maritime shipping plays a vital role in the global supply chain and ports are today a linking strategic point between the supplier and the consumer. As a matter of fact, the shipping sector has been driving the performance of global supply chains (Yuen, Wang, Ma, Gunwoo, & Xiangyi, 2019). Needless to mention, under the effects of globalisation, the nodes within the global supply chain have increased in number. As a consequence, consumers, NGOs as well as environmentalist groups have raised their concerns: the bigger the supply chain, the higher its environmental impacts in terms of air pollution (Christopher & Peck, 2003). Actually, since the Industrial Revolution in the 18th Century, global concentrations of greenhouse gases (GHGs) including carbon dioxide (CO_2), methane (Ch4) and nitrous oxide (N_2O) have drastically increased and have considerably contributed to the warming of the Earth's atmosphere. This phenomenon is called "greenhouse effect" and has led to more frequent wildfires, longer periods of droughts, rising sea levels, increasing frequency and intensity of storms. The increase in CO_2 concentrations – having reached 415.26 parts per million today (Shieber, 2019) - can primarily be attributed to the globalization of economic activities and the increase of international trade. Recent research has shown that shipping is particularly contributing 30% of Sulphur and Nitrogen emissions worldwide (Martinsen & Torvanger, 2013) to global air pollution. In addition to the sector's overall contribution to greenhouse effect, ports also generate other environmental externalities such as loss of coastal land, noise pollution, dredging and loss of biodiversity (Garnett, 2003); as well as major alterations in the ecosystem: oil spills, CO_2 emissions, invasive species, noise pollution and disposal of hazardous material in the ocean such as chemicals (Bainbridge, et al., 2018). Similarly, air pollution affects health and environmental ecosystems across the world. In fact, sulphur emissions cause acid rain and are also responsible for some of the ozone depleting gases, which contribute to increasing rates of skin cancer.

Unless immediate actions are taken, an increase of 50% to 250% of CO_2 can be projected for 2050 under business-as-usual scenario (IMO, 2014). Under an increasing pressure, the maritime shipping industry is required to take actions towards the Paris Agreement targets and to reduce greenhouse gas emissions (GHG). The 21st session of the Conference of the Parties (COP21), which took place in late November 2015 in Paris, was just the beginning of the fight against of climate change. The COP24 that took place in Poland, in December 2018, witnessed thousands of world leaders, experts, activists, representatives from both the public and private sectors, coming together to strengthen the commitments agreed upon at the COP21 (United Nations , 2018). One of the key messages during COP24 focused on the need to change through solidarity and transformation of regions and industrial sectors (United Nations Climate Change Conference, 2018). Furthermore, in response to air pollution generated by the shipping industry, the International Maritime Organization (IMO) has reinforced MARPOL Annex VI by developing new regulations aimed to improve the environmental performance of maritime transport. For instance, the shipping industry will see the introduction of a global sulphur limit from January 2020, requiring ships to limit the amount of sulphur in their bunker fuel to 0.5%. Similarly, the IMO has set the ambition to reduce greenhouse gas (GHG) emitted by the global shipping sector, by at least 50% in 2050 (International Maritime Organisation, 2018). Against this framework, regulatory framework and policies are expected to be stricter over the coming years.

From this point of view, the problematic lies in the question of how can the shipping industry participate in the reduction of global CO_2 emissions? As the sector is gearing towards the emission reduction goals, it leaves a window of opportunity to drive innovation as well as to introduce low-carbon fuels. Through energy management, the shipping industry has the opportunity to maximise profitability while meeting all regulatory requirements (Olc18). To meet regulatory requirements, the world fleet will have to converge and rely on a diversified range of fuel alternatives, energy propulsion solutions and measures for energy efficiency. Needless to mention, all alternatives carry both benefits and challenges.

The following research identified biofuels as an alternative to which shipping companies can turn to, taking into account that the goal is to optimise both economic and environmental benefits.

1.2.Statement of the research problem

Within the context of globalized production of goods and distribution, the key challenge is to balance operational costs and environmental compliance costs. Considered like any other disruptive force, climate change creates opportunities for any stakeholders willing to innovate and adopt new strategies to reinforce their competitive advantage. This is in line with one of the key intents at the Nairobi Sustainable Blue Economy Conference, held in November 2018 in Kenya, of "promoting economic activities consistent with conservation and long-term capacity of the ocean, seas, lakes and rivers to remain healthy and resilient" (The Blue Economy Conference, 2018). In fact, the aim is to reduce the effects of climate change, enhance adaptation to climate change, create competitive advantage and boost economic growth, in a low-carbon economy, where customers' expectations are higher and international regulations are tighter.

In light of the urgent need to adapt to future energy needs, the question is: which fuel alternative should the shipping industry turn to, keeping in mind that the ultimate goal is to decarbonise the global supply chain while maximizing economic and environmental benefits?

1.3.Significance of the study

It is important to note the shortage in research in shipping strategic issues. For this matter, the findings of the following research will benefit shipping companies and ship owners. On one hand, it will facilitate decision-making processes support for investment in ships over the next decade. On the other hand, the research could help entrepreneurs in to identify window of opportunity for them to venture into, in terms of technology developments or finding alternative solutions to heavy fuel oil. Furthermore, it contributes to the existing knowledge on the options for decarbonizing the global supply chain.

1.4.Aim of the research

The need for alternative fuels in the maritime shipping sector is driven by two main factors. On one hand, to reduce pollutants by complying to existing regulation and on the other hand, to mitigate the effects of climate change by cutting greenhouse gas emissions.

Keeping in mind that the goal is to fight against climate change, attain emissions reduction goals set by societal and regulatory standards as well as maximize profitability for shipping companies, the aim of this research is to identify the most influential factors that would enable the effective implementation of biofuels in the shipping industry. From the point of view of a shipping company, an effective implementation of biofuels entails the fact that biofuels must meet a range of requirements in order to be a viable and sustainable candidate, such as availability, affordability, compatibility with current infrastructure and engines, ability to reduce emissions throughout entire life-cycle, etc.

1.5.Research Objectives

(a) To identify the level of preference towards biofuels
(b) To compare the levels of costs and price of the production of biofuels with other marine fuels
(c) To investigate on the amount of Research & Development initiatives dedicated to biofuels for the shipping industry
(d) To measure the extent to which regulations lead to achieving emission reduction targets
(e) To evaluate the level of contribution of biofuels to long-term social and environmental sustainability

1.6.Research Questions

(a) What is the industry's overall perception of biofuels in comparison to other alternative marine fuels?
(b) How does the costs of production of biofuels affect their effective implementation?
(c) What is the Technological Readiness Level of the industry towards biofuels?
(d) How does the current mitigation policies affect the implementation of biofuels?
(e) What are the social and environmental challenges hindering the adoption of biofuels in the shipping industry? With an emphasis on developing countries.

1.7.Methods

In the framework of this dissertation, both primary and secondary data were used to meet the research objectives mentioned above. Secondary data was gathered from peer-reviewed journals, scientific publications (e.g. European Union, International Energy Agency) as well as other websites (e.g. Clarksons Shipping Intelligence Network). Primary data was collected through semi-structured in-depth interviews (20 to 45 minutes) with individuals with different backgrounds including shipping, engineering, logistics as well as academic. It is important to note that the responses obtained during the interviews are solely personal opinions and do not, in any way, represent the standpoint of the respective organizations of the respondents.

Accordingly, two matrices were established, each containing four different scenarios. The scenarios were built in order to get insight on the extent to which the adoption of biofuels is feasible and then, identify the most influential factors that would enable shipping companies to effectively implement biofuels. Some of the factors taken into account include the nature of technology deployment; the costs of biofuels production; the level of compliance with the current environmental legislation; the social perception on biofuels; the efforts dedicated to biofuels R&D; the interaction between international trade, the shipping industry as well as the agricultural sector.

1.8.Structure of the research

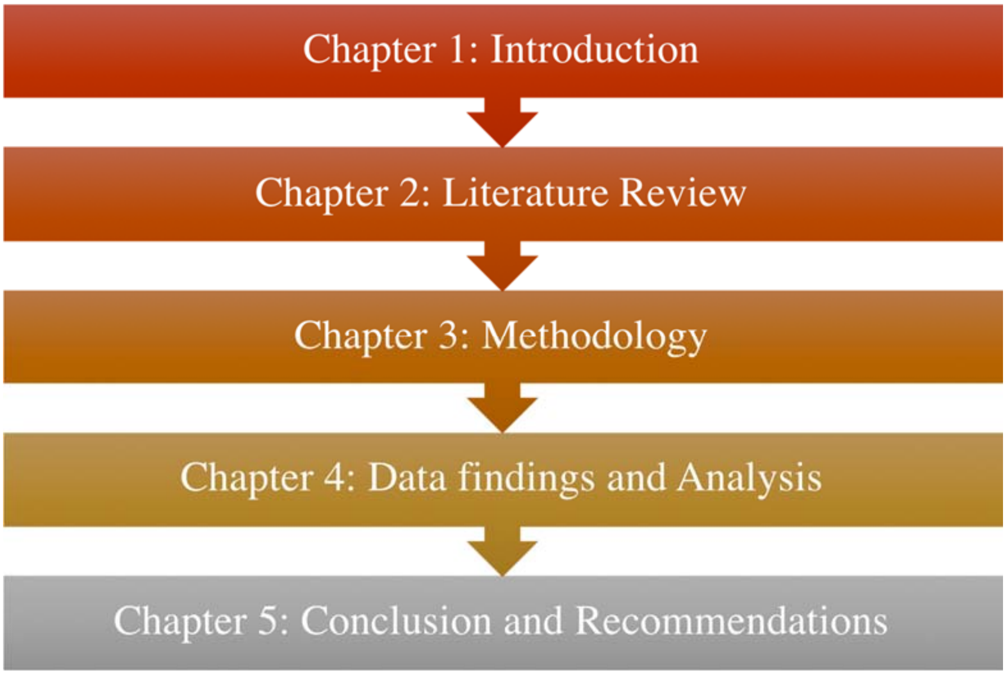


Figure 1: Structure of research. Compiled by author

1.9.Limitations of the research

Throughout the research, the limitations encountered include:

- Geographical and time differences
- Reliability and validity of secondary data obtained

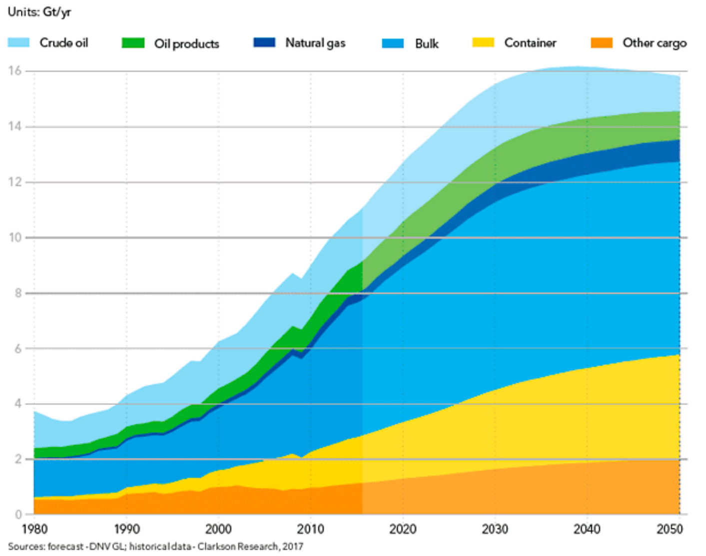
- Overall limited time for research
- Language barrier during interviews hence some elements may have been lost in translation
- Technological barriers i.e. weak internet connection during interviews

2. LITERATURE REVIEW

2.1. Current status of the shipping industry

2.1.1. The relationship between the shipping industry and international trade

Today, the world counts approximately 52,000 merchant ships contributing to the international exchange of goods and passengers (Balcombea, et al., 2019). The maritime shipping industry is responsible for carrying 90% of world trade, which makes this industry the lifeblood of globalisation (ICS, 2019). In the European Union itself, almost 90% of the external freight is through sea carriage (European Commission, 2019). Indeed, the industry holds a carrying capacity of around 1 200 million tons of freight amounting up to a worth of $7 trillion (IEA Bioenergy, 2017). Globalization along with technological advancements, enhanced living standards, requirements for raw and finished goods, the liberalisation of world economies and the faster exchange of information, are all favourable factors that further push the expansion of seaborne trade. As a matter of fact, world seaborne trade has witnessed an annual growth of 4%, reaching a global volume of 10.7 billion tons (UNCTAD, 2018). There are several reasons why seaborne trade will continue to experience a long-term increase. First, this increase can be attributed to the fact that maritime shipping is the most cost-effective and most fuel-efficient transportation mode. In addition, shipping is reliable and the largest carrier of goods. Furthermore, the demand for world seaborne trade is a derived demand, which implies the fact that merchant shipping grows along with world population and hence with the demand for traded goods. For this matter, an expected increase of 39% in seaborne borne trade is expected between 2016 to 2030 and similarly of 2% between 2030 to 2050 (DNV GL, 2018).



Average annual growth rate in %	2010-2016	2016-2030	2030-2050
Crude oil	0.7	1.1	-2.9
Oil products	3.3	1.5	-1.3
Natural gas	4.3	4.3	1.0
Bulk	4.9	2.3	0.1
Container	5.0	3.6	1.4
Other cargo	5.0	3.6	1.0
Average	3.8	2.4	0.1

Figure 2: World seaborne trade in tonnes by 2050. DNV GL (2018)

In Figure 2, the most striking figures are the annual growth of the seaborne trade for crude oil and oil products, which dramatically drop to negative for the 2030 – 2050 period. This drop may be attributed to future market conditions, such as emerging technologies and policies, which will be further elaborated in the subsequent section.

2.1.2. The global dependency on fossil fuels in the transportation sector

Fossil fuels have been used for global energy supply and transportation fuel since the first commercialization of coal in 1750 (Asantewaa & Asumadu-Sarkodie, 2016). In fact, almost 80% of the world's energy supply are generated by fossil fuels, of which oil caters 40% of the total global energy needs and provides 90% of the transport sector (Balachandar, Khanna, & Das, 2013). In other words, the transportation sector is a major leading energy consumer. In 2016, the International Energy Agency reported an amount of 35 billion barrels was used throughout the year (IEA, 2016). In this sector, fossil fuels continue to play a dominant role in the market to meet the constant increasing demand for transportation fuels. Among the European Environment Agency country members, their yearly energy consumption of transport increased by 38% in the period 1990-2007 (EEA, 2018). Nonetheless, the consumption levels decreased by 3% due to the economic recession in the period 2007 – 2016 (EEA, 2018). In the overall period of 1990-2016, a net growth of 24% in transport energy system was recorded. Figure 3 illustrates the predicted continuous rising amount of fossil fuels used in transportation for the period 2010-2040.

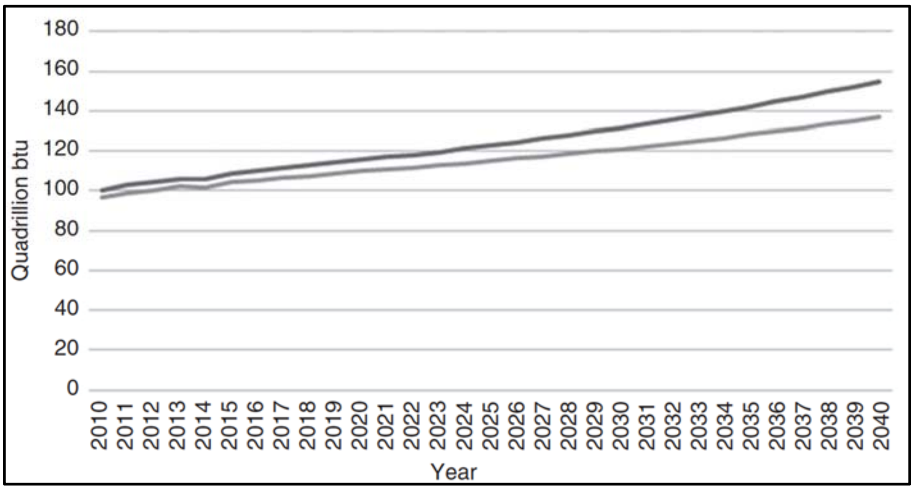


Figure 3: World Total Energy: Petroleum used in the transportation sector in the period of 2010 – 2040 *(Erickson, Lutt, & Winters, 2016)*

By 2030, according to Figure 3, the total amount of petroleum consumed in the global transportation sector would approximately be equal to 120 quadrillion BTU, in comparison to approximately 100 quadrillion BTU in 2016.

As for the maritime shipping industry, it is one of the largest consumers of petroleum fuels, given its global aspect. This entails the fact that it is also one of the largest emitters of air pollutants. The International Energy Agency reported a consumption of more than 330 million tons of oil products per annum in the maritime shipping industry (IEA Bioenergy, 2017). Likewise, a study conducted by the Oak Ridge National Laboratory concluded that marine fuel consumption was estimated to reach about 330 million metric tons equalling to 87 billion gallons (Oak Ridge National Laboratory, 2018). The industry’s energy consumption has increased by 56% since 1990, then a decrease of 19% in the period of 2007-2016 was observed among the EEA country members (EEA, 2018). Figure 4 shows that 12% of the global transport energy demand come from the shipping industry.

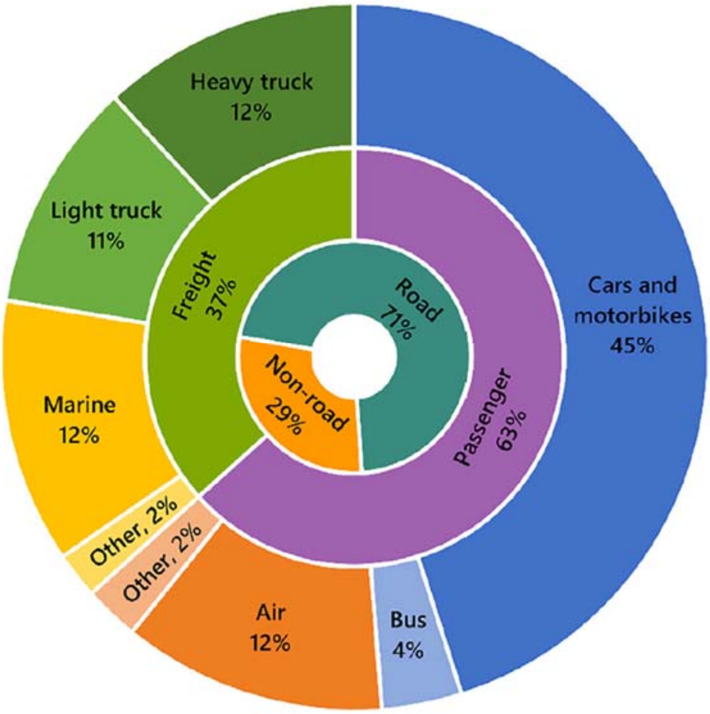


Figure 4: Energy usage in the transport sector in 2015 *(Balcombea, et al., 2019)*

The most common used marine fuels are Heavy Fuel Oil (HFO), Marine Gas Oil (MGO) and Marine Diesel Oil (MDO). Table 1 shows the approximate quantities used to power marine vessels as well as their respective costs.

Marine fuel type	**Approximate quantity used (metric ton/year)**	**Estimated costs**	
		$/ metric ton	**$/ gallon**
HFO	250	460	1.72
MGO	10	700	2.62
MDO	70	700	2.62

Table 1: Common marine fuels consumption and costs. Retrieved from Oak Ridge National Laboratory (2018). Compiled by Author

Fossil-based fuels are the first choice in the shipping sector mainly due to the properties that allow them to be stored and delivered in large quantities, in comparison to other alternative energies (Wang & Economides, 2013). Nonetheless, to meet the expected increasing demand for international trade, fossil fuels are considered to be inadequate. As a matter of fact, fossil fuels are non-renewable and are exhausted faster than new reserves can be generated (Gautam, Sunil, & Lokhandwala, 2019). Research shows that the world will run out of petroleum in the next 50 years, at the current rate of consumption (Soetaert & Vandamme, 2009). For this matter, the gap between the supply and demand for fossil-based fuels will grow in the shipping industry. Along the same lines, the following section discusses additional factors that render fossil fuels inadequate to meet energy demand in the maritime shipping industry on the long-term.

2.2.Drivers of change

2.2.1. The anthropogenic era: the threats of climate change

An added disadvantage to the use of fossil fuels is the release of CO_2 during their combustion. In fact, extensive research from activists shows that GHG emissions can primarily be attributed to fuel combustion, and then deforestation (Ölçer & Mutombo, 2016). The estimated value of CO_2 released per year is approximately 21.3 billion tons globally (Gautam, Sunil, & Lokhandwala, 2019). The levels of CO_2 emissions are expected to increase exponentially with the trade volume of merchant shipping in the following years. In fact, studies estimate that by 2040, energy-related emissions would increase by 16%, on a global scale (IEA, 2015). Subsequently, the high levels of GHG emissions lead to the increase of global warming and more severe consequences of climate change.

The severe consequences of climate change have long been witnessed by humanity. The Intergovernmental Panel for Climate Change reported numerous alterations in the natural and human ecosystems (IPCC, 2018). These alterations can be observed in all regions under different aspects across the globe: environmental, social and economic. Some regions are experiencing extreme weather events with increased frequency and intensity of storms, while other regions are experiencing longer droughts and heat waves. Rising temperatures lead to melting polar ice sheets, causing sea levels to rise and subsequently flooding and erosion in coastal or low level areas (Noone, 2013). In terms of biodiversity, global warming is likely to filter out species that are not able to adapt to climate change, leaving space for "weedy" vegetation and invasive species (WWF, 2019). For instance, the IPCC's projections concluded that at 1.5°C temperature rise, 9.6% of insects, 4% of vertebrates and 8% of plants of 105,000 species studied would be lost (IPCC, 2018). Similarly, the impacts of climate-related risks on the ocean include impacts on marine biodiversity, eutrophication and ultimately affect fisheries and aquaculture at 1.5°C warming. For instance, coral reefs are estimated to decline further by 70% - 90% at 1.5°C warming (IPCC, 2018). Regarding climate-related risks on human population, impacts on health, food security, water supply and livelihoods are likely to incur

(IPCC, 2018). The most vulnerable populations are the ones that are dependent on agriculture for their livelihoods i.e. in developing countries (European Commission, 2019). As a consequence, as weather conditions may not be favourable to agriculture, crop yields may decrease and ultimately increase the risks of poverty and hunger.

2.2.2. The contribution of the shipping industry to climate change

The shipping industry contributes to a total amount of 2% to 3% of CO_2 per tonne of cargo / km (IMO, 2014). In addition to CO_2, vessels also emit other global warming pollutants such as Sulphur oxide (SO_x) accounting up to 4% to 9%, as well as nitrogen oxide (NO_x) accounting up 10% to 15% on the global scale (IMO, 2014). The following research is only interested in the issue revolving around carbon dioxide, which is estimated to increase from 50% to 250% by 2050 under a business-as-usual scenario (IMO, 2014). As mentioned earlier, emissions from fossil fuels particularly highly contribute to the increase in GHG emissions in the atmosphere, which enhance global warming and heighten climate change. Figure 5 demonstrates that the biggest source of GHG emissions in the shipping industry is containers ships followed by bulk carriers and oil tankers.

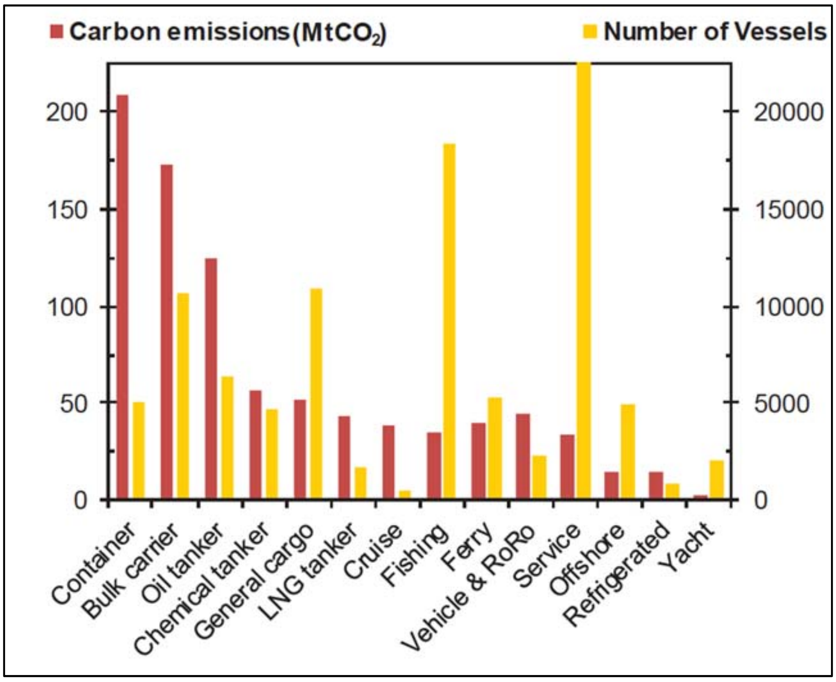


Figure 5: Global number of ships and respective emissions *(Flottenkommando, 2018)*

The high volume of GHG emitted by these types of vessels can be attributed to the fact that they cover longer geographical distances to deliver cargo. Although the shipping industry seems to contribute to only 3% of the world's CO_2, reports have shown that the largest 15 vessels caused more sulphurous pollution than the total global car fleet (Vidal, 2009). Along the same lines, the shipping emissions cost the Danish health service almost up to 5 billion GBP / year to treat cancer and heart diseases related to shipping pollution (Vidal, 2009). If no immediate action is taken, the consequences of climate change are expected to become more severe.

In a nutshell, the shipping industry plays a controversial role in driving the global economy but also by holding a heavy ecological footprint. Table 2 depicts the controversial role that the shipping industry plays on the international platform.

STRONG ECONOMIC DRIVER	HEAVY ECOLOGICAL FOOTPRINT
80 % world seaborne trade	**3%** contribution to global GHG emissions
Globalization facilitated by seaborne trade through the transportation of raw materials and manufactured goods	**SO_x, NO_x, PM** emitted by the shipping industry
90% EU external trade is through sea carriage	**50% - 250%** increase in GHG emissions by 2050 if no action is taken

Table 2: The controversial global role of the shipping industry. Compiled by author

2.2.3. The climate regulatory framework

In the quest for a sustainable long-term growth, the 21st session of the Conference of the Parties (COP21) gathered thousands of world leaders, experts, activists, representatives from both the public and private sectors across the world to establish emission reduction targets in 2015. In 2018, the COP24 took place in Poland during which participants strengthened the commitments agreed upon at the COP21 (United Nations , 2018). One of the key messages during COP24 focused on the need to change through solidarity and transformation of regions and industrial sectors (United Nations Climate Change Conference, 2018).

The shipping industry was not included in the COP Agenda. Instead, the shipping industry has always been regulated by the International Maritime Organization (IMO), which is a specialized agency of United Nations agency. The Agency's main role is to promote sustainable maritime safety, establish a level playing-field for international trade as well as reinforce environmental and safety regulations on a global scale. Today, it counts 174 Member States and 3 Associate Members (IMO, 2019). The IMO provides a forum for Member States and other stakeholders in the shipping industry to collaborate and cooperate in order to implement global standards in terms of maritime security, energy efficiency, maritime education, maritime traffic management, technology and innovation as well as the development of maritime infrastructure (IMO, 2019). The ultimate goal is to create a unified framework across the global shipping industry. IMO regulations must be ratified by more than half of the Member States, which are then translated into domestic law.

Taking into account the importance of the shipping industry to the global economy as well as its ecological burden, the IMO has developed regulations to adapt better to the consequences of climate change. Of all the ratified international treaties, the most important with regards to GHG emissions is the International Convention for the Prevention of Pollution from Ships, known as MARPOL established in 1973 (Hsieh & Felby, 2017). The treaty is divided into six annexes according to the type of pollutant that have, through the adoption of successive amendments, have become relevant with time. In particular, MARPOL Annex VI addresses the prevention of air pollution from ships. The most relevant policy to GHG emissions and to the use of biofuels are the Ship Energy Efficiency and Management Plan, the Energy Efficiency and Design Index and the adoption of Emission Control Areas (ECAs). Table 3 provides a summary of these policies.

Policies	**Description**
Energy Efficiency and Design Index (EEDI)	The EEDI was put in force at the 62nd Marine Environment Protection Committee in 2011. The goal was to improve specific fuel consumption for new built ships from 2013 onwards, with the aim of reducing ship emissions. It does not consider operational features, it solely addresses design (Ölçer, Kitada, Dalaklis, & Ballini, 2018). The IMO stated that EEDI was put in place in order to stimulate constant innovation and technical development within the industry (IMO, 2011). The policy sets a fixed amount on the allowable CO_2 emissions for every amount of transport work delivered as measured in grams of CO_2 / ton-mile of cargo transported. The limit is set to get stricter every 5 years. A 10% reduction is prescribed for the 2015-2020 period, then 20% 2020-2025

	and 30% for 2025-2030. Finally, the policy does not recommend any particular technology to be adopted in order to ensure compliance, which leaves the choice to the industry on how to comply.
Ship Energy Efficiency and Management Plan (SEEMP)	The SEEMP is applicable to vessels 400 GT and above (Hsieh & Felby, 2017). The goal is to review the shipping industry's best practices for fuel-efficient operation of vessels (IMO, 2011). Unlike EEDI, SEEMP focuses on operational practices such as slow steaming or new methods of waste heat recovery systems or propeller designs.
Non-GHG Emissions and Emission Control Areas (ECAs)	ECAs were introduced in order to regulate the global emission limits of So_x, NO_x and other particulate matter. Basically, they are jurisdictional areas where the emission of So_x and NO_x are more rigorous than in the case of outside ECAs. To date, there are four ECAs under MARPOL Annex VI including the North American ECA, the United States Caribbean ECA, the North Sea ECA and the Baltic Sea ECA (IMO, 2019). This entails the fact that vessels are unusable without further post-combustion treatment. ECAs are expected to affect fuel market and technological development (Hsieh & Felby, 2017).

Table 3: Summary of GHG emissions regulations - at international level. Compiled by Author

In support of the policies mentioned in Table 3, the IMO has set an agreement to reduce GHG emissions by 50% in 2050 in comparison to emissions in 2008 (IMO, 2014). Reduction targets can be achieved by changing fuel usage or increasing the efficiency of vessels, such as stated in the EEDI.

At a regional level, the example of the European Union can be taken, as they have pledged to support the efforts of the IMO with regards to GHG emissions reduction. The Renewable Energy Directive 2009/28/EC (RED I) and the Renewable Energy Directive for the 2021 – 2030 period (RED II) were developed to set out renewable energy adoption targets. For instance, the European Commission consider biofuels as an essential tool in meeting 10% of the energy demand in the transportation sector (European Commission, 2019). In addition, the RED sets out a clear framework to ensure that the production of biofuels is sustainable. Growing biofuels may controversially contribute to the increase of net GHG emissions, because trees may be removed to produce biofuels when they are meant to absorb CO_2. For this matter, voluntary schemes were established to ensure that biofuels are not from land with high biodiversity nor from land with high carbon stock (European Commission, 2019).

Overall, the finite nature of crude oil in addition to the environmental impacts of fossil fuel combustion, projected increase in international merchandise shipping and stricter regulations governing GHG emissions have driven the sector to weigh other alternative options. In fact, with the projected demand for goods, emissions from the shipping sector need to make some space for sustainable long term growth. The constant increase of demand for energy in the shipping industry entails global severe problems due to the growth in CO_2 emissions in the atmosphere. The overview of the regulatory framework relevant to biofuels shows that international institutions do not prescribe a particular technology for achieving the targets set by the IMO. Therefore, shipping companies are left to innovate and weigh out the different options that are presented to them.

2.3.Comparison between HFO, LNG and biofuels

2.3.1. Overview: Heavy Fuel Oil (HFO)

The most used marine fuels are HFO and MGO which are produced from crude oil in refineries. These fuels usually have lower quality, and hence lower costs in comparison to other transportation fuels such as aviation or road (IEA Bioenergy, 2017). The consumption rate for large ships, transiting between the EU and the US, can reach 140 to 150 tons / day in comparison to 200 to 250 tons / day for ultra large vessels (IEA Bioenergy, 2017). Similarly, the world's largest container vessels can consume up to 16 tons of fuel / hour, amounting up to approximately 380 tons/ day (IEA Bioenergy, 2017). The upcoming IMO 2020 and IMO 2050 regulations to control GHG emissions pollution from the shipping industry will affect the oil industry as well as shipping companies. For instance, the IMO 2020 will only allow vessels equipped with scrubbers or other equivalent technology to consume HFO. As a consequence, this will result in a lower demand for global demand for HFO. A report prepared by the consultancy firm CE Delft which was used as a basis for the IMO's decision-making process, states that by 2020 approximately 4000 vessels will operate with scrubbers (DNV GL, 2019). Subsequently, the report concluded that HFO would only represent 6% of the fuel mix once IMO 2020 will be put in to place; and as of January 2019, 2 800 vessels were recorded to have installed or ordered scrubbers (DNV GL, 2019).

2.3.2. Overview: Liquefied Natural Gas (LNG)

As a response to the changing business environment, the shipping industry tends to be inclined towards the use of Liquefied Natural Gas (LNG). For a few number of years, Liquefied Natural Gas has proven to be commercially viable and available (DNV GL, 2019). As a matter of fact, a few small number of ships have been recently built with LNG engines and have been introduced in the market in 2010 (IEA Bioenergy, 2017). In terms of supply, Qatar has been the world's largest exporter of LNG, supporting the needs of 1/3 of world economies and local communities (QatarGas, 2019). Throughout the years, more countries have started the production of LNG and recently, Australia has surpassed Qatar's production (Jaganathan, 2018). In November 2018, Australia produced 6.5 million tons of LNG to be exported in comparison to 6.2 million tons for Qatar (Jaganathan, 2018). However, since LNG is still a relatively new marine fuel, access to bunkering stations is still limited and ports still needs to install the necessary storage facilities to facilitate the use of LNG (IEA Bioenergy, 2017). From an environmental perspective, LNG is an appropriate fuel for low carbon shipping due to its lower CO_2 emissions in comparison to distillate and residuals fuels. In other words, LNG is an option to meet the upcoming requirements for the main types of emissions. For this reason, researchers have predicted a higher demand for LNG in the near future, due to its little Sulphur and its ability to hold more energy / ton (IEA Bioenergy, 2017). Nevertheless, environmentalists and other relevant stakeholders in the industry have reported that the production of LNG generates methane leaks, one of the most notorious greenhouse gases (Gordon, 2018). For this reason, it can be concluded that LNG does not solve the climate change dependency and does not contribute to the reduction of the effects of climate change. In terms of infrastructure, the use of LNG does not require the installation of additional processing technologies. However, the cryogenic storage vessels designed to transport and store LNG on board take up more DWT in comparison to conventional heavy fuel storage tanks, hence it requires additional safety features (IEA Bioenergy, 2017).

2.3.2. Overview: Biofuels

Against the background of LNG and its dependency on fossil fuels, biofuels have the potential to become an important part of the fuel mix in the shipping sector. As a matter fact, biofuels are produced from biomass which is a renewable source and does not contain Sulphur (IEA Bioenergy, 2017). For this reason, biofuels are likely to reduce the shipping industry's dependence on fossil fuels and ultimately reduce GHG emissions by at least 50% by 2050. Indeed, the main reason for shipping companies to consider biofuels is because the combustion of biomass is "carbon neutral" over its life cycle as it emits the exact amount of CO_2 that was captured by the plant during its growth (Bengtsson, Fridell, & Andersson, 2012). Research shows that the reduction effectiveness of biofuels is dependent on the production process (DNV GL, 2019). Generally, biofuels are derived from biologically renewable resources including animal fat waste, plant based sugars, oils and terpenes (IEA Bioenergy, 2017). On the global scale, biofuels are commercially being produced. Nevertheless, the shipping industry has not been exposed to any biofuels experience yet as most biofuel research has been directed towards either road-based transportation or energy generation. The production of biofuels also brings other socio-economic controversies such as land use or hunger. From an operational point of view, it is possible to produce biofuels based on the existing infrastructure in order to minimize infrastructure adaptation costs (IEA Bioenergy, 2017).

Based on the overviews previously given, Table 4 provides a general comparison between HFO, LNG and biofuels. The comparison criteria used are the following criteria: regulatory framework, environmental impacts, price affordability, infrastructure compatibility, investment as well as technological developments.

Criteria	Marine fuels		
	HFO	**LNG**	**Biofuels**
Relevant regulatory framework	IMO 2020; IMO 2050; ECAs	IMO 2020; IMO 2050	IMO 2020; IMO 2050; EEDI; SEEMP; RED I; RED II; ISO 8217 2017
Environmental impacts	**HIGH** Contribution to the increase of GHG emissions due to high CO_2 emissions, high Sulphur content and other particle matters emissions. Research shows that even Low Sulphur fuels produce higher particle emissions than alternative fuels (DNV GL, 2019).	**MEDIUM** Cleaner than fossil fuels because no NO_x nor SO_x emissions and particle emissions are very low. However, research has shown that a leak of methane occurs along the value chain. This leads to question the long-term sustainability of LNG.	**LOW** CO_2 emitted from combustion of biofuels is considered neutral because the amount of CO_2 emitted during the combustion of biofuels is equivalent to the amount of CO_2 captured by the plants during their growth. However, it is important to note that the environmental impacts of biofuels are dependent on the biomass used during the production process. In fact, the production of biofuels could have adverse impacts on the environment if the correct processing technology is not applied.

Price competitiveness	Fall in price following the implementation of IMO 2020, however probable increase in Low Sulphur Fuels	Competitive with the price of MGO as the price is below crude oil and HFO (DNV GL, 2019); research shows that projected prices for LNG is 11.60 €/ GJ and 11,75 € / GJ for HFO in 2030 (Grijpma, 2018).	Not competitive unless the price of crude oil rises to $60 / barrel (IEA , 2017). Similarly, the break-even point between biofuels and fossil fuels ranges between USD 100 to USD 120 / barrel (IEA , 2017).
Demand	Decrease in demand following the implementation of IMO 2020	344.61 million tons of world seaborne trade; forecast of 370.95 million tons of world seaborne trade for 2020 (Clarksons , 2019).	No current existing demand for biofuels in the shipping sector due to its high price
Infrastructure compatibility (i.e. marine engines, bunkering, fuel transport pipelines)	A well-established worldwide HFO supply infrastructure is in place. Major bunkering ports include Antwerp, Rotterdam, Fujairah, Hong Kong and Los Angeles (Ship & Bunker, 2016).	The relevant engines and gas turbines as well as storage tanks are commercially available for LNG (DNV GL, 2019).	Global infrastructure is still lacking for biofuels. Today, only a few international ports are able to supply biofuels (e.g. Netherlands, Australia). However, most engines are compatible with biofuels, in particular biodiesel (Grijpma, 2018).
Investment and technological developments	From 2020, ships will be required to comply with regulations. So far,	The technology required for using LNG as ship fuel is readily available. As of 16th August 2019, 517 ships (equivalent to 0.5	Biofuels can be used either as drop-in fuels or as a blend with conventional fuels (DNV GL, 2019). Although scaling has not been as fast as industry

		% of total world fleet) are LNG fuel capable (Clarksons, 2019).	stakeholders have hoped, research shows that there has been a great deal of investment towards biofuels in some countries only. For instance, Pension Denmark invested £160 million in the construction of a biomass power plant (ETIP Bioenergy, 2019).

Table 4: Comparison overview between HFO, LNG and Biofuels

2.4.Strategic option for shipping companies

To adapt to the changing environment, shipping companies need to find the balance between the main three pillars of sustainability: social, economic and environmental (Purvis, Mao, & Robinson, 2019). If no action is taken, climate change may impact businesses on a large scale through its supply chain. For instance, anticipated consequences may include changed timing and location of production, access to distribution channels and customers (Linnenluecke & Griffiths, 2015). To act upon the Paris Agreement targets and contribute to the reduction of GHG emissions targets by 2050, adaptation options for the shipping industry include enhancing the energy efficiency level of ships, using renewable energy on board or employing cleaner alternative fuels (Ölçer, Kitada, Dalaklis, & Ballini, 2018). In the context of the following dissertation, the strategic adaptation option considered is the use of cleaner alternative fuels. In fact, extensive research shows that alternatives fuels are the way forward for two main motives. First, to reduce pollutants and cut GHG emissions. And second, to mitigate the effects of climate change and comply with regulations. From the comparison conducted in Table 4 and given that the ultimate goal is to decarbonize the global supply chain, biofuels seem to be the most viable option. As a matter of fact, biofuels are preferred to fossil fuels given their sustainable and renewable features, their biodegradability aspect, their abundant local availability, their potential to create more farming jobs, their contribution to rural economic development as well as their potential to reduce GHG emissions (Demirbas A. , 2009; IEA, 2016).

By definition, biofuels are crop-based products which were initiated in the 19th Century. In fact, in 1897, Rudolf Diesel's first engine was powered with peanut oil and had proven to have 75% efficiency (Brownstein, 2014). Until the 1940s, vegetable-based oils were considered a practicable transport fuels, however the fast-growing fossil fuel refining industry combined with their falling prices hindered the further research and development of biofuels (Elbehri, Segerstedt, & Liu, 2013). Depending on the biomass used and methods of production, biofuels can be separated into different categories of generations (1) either from agricultural crops such as grains or oil seeds, which has sparked debates over competition with other sectors or (2) from lingo-cellulosic materials such as waste, which avoids competition with other sectors like the first generation is facing but also does not come without challenges, or also (3) from algae biomass (Bengtsson, Fridell, & Andersson, 2012). The different distinctions of biofuels are described in Table 5.

	First generation	Second generation	Third generation
Biomass	e.g. cereals, starch and sugars crops, animal fats, oil crops such as jatropha or palm oil or rapeseed oil, soy bean	e.g. municipal waste, industrial waste, forestry waste, nutshell, manure, perennial grass, short-rotation coppice willow, lignocellulosic biomass	e.g. algae, wood biomass
Technology	Pressing or extraction	Hydrolysis, pyrolysis, gasification, hydrothermal liquefaction	Pulping, oil extraction
Biofuel	Biodiesel, fatty acid methyl ester (FAME), Renewable diesel (HVO), Straight Vegetable Oils (SVO), bioethanol	Biohydrogen, methanol, biogas	Renewable diesel

Table 5: Generations of biofuels (Luque, Clark, & Campelo, 2010); (IEA Bioenergy, 2017)

Research suggests that there are two pathways to ease the transition to biofuels. On one hand, starting with HFO then gradually shifting to marine gas oil to slowly adopting biodiesel; and on the other, adopting LNG and slowly shifting to liquefied biogas (Bengtsson, Fridell, & Andersson, 2012). In the present dissertation, only one pathway is taken into account: the biodiesel route, part of the first-generation biofuels. The reason for this is because a survey, conducted by investment bank UBS in 2017, concluded that 74% of shipping companies will switch to diesel in 2020 (Ronan, 2018). Plus, it is assumed that biodiesel will likely be replacing diesel, due to infrastructural and engine compatibility. As a matter of fact, biodiesel can be applied directly in diesel engines or blended with diesel derived from fossil fuels. Nevertheless, the implementation of biofuels does not come without challenges. Therefore, the problematic is to measure the extent to which biofuels are sustainable for shipping companies. How environmentally and economically sustainable are biofuels? Could the production of biofuels interfere with other industries?

3. METHODOLOGY

The previous chapters highlighted the possibility for biofuels to overtake the shipping industry. For the purpose of the present dissertation, a qualitative approach was chosen combining a literature review, a PESTLE analysis and semi-structured interviews. In line with the stated research aims, objectives and questions, this chapter discusses the methodology employed and their respective rationale.

3.1. PESTLE analysis

The PESTLE analysis identifies risks and influential factors under different sub-categories including Political, Economic, Social, Technological, Legal and Environmental. It is a strategic tool used to evaluate the potential impacts that political, economic, social, technological, legal and environmental factors may have on a given project (Rastogi & Trivedi, 2016). Within the context of the present dissertation, an explanation of each subcategory is provided below.

Political – these factors determine the extent to which Governments may influence the shipping industry. For instance, a Government may introduce new tax policies or levy existing ones.

Economic – these factors represent an economy's performance that have a direct impact on shipping companies. For instance, a rise in the price of raw materials.

Social – these factors take into consideration how certain projects impact the social community. For instance, social expectations or health consciousness.

Technological – these factors include innovations that may affect the operations of the shipping companies, including technological level readiness as well as R & D.

Legal – these factors ascertain how certain laws, whether existing or potential, affect the operations of shipping companies. For instance, environmental regulations.

Environmental – these factors take into account how the natural environment has an impact on the operations of shipping companies. For instance, climate change and extreme weather conditions.

The rationale behind the choice of conducting a PESTLE analysis is because it will enable shipping companies to make their decision-making processes based on a thorough understanding of the business environment, including the threats and opportunities. This way, shipping companies would be able to anticipate potential issues and minimise their effects. The findings of the PESTLE analysis serve as data input for scenario building, namely identifying trends that have the highest impacts on the business environment where shipping companies operate.

3.2.Semi-structured interviews

In-depth qualitative interviews were conducted, involving semi-structured questions. There are two main reasons behind the choice conducting semi-structured interviews. First, the aim was to collect personal opinions from relevant stakeholders. Semi-structured interviews allow the interviewer and the interviewee to diverge in order to elaborate more on an idea or a response. This allowed the interviewer to assess where they stand in light of the future uncertainties in the shipping industry. For this reason, particular attention was given to what the interviewees considered as significant and relevant in the context of the dissertation. Secondly, secondary data may change over time (i.e. literature review) hence primary data was collected through interviews to emphasize the findings of the secondary data. Furthermore, a non-probability sampling method was applied as the interviewees were carefully selected. It was crucial to target the correct sample of the population in order to ensure that the respondents were experts in the area. The questions asked in the interview were in line with the findings from secondary data collected from the literature review and the PESTLE analysis on biofuels. The questions asked are indicated in Appendix A. The findings of the interviews serve as input to identify the scenario where shipping companies currently stand with regards to the implementation of biofuels.

3.3. Description of the scenario planning framework

Given the high levels of uncertainty in the shipping industry, the problematic is how do shipping companies develop strategies? To face uncertainties, traditional approaches tend to incline more towards laying different alternative scenarios and testing the sensitivity of forecasts when changes in key variables are made. However, the goal of traditional approaches is often to find the outcome with the highest occurrence probability and create a strategy based on it (Lee, Lee, & Lee, 2009). This traditional approach has been proven to work in stable business environments. Nevertheless, such is not the case for volatile industries. And the shipping industry is navigating in uncertain waters in particular due to the irregularity in freight rates and asset prices. Under-estimating the uncertainties of the future may lead decision-makers to overlook risks and fail to exploit opportunities; while over-estimating uncertainties may lead to decision-makers to only use "gut instinct" (Courtney, Kirkland, & Viguerie, 1997). Based on what we know today, forecasting foresees one future while scenario planning, multiple possible futures.

The approach used in this dissertation is based on Courtney, Kirkland and Viguerie's framework (1997) for determining the level of uncertainty that influences strategic decisions and for applying the appropriate strategy to that uncertainty. It is important to note that this framework would not reduce the levels of uncertainty, but instead enable more informed and sound strategic business decisions (Courtney, Kirkland, & Viguerie, 1997). In other words, this methodology is best used when uncertainty levels are high or significant changes are being experienced or anticipated. The rationale behind the use of scenarios is to make sound business strategic decisions for shipping companies i.e. identify the factors that enable the effective implementation of biofuel for shipping companies. Moreover, scenario planning leads to further research to compensate for errors that usually occur in the decision-making process (Schoemaker, 1995). Figure 6 describes the framework proposed by Courtney, Kirkland & Viguerie (1997), which encompasses four steps.

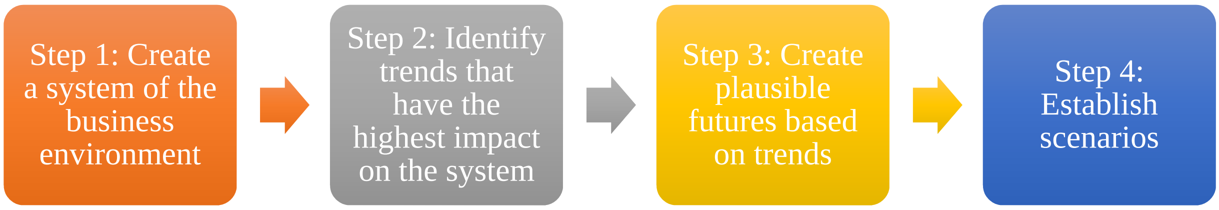


Figure 6: Scenario planning steps. Adapted from Courtney, Kirkland & Viguerie (1997)

The first step consists of identifying the different stakeholders involved in the shipping industry, establishing their relationship and how their actions may affect each other. In the second step, the findings from the PESTLE analysis of biofuels were used as data input. This data served to determine the most prominent trends that have the highest impacts on the system of the business environment. Following this, possible futures that capture all of the trends and uncertainties are developed, in order to generate a matrix of possible scenarios. It is important to note that scenarios need to be set in the future horizon, of at least more than ten years ahead. In the example provided in Figure 7, the axes create a matrix which in turn can be used to generate four plausible scenarios.

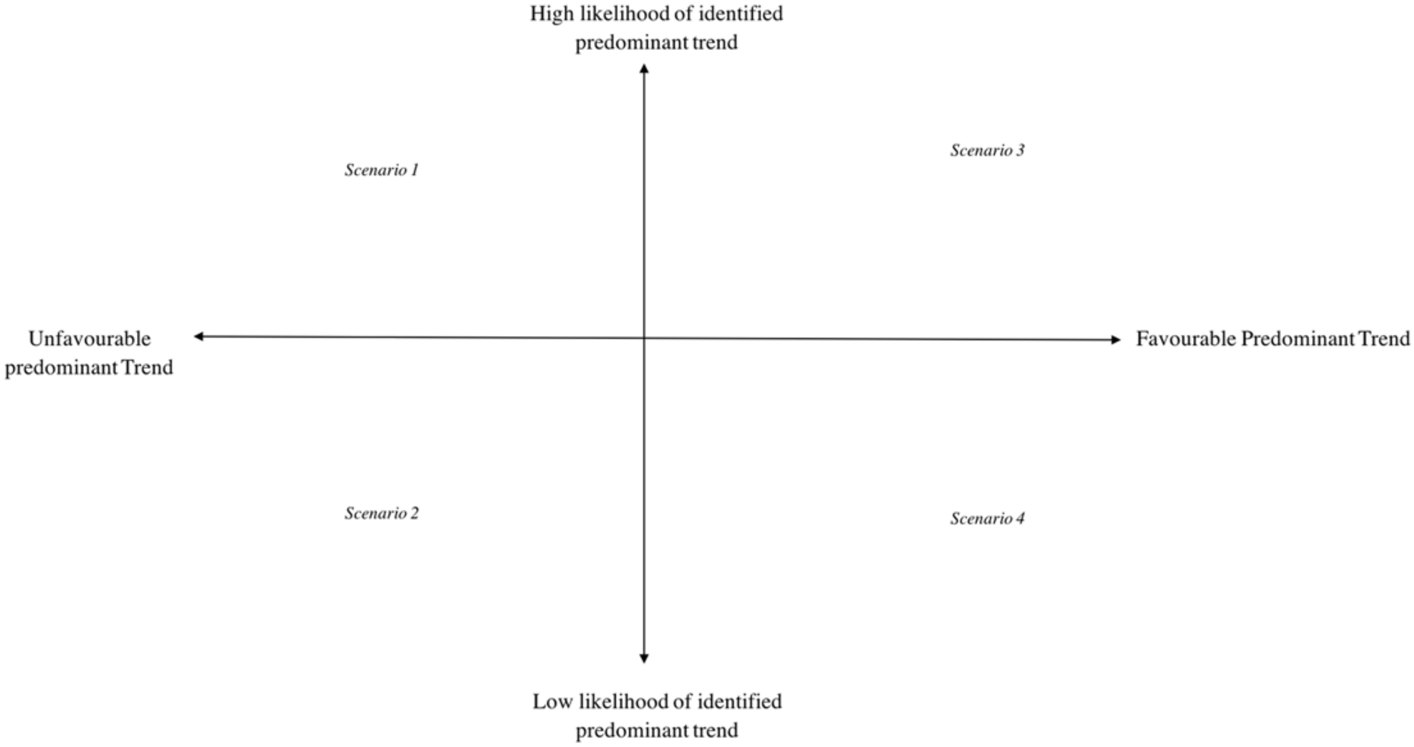


Figure 7: Scenario Planning Description. Compiled by author

3.4. Data analysis

The commonalities between the findings of the literature review, PESTLE analysis and semi-structured interviews were compiled into themes. Then, the themes served as input for scenario building: to identify where shipping companies stand with regards to biofuels and to identify the desirable scenarios that would facilitate the effective implementation of biofuels.

4. DATA FINDINGS AND ANALYSIS

This chapter aims to present the analysis and interpretation of the findings during the interviews and the PESTLE analysis conducted. In this chapter, the findings are also compared against the research questions. Then, an analysis in the context of the developed scenarios is given.

4.1. PESTLE Analysis findings

4.1.1. Political and legal

Political and legal dimensions have been combined for the purpose of this dissertation, because these dimensions both encompass policies and regulating enforcement laws. As previously scrutinized in Table 4, the regulatory framework relevant to the implementation biofuels is MARPOL Annex VI namely EEDI, SEEMP and ECAs. Policies play a crucial role in imposing a regulatory framework to encourage the implementation of biofuels in the shipping industry. Policy instruments may include tax exemptions, subsidies or mandates. Introducing biofuels in the shipping industry is complex because of the multiple stakeholders involved in the supply chain and would require a specific set of policies at every stage (Basavaraj, et al., 2012). Establishing policies at a national level is particularly crucial. The Netherlands' efforts in continuously contributing to the reduction of GHG emissions have succeeded through the adoption of renewable energy technologies on a national scale (Grijpma, 2018). In fact, when an agreement is reached on an international level, the Netherlands implement it on the national level. For instance, in 2016, the EEDI and SEEMP were reinforced on the local and national levels through the implementation of the COBALD deal (Continuous On-Board Analysis and Diagnosis) by the Dutch Ministry of Infrastructure and Environment (Grijpma, 2018).

Nevertheless, setting policies is not difficult, the challenge is to understand the implications of their implementation. Taking from the example of the implementation of biodiesel in road transportation in Germany, tax exemptions were applied on both the consumers and the producers of biodiesel. Germany introduced the Eco-Tax in 1999 to help reduce fossil fuel consumption, followed by further tax exemptions on biofuels for consumers in 2002 (IEA, 2012). Henceforth, the price of biodiesel has seen a fall below the price of diesel because of the incentives and the obligation to convert the fuel station pumps to handle only biodiesel (Wiesenthal, et al., 2009). In USA, however, tax exemptions were imposed on producers of biodiesel. Research shows that when tax incentives for consumers were abolished in Germany, biodiesel consumption decreased and similarly, when tax incentives for producers were abolished in USA, production of the same decreased (Stead, Wadud, Nash, & Li, 2019). These examples imply the fact that policies have an impact on the demand and supply of biofuels. Therefore, if policies are established correctly, they can facilitate the implementation of biofuels. Furthermore, it also implies that the implementation of biofuels on an international level is a shared responsibility between all stakeholders; and most importantly Governments and policy makers on the national level. Today, only a few countries have put forward policies that encourage the production and consumption of biofuels, as illustrated in Table 6.

Countries	**Policies**
Europe: Denmark, Finland, France, Germany, Italy, Norway and the UK	Renewable Energy Directive (RED) with a production target of 3.5% of advanced biofuels set for 2030
USA	Renewable Fuel Standard, low-carbon fuel standard (California)
India	Fiscal and investment support policy (2018) with the target to develop twelve commercial plants dedicated to advanced biofuels.

Table 6: National level policies in support of biofuels production. Source: IEA (2019)

4.1.2. Socio-economic and technological

The socio-economic and technological analyses were combined because of their high correlation. The cost of production of biofuels is dependent on the technology used, and the former has repercussions on socio-economic dynamics. From a general point of view, biofuels generate several economic advantages such as increased number of rural farming jobs, of investments in infrastructure, increase in income and international competitiveness as well as the decrease of dependency on fossil-based fuels (Demirbas A. , 2009). Often, industrialized nations, such as in Europe, do not possess the appropriate raw materials and feedstock for the production of biofuels. For this matter, they take advantage of economic globalization and regional integration to explore markets worldwide where feedstock is available such as in Brazil, Malaysia, Peru, Argentina, Sub-Saharan Africa (Ewing & Msangi, 2008). Hence, the production of biofuels particularly holds economic opportunities for developing countries, which have the potential to become feedstock and raw materials suppliers to the world. As a matter of fact, with the favourable weather conditions and low-cost labour, developing countries have the opportunity to attract investments which would lead to economic rural development. In comparison to the fossil fuel industry, reports show that the biofuels industry has been employing 100 times more workers / unit of energy produced (Kojima & Johnson, 2005). For instance, the Brazilian sugar cane plantations have generated 1 million small scale farming jobs for the purpose of producing biofuels (SwedBio, 2009).

From a shipping company's perspective, bunkers account for 70% of the operational costs hence it is important to take certain economic factors into account. The price of biodiesel would depend on capital cost, process technology, feedstock, labour and chemical costs.
For biodiesel production, the most important factor to consider is input costs i.e. feedstock which accounts for approximately 75% to 80% of the total operating costs of production (Demirbas A. , 2009). Similarly, other studies suggest that 60% to 80% of the costs of biofuels are dependent on feedstock and profitability would depend on the price of crops and crude oil (Marelli, et al., 2015). Previous research of biodiesel production shows an estimated production cost of USD 0.158/L for biodiesel, with an additional estimated feedstock cost of USD 0.539/L for soy oil, USD 0.70 / L for soya and USD 0.88 / L for palm oil (Demirbas A. , 2009). Similarly, other researchers suggest that the price of biodiesel would usually start from USD 0.2 / L, with waste feedstock whereas it could reach over USD 2 / L for palm oil and sunflower oil. Further researches estimate the cost of biodiesel to be in the range of 15.5 Euros to 17.8 Euros / GJ; in comparison to the price of HFO which equates 10 Euros / GJ (Bengtsson, Fridell, & Andersson, 2012). Another example is China, where biodiesel produced from jatropha was estimated to cost in the range of 4 RMB to 11.5 RMB / L (USD 0.5 to USD 1.47 / L), in comparison to diesel in Northern China is 4.55 RMB to 4.92 RMB / L (USD 0.58 to USD 0.68 / L) (Weyerhaeuser, Tennigkeit, Yufang, & Kahrl, 2007). These prices are almost twice the price of diesel (You, et al., 2008). And it can be assumed that the high price of biofuels could be considered as the greatest hurdle to its fast-commercial scalability, unless sufficient investment is allocated towards the cost-effectiveness of biofuels.

On the social front, shipping companies are facing pressure from society to comply with environmental regulations and contribute to the reduction of GHG emissions. In addition to agility, reliability and lower costs, customers and other stakeholders expect sustainability to be added at the top of management agenda in shipping companies (Pruzan-Jorgensen & Farrag, 2010). In other words, customers will look at shipping companies as strategic innovation entities instead of just being service providers, which thereby pushes shipping companies to

adopt better differentiation strategies. It is important to note that shipping companies fall under the business-to-business (B2B) service provider category. In comparison to the purchase of goods, providing services is riskier and more complicated because services are intangible. For this matter, reputation and effective brand management are crucial elements that help to achieve high customer retention, and ultimately reach success in the logistics service industry (Marquardt, Golicic, & Davis, 2011). To date, a few shipping companies have already taken a stepping stone in adopting green shipping technologies. For instance, shipping giant Stena Line introduced the world' first vessel powered by methanol: Stena Germanica (Stefenson, 2016).
Although biofuels generate economic advantages, they also suffer from a range of challenges associated with their real and/or perceived social performance. These challenges arise from food security, labour rights and land use. In 1998, research estimated that biofuel production would not have any impacts on food production and land uses. And in fact, it has been estimated that the biofuels could satisfy 80% of the world's energy demand while still meeting food demand (Hall & Scrase, 1998). However, the FAO has recently reported approximately 821 million malnourished people on the global scale (FAO, 2018). In addition, the most recent IPCC report on food security argues that climate change is predicted to do further damages to the four pillars of food security: availability, access, stability and utilisation (FAO, 2018). The controversy originates from the point where food producers and first generation biofuels producers compete for the same goods: crops. During the period 2002 to 2007, the production of maize-based biofuels in the US generated an increase of 30% in global wheat and grain use (Ewing & Msangi, 2008). Biomass is a limited resource, which means land should be used as efficiently as possible. This implies that if the shipping industry were to entirely implement biofuels, there are high chances of conflict with food production and food prices.

Moreover, as mentioned earlier, biofuels producers take advantage of globalization to expand their markets where they can procure raw materials. For instance, Madagascar has seen the arrival of a number of investors from Italy, Germany and the UK for the plantation of jatropha (Rajoelina, 2016). Italian biofuel producer, Tozzi Green, settled in the south of Madagascar to cultivate jatropha for the purpose of producing biofuels. Given that jatropha is not edible, it would not logically have any conflict with the food production market. Reports show that Tozzi Green generated employment and enhanced rural development. However, the local rising sentiment was due to the need for villagers to relocate, the loss of land and the threat to their livelihoods. And most villagers claim that their livelihoods highly depend on their land as it provides crops, rice, potatoes and medicinal plants. In Madagascar, the loss of land is particularly sensitive because locals have a sacred attachment to their lands, which have been passed from one generation to another (Franchi, Rakotondrainibe, Raparison, & Randrianarimanana, 2013). In 2013, carried out inspections by NGO called *Collectif Tany* describe that farmers have been experiencing land grabbing, where farmers are forced to hand over their lands in Madagascar (Franchi, Rakotondrainibe, Raparison, & Randrianarimanana, 2013). Furthermore, in the southern region of the island, called Ihorombe, cattle farming is popular and many farmers depend on it for their livelihoods. Testimonies report that the farmers' cattle almost have no way to get to their pasture, because it is located in a piece of land enclosed in the middle of Tozzi Green's domains. Hence, when the dry season arrives, their cattle do not find anything eat and die of starvation. And even if there is a rice field and that jatropha is planted by its side, they would have to make a long detour of 20 km to get to the rice field because it is forbidden to cross the jatropha plantations (Franchi, Rakotondrainibe, Raparison, & Randrianarimanana, 2013).

Ultimately, these real and/or perceived social issues could tarnish the brand image of shipping companies. Indeed, by adopting biofuels, shipping companies could contribute to the amplification of the social issues mentioned above. From this point onwards, it is possible to question the long-term social sustainability of biofuels.

4.1.3. Environmental

From the environmental perspective, biofuels hold numerous advantages over fossil fuels, as the use of biofuels have the potential to reduce GHG emissions. Nonetheless, quantifying the potential of GHG emissions reduction has been controversial. Some critics argue that advocates of biofuels do not take into account the entire life cycle of biofuels (de Jong, et al., 2017). In fact, biofuels affect the environment at all stages of their production: cultivation, land use, transport of feedstock, processing, transportation and distribution. Previous life-cycle assessments of biofuels show for instance, odours stemming from ethanol plant, nitrate appearing in the surface of waters due to the use of nitrogen fertilizers on the fields or even loss of biodiversity induced by land use (US National Research Council, 2012). The impacts start where peatlands or forests are converted into agricultural lands for the purpose of biofuels production (Gheewala, Damen, & Shi, 2013). The "carbon debt", created by the initial release of GHG emissions during the conversion of lands into palm oil plantations in Southeast Asia, can take centuries to pay back. It is assumed that the amount of CO_2 emitted by biofuels is counterweighted by the amount of CO_2 captivated by plants used during the growth process of the biomass. Nevertheless, allocating those plants to the production of biofuels does not remove additional CO_2 from the atmosphere and hence does not weigh out CO_2 emissions from burning that biomass. To illustrate this, we can use a scenario where biofuels do not exist: ships run on HFO (emitting high amount of CO_2) and farmers harvest for feed (which absorb CO_2). Now, when the crops that are dedicated to produce biodiesel are allocated to run ships, they do not absorb any supplementary amount of CO_2 emissions and ships would still emit roughly the same quantity of CO_2.

Additionally, planting biofuel feedstocks affect soil quality. On one hand, some biofuel crops such as jatropha help to reinstate soil quality, while others require a significant amount of nutrients and water. And with time, soil health and productivity deteriorate by over-cultivation (Marelli, et al., 2015). In addition to the direct change in land use, production of biofuel feedstock also displaces land for food crops production (Gheewala, Damen, & Shi, 2013). Among others, the impacts of climate change on land, such as desertification, may affect the plantations of feedstocks, either dedicated to food or biofuels (IPCC , 2017).

In a nutshell, on the political and legal aspects, legislation needs to be reinforced for biofuels to be implemented. Legislation needs to be applied at all levels, local, national and international for biofuels to be implemented on an international scale. With regards to socio-economic aspects, the production of biofuels can generate rural development through the creation of farming employment. Adversely, the production of biofuels can interfere with agricultural production of crops for feed, which in turn increases food price and further enhances poverty and hunger. Although biofuels have been proven to have the potential to reduce GHG emissions research has shown that they also have the potential to increase GHG emissions along their entire supply chain, from production to use. In addition, the production of biofuels also affects soil quality and water, through land-use. In other words, each stage in the life cycle of biofuels generates GHG emissions that affect air, water and air. For this reason, the benefits and drawbacks of fossil fuels and biofuels need to be compared with each other so that policymakers can determine which trade-offs are acceptable. Table 7 summarizes the benefits and drawbacks identified from the PESTLE analysis.

	Advantages	**Disadvantages**

Political and legal	High concentration of policies and regulatory framework in industrialized nations (e.g. Europe)	Insufficient legal framework on national and local levels that reinforce the implementation of biofuels; Lack of legal framework that regulate land grabbing and food security in developing countries
Socio-economic and technological	Creation of employment; development of rural areas	Fight for land; threat to food security; increase in food crop prices leading to poverty and hunger; high costs of biofuel production
Environmental	Reduction in GHG emissions; cleaner than fossil fuels	Adverse impacts on land, air, water and soil quality; threat to biodiversity

Table 7: PESTLE Analysis - implementation of biofuels. Compiled by Author

4.2. Interviews

Four in-depth semi-structured interviews, lasting 20 to 45 minutes were conducted. The respondents hold different backgrounds: shipping, logistics, engineering and academics. It is important to note that the responses obtained during the interviews are solely personal opinions and do not represent the standpoint of their respective organizations. In fact, the aim was to seek personal opinions in order to obtain an accurate representation of where shipping companies stand with regards to biofuels. Furthermore, the rationale behind choosing these respondents was to ensure the reliability and validity of the study as well as to be able to provide a comparison of opinions.

4.2.1. Respondents' characteristics

Shipping industry

Title: Deputy General Manager

Organization: Ranked Top 10 – World's Largest Shipping Companies (2018)

Logistics

Title: Country Manager

Organization: Ranked Top 10 – World's Largest Logistics Companies (2019)

Engineering

Title: PhD Candidate in Aeronautics Engineering

Organization: University based in Australia

Academia

Title: Professor, Geopolitical dimensions of Renewable Energy

Organization: University based in Madagascar

4.2.2. Interview findings

Q1. What is your opinion on the overall level of acceptance of biofuels in the shipping industry?

The respondents were first asked to give their opinions on the level of acceptance of biofuels in the shipping industry. In other words, the purpose of the first question is to obtain the respondents' perception of biofuels. Overall, the respondents stated that the shipping industry is rather in favor of biofuels. According to them, this positive outlook can be attributed mainly to the fact that biofuels contribute to the

> "Since the IMO has announced their targets to reduce GHG emissions to tackle climate change, the shipping industry has been experiencing a shift – a will to move towards greener shipping through the use of cleaner energy"
> General Deputy Manager at Top 10 of the World's Largest Shipping Companies

> "Biodiesel is biodegradable and the main advantage is that there is no major change in infrastructure required to implement them in the industry. Hence, current fleet are able to use biofuels today"
> Country Manager at Top 10 of the World's Largest Logistics Companies

achievement emission reduction targets set by the IMO, the effects of climate change and quest for building long-term sustainability. Nevertheless, the stance differs per region – for instance, Europe has started implementing biofuels in certain sectors, Nordic countries possess the appropriate technology and South America produces raw materials.

> "[…] however, there is a paradox: the high level of acceptance does not match the production levels of biofuels. In fact, the level of production does not match the level of positive outlook on biofuels"
> Professor at University based in Madagascar

For instance, France would like to put forward a green agenda but because there are no raw materials (e.g. sugarcane), there is a low level of biofuels production. Hence, this might refrain manufacturing industries to design engines to be compatible with biofuels – which is the case for the automobile industry in France. This implies the fact that biofuels may still have a long way to go before they can take over fossil fuels, due to the different levels of acceptance of biofuels across the world.

<u>Q2. Which criteria would influence your decision to implement biofuels, as a shipping company?</u>

The aim of this question was to find out how high costs production of biofuels could hinder their implementation in the shipping industry. For this matter, the respondents were asked to classify in order of importance the criteria that could influence the adoption of biofuels, including: affordability, availability, compatibility with current infrastructure and engines, legal compliance, reduction of ecological footprint and others. The majority of the respondents classified them in order of importance, as follows:

1. Legal compliance
2. Availability
3. Compatibility with current infrastructure and engines
4. Affordability
5. Reduction of ecological footprint

Given that legal compliance has been ranked first by most respondents, it implies the fact that the effective implementation of biofuels ideal scenario is where global institutions, policy-makers and Governments closely collaborate to impose stricter regulations in favor of the implementation of biofuels. In fact, the respondents stressed out that as long as the IMO imposes it on the industry, major players would not have any choice but to comply. Ranked in second place was the availability of biofuels in major ports. In general, ports with high levels of trade have frequent supply of bunkers, while smaller ports do not have the adequate infrastructure to supply fuel on a regular basis. For biofuels to be implemented on the global scale, it is important to ensure their availability at all ports. However, one of the respondents mentioned that the type of biofuels available would be dependent on the geographical location of the port. For instance, major ports in the US would supply first generation biofuels due to their proximity to feedstock in South America; while major ports in Scandinavia would supply second generation of biofuels (i.e. sourced from waste) because they hold the appropriate technology. Following this, compatibility with current infrastructure came in third place. The latter holds less importance because biofuels, in particular biodiesel, does not require much infrastructure renovation in order to be compatible with ships. Indeed, respondents stated that ships travel long distances and hence need to stay a constant speed. For this matter, diesel engines are more efficient for this configuration and it is the main reason why most ships are powered with diesel engines. However, the challenge is that it will take time because it is the entire global supply chain that would need to be altered. The affordability of biofuels comes in fourth rank. This is mainly due to the fact that shipping companies would still have to move cargo in order to satisfy their customers' demand – regardless of the price of the fuels. Lastly, the results of the classification found that the reduction of ecological footprint is the least important. All respondents share the same opinion that the sole purpose of a shipping company is to make profit; and hence if it is not required by law, they would go for the most cost-effective alternative.

Q3. What is your opinion on the social acceptance of biofuels, in particular in developing countries?

> "80% of farmers are in the agribusiness sector but we still do not have enough to meet the food demand in the country […] And in fact, we import 400 000 tonnes of rice / year – which accounts for up to 60% of local consumption of rice […] they even ceased the cotton processing operations in the South of the country because it is not dedicated to food consumption."
> General Deputy Manager at Top 10 of the World's Largest Shipping Companies

> "[…] it takes so much land space to produce biofuels. The third generation of biofuels, produced from waste, would take less space of land in comparison to first generation. Nevertheless, it is still a big challenge because of the storage capacity: instead of using warehouses to store food, we would use them to store biofuels"
> Country Manager at Top 10 of the World's Largest Logistics Companies

The responses to this question were rather negative than positive. Respondents have highlighted the sensitivity of the production of biofuels, particularly because it clashes with other markets such as food production and land. In some developing countries, the protection of the environment or the reduction of ecological footprint is not seen as a priority yet, both on the local and national levels. In other words, the majority of the population in developing countries are not environmentally conscious. Instead, the fight against poverty and hunger are still on top of the agenda. On one hand, the respondents gave the example of how some developing countries do not understand the impacts of deforestation. For this reason, a switch to biofuels would require developing countries to see an evident economic advantage for doing so. Furthermore, the respondents stated that "there would be a clash with food production because there are no policies supporting food production as the Government is barely making land available for it in that sense […] Hence, as long as there is a high level of hunger, the focus for farmers would always be on food production". Moreover, if biofuels were to be implemented on a global scale, there might be a surplus in demand for biofuels. In other words, the quantity of feedstock produced might not meet the quantity of demand for biofuels, as most of the feedstock would be dedicated to food supply.

Q4. Are there enough technological efforts deployed towards the development of biofuels?

> "There is a lack of incentives for shipping companies to develop, research and innovate towards biofuels."
> General Deputy Manager at Top 10 of the World's Largest Shipping Companies

The respondents were asked to give their opinion on the levels of investments, research and development allocated to biofuels. The rationale behind the question was to identify the Technological Readiness Level of the industry towards biofuels. The majority of the respondents expressed that the level of technological development towards biofuels is rather low, in comparison to other alternatives. LNG has been popular because it is cost-efficient, according to them. For this reason, as long as biofuels are more expensive than fossil fuels then no research and development would be allocated to biofuels. Another reason for the low technological investments is the lack of land to cultivate feedstock and the obvious clash between biofuels production and food production. For this reason, their responses entail the fact that global commitment towards biofuels should start from the Government, creating incentives that push R&D.

Q5. To which extent do you think biofuels contribute to the reduction of GHG emissions?

The rationale behind this question was to find out to which extent biofuels could help achieve IMO 2050. All respondents agreed that biofuels can undeniably reduce GHG emissions by 25% at least. Nevertheless, biofuels would only be implemented post 2025 because other alternatives are still available at a cheaper price today. In fact, biofuels still have a long road to go before they can reach their full implementation in the shipping industry, which might take more than 20 years from now. From a technical point of view, the amount of CO_2 emissions released throughout the value chain of biofuels can be monitored and controlled with the correct processing technology.

Q6. Do you think international institutions are doing enough to meet IMO 2050?

The rationale behind the question asked to find how the current mitigation policies affect the implementation of biofuels. Respondents agreed that policies exist but they are not strict enough to encourage the implementation of biofuels. For instance, the recent G20 Summit where the US did not agree to cooperate with the proposed environmental plan, because they have their own source of energy. In other words, political dimensions are involved in the establishment of environmental agenda. Additionally, regulations are mandatory in some countries (e.g. Europe) and are not in other places (e.g. Africa). This imbalance creates a disparity in the commitment of shipping companies to sustainable development on a global level.

The final question required the respondents to score the likelihood of the implementation of biofuels in the shipping industry, on a scale of 5. On average, respondents answered 3 (moderate) on the short to medium term. However, if the institutional framework gets stricter and offer a compensation for food production as well as encourages efforts towards R&D and innovation, biofuels may take over fossil fuels on the long-term.

4.3.Scenario building

4.3.1. System of the business environment

As previously mentioned, the system of the business environment identifies the different stakeholders and enables to grasp a better understanding of how the interactions between them have an impact on each other. Figure 8 illustrates the system of the business environment in which shipping companies operate.

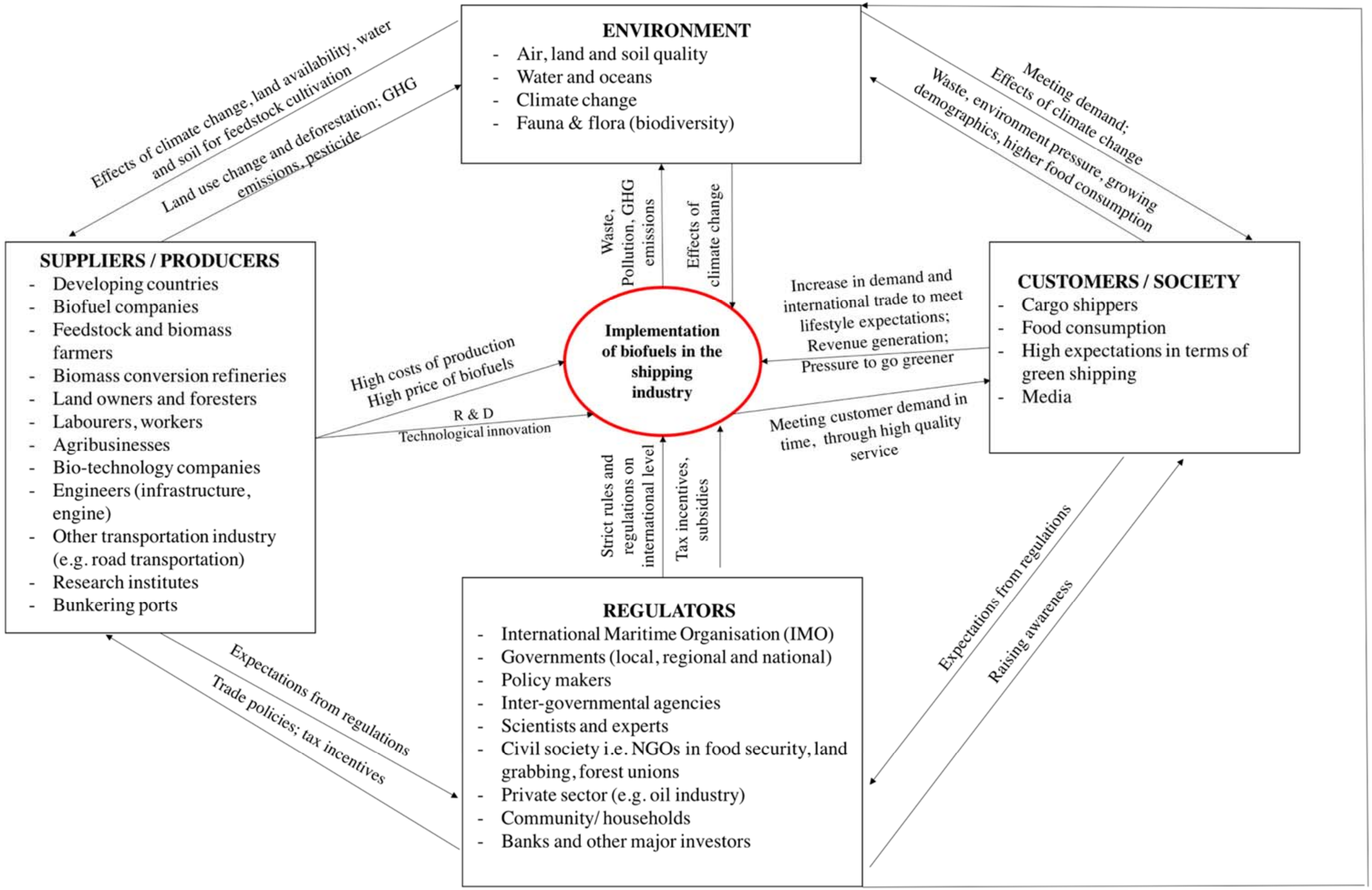


Figure 8: System of shipping companies' business environment. Compiled by Author.

In the scope of the present dissertation, the shipping industry comprises of major shipping companies, as well as smaller actors that offer maritime transport such as ferries or taxi boats. The stakeholders that have a direct involvement with the shipping industry have been identified based on the Triple Bottom Line: environmental, social and economic (Elkinjton, 1998). In fact, the system illustrated above encompasses stakeholders from the three categories of the Triple Bottom Line. Along the supply chain, the stakeholders directly associated with the shipping industry are suppliers and customers. In Figure 8, suppliers mainly include feedstock and biomass farmers, land owners, biofuel producers and biomass conversion refineries, bunkering ports, research institutes, engine and infrastructure manufacturers as well as other transportation sectors. These stakeholders determine the availability, affordability and compatibility of biofuels in the shipping industry. Suppliers also have expectations from regulators, in terms of subsidies; but have a negative impact on the natural environment through land use, GHG emissions, and other forms of pollution. On the other hand, customers include shippers, increasing levels of demographics as well as the media. Both the population and media have a positive influence on the demand for international trade. In fact, media has enhanced globalisation through the faster spread of information, which led to societies converging towards similar lifestyles (Chrisman, 2013). In turn, similar lifestyles entail the fact that the demand for the same goods in different parts of the world is almost similar. For this reason, they have high expectations from shipping companies to meet their demand in goods. Nonetheless, growing demographics are putting pressure on the natural environment as resources are becoming scarce. In turn, the natural environment responds to these economic and social pressures with climate change. The latter has impacts on all stakeholders in the system: ecosystems, health, economic development, regulatory framework and the long-term sustainability of businesses (Linnenluecke & Griffiths, 2015). Finally, regulators were added in the system because the international regulatory framework is also considered as one of the main drivers of change and adaptation. Besides, international institutions have the power to encourage the adoption of biofuels in the shipping industry.

4.3.2. Identification of trends with the highest impacts

From the literature review and the PESTLE Analysis conducted, the trends that would most likely have the highest impacts on the implementation of biofuels in the shipping industry are:

a) Regulations and legislation
b) World population growth and increase in international trade

c) Inclination of shipping companies towards biofuels
d) Investment and research allocated to biofuels

4.3.3. Plausible futures based on trends

a) Regulations and legislation:

- Baseline: no mitigation policy measures that are implemented beyond that are already in force and / or legislated or planned to be adopted
- Stricter regulations set by Governments and the IMO

b) World population growth and increase in international trade

- World population increase leading to food demand surplus and the need for more international trade
- Steady population growth; equilibrium in food demand and supply

c) Inclination of shipping companies towards biofuels

- Minimum preference towards biofuels
- High preference biofuels

d) Investment and research allocated to biofuels

- R&D and innovative solutions in favour of the implementation of biofuels production
- Lack of investments towards the production of biofuels

4.3.4. Establishing scenarios

The final step involves establishing the scenarios. In line with the methodology, a matrix can be created in order to generate different scenarios from it. Figures 9 & 10 illustrate respectively Matrices 1 & 2.

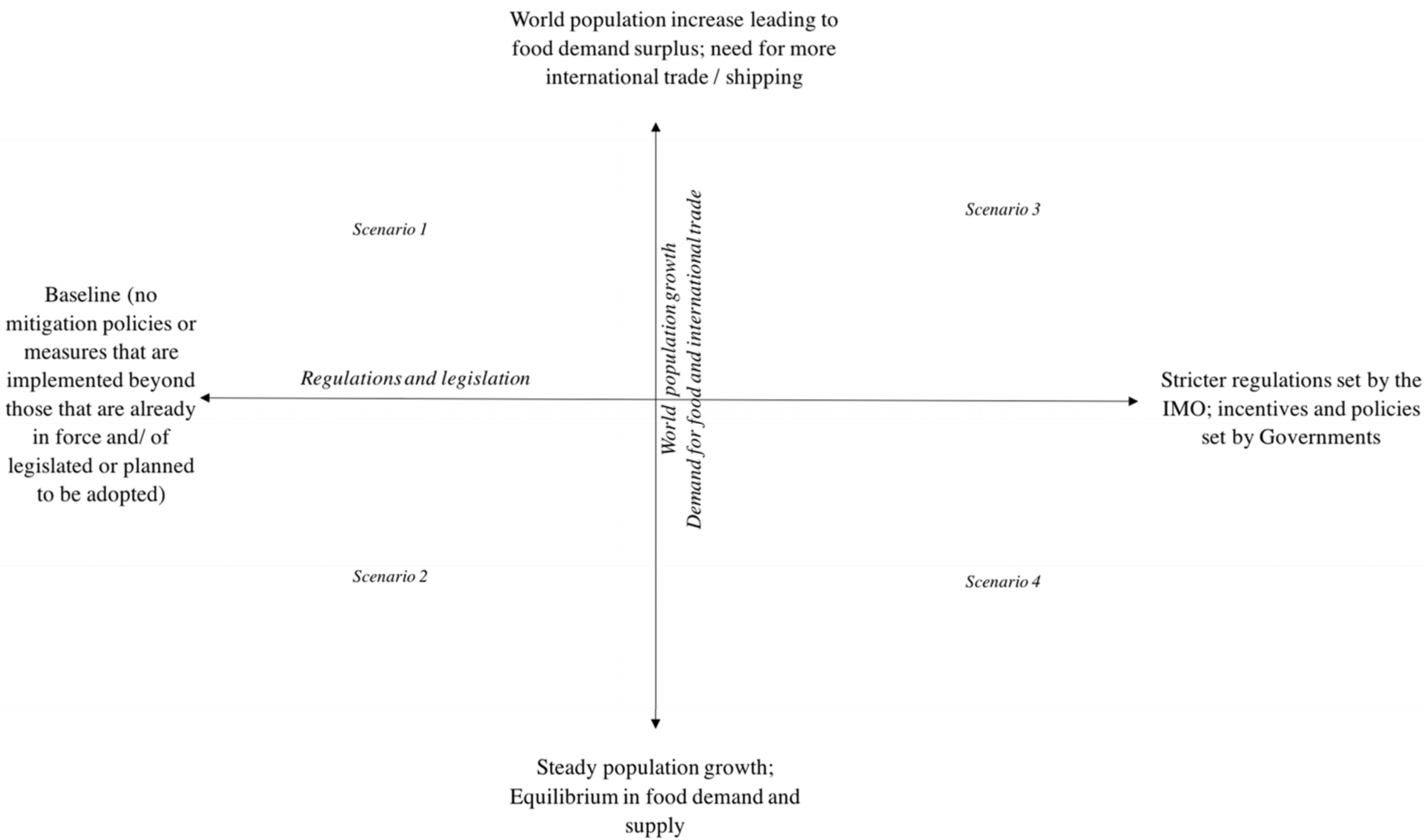


Figure 9: Matrix 1 - Scenarios 1 to 4. Compiled by Author

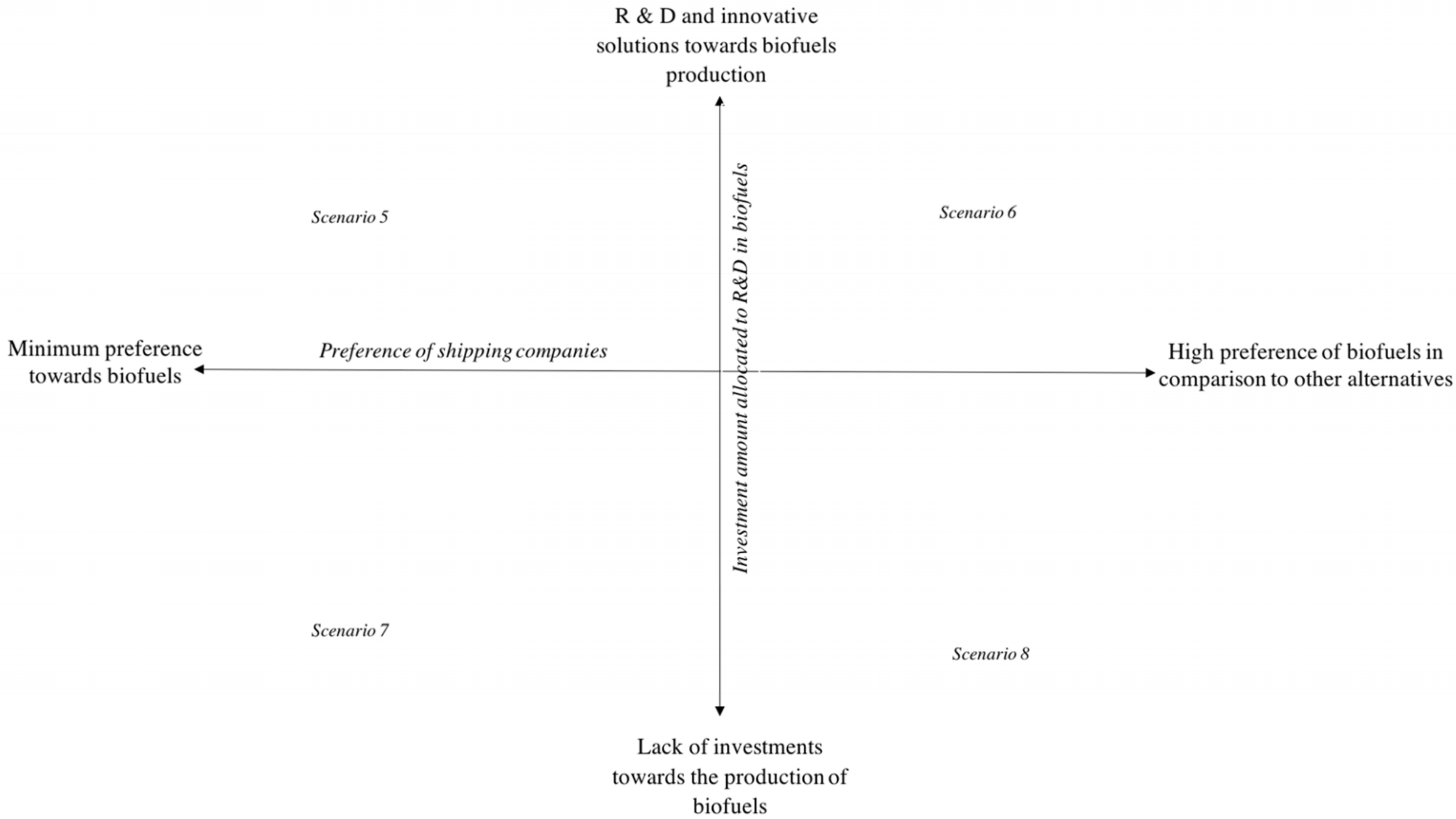


Figure 10: Matrix 2 - Scenarios 5 to 8. Compiled by Author

In Figure 9, Matrix 1 is the combination of world population growth with regulations and legislation. The reason why these trends were combined is because the PESTLE analysis showed that one of the socio-economic challenges is the clash between food production and biofuels production. For this matter, regulatory framework is the most efficient tool to ensure that biofuels production does not interfere with other sectors.

In Figure 10, Matrix 2 is the combination of the inclination of shipping companies towards biofuels and the amount of investment allocated to the production of biofuels. The reason why these trends were combined is because the PESTLE analysis showed that the production costs and price of biofuels depend on the technological process adopted. In other words, R&D can drive the cost-effectiveness of biofuels. Ultimately, shipping companies would be more inclined towards the adoption of biofuels as the prices go down.

These combinations of factors were found to be the most relevant to the research questions and objectives within the context of the present dissertation.

4.4.Data interpretation and analysis

This section presents the commonalities between findings of the interviews, Literature Review and the PESTLE analysis. These commonalities were compiled into three different themes. The themes can also serve as answers to the research questions. Theme one addresses the first research question on the industry's perception on biofuels. The second theme addresses the research question on the social and environmental challenges hindering the adoption of biofuels. And the final theme addresses the remainder of the questions on how the production costs, technological level readiness and mitigation policies affect the implementation of biofuels.

<u>Theme One. The overall positive outlook of biofuels in the shipping industry can be attributed to the several economic, environmental and social advantages that their production generates.</u>

Interviews	PESTLE Analysis	Literature Review
The shipping industry is rather in favor of biofuels for several reasons. The positive outlook can be attributed mainly to the emission reduction targets set by the IMO, the effects of climate	The use of biofuels can generate many advantages to shipping companies: meeting customers' expectations on adopting a greener agenda, reducing GHG emissions, and achieving legal	To adapt to the changing environment, the shipping industry needs to find the balance between the main three pillars of sustainability: social, economic and environmental (Purvis, Mao,

change and the quest for building long-term sustainability. In addition, the respondents were confident that biofuels can help reduce GHG emissions to a certain extent, of at least 25%. Moreover, biofuels are already compatible with most of the current infrastructure which entails the fact replacement costs would not be too high.	compliance – which ultimately enhances the company's brand image. On the wider community, the production of biofuels enhances rural development and job creation. In fact, biofuels production can be considered as a window of opportunity for developing countries as they possess favorable weather conditions and low-cost labor.	& Robinson, 2019). Biofuels are preferred to fossil fuels given their sustainable and renewable feature, their biodegradability aspect, their abundant local availability, their potential to create more farming jobs, their contribution to rural development as well as their ability to reduce GHG emission (Demirbas A. , 2009; IEA, 2016).

Theme Two. The challenges hindering the implementation of biofuels are linked to (1) land (2) food production (3) environmental externalities

Interviews	**PESTLE Analysis**	**Literature Review**
The main issue related to the production of biofuels is that there is not enough land available that could be dedicated to the production of feedstock. Instead, land is allocated to food production. For the production of biofuels, feedstock / raw materials can be produced in mostly developing countries. However, hunger is one of the most predominant issues in developing countries. For this matter, the production of	Biofuels may have a negative social perception attached to them, which may tarnish their users' brand image on the long-term. First, farmers in developing countries rely on their land for their livelihood. Hence, when land is taken to cultivate feedstock for, it enhances poverty and hunger. Third, cultivating feedstock for the purpose of biofuels production leads environmental trade-offs. In	CO_2 emitted from combustion of biofuels is considered neutral because the amount of CO_2 emitted during the combustion of biofuels is equivalent to the amount of CO_2 captured by the plants during their growth. However, it is important to note that the environmental impacts of biofuels are dependent on the biomass used during the production process. In fact, the production of biofuels

biofuels would clash with food production sector and would only enhance poverty and hunger. Governments and policy-makers are not regulating the food production sector in this matter.	fact, it deteriorates soil quality and depletes water reserves. In addition, CO_2 emissions are leaked throughout the value chain production.	could have adverse impacts on the environment.

Theme Three. Legal framework and policy-makers play a crucial role in the implementation of biofuels in regulating production and creating incentives for R&D in the shipping industry

Interviews	**PESTLE Analysis**	**Literature Review**
Findings from the interviews conclude that regulations play a crucial role in the implementation of biofuels. Regulations need to be put in place and reinforced at all levels, local and national, in all parts of the world. The regulation with regards to land particularly needs to be developed because it threatens the livelihoods of farmers and clashes with food production. Furthermore, Governments play a crucial role in allocating technological investments in order to make biofuels cost-competitive and cost-effective.	The implementation of biofuels in the shipping industry requires the involvement of many stakeholders. Hence, it is crucial to develop stricter regulations that would encourage stakeholders, both on the global and national levels. In fact, countries that have incentivized the use and the production of biofuels have witnessed their successful implementation.	The current regulations set by the IMO and other institutional bodies do not specifically indorse the implementation of biofuels. Instead, they leave the choice to shipping companies on how they would like to comply with the regulations. This leads to a lack of R&D in biofuels. And instead, the private sector is accountable for investing in biofuels. For instance, Pension Denmark invested £160 million in the construction of a biomass power plant (ETIP Bioenergy, 2019).

4.5.Scenario analysis

The themes that have emerged from the data collected helped to raise awareness on the dynamics that are happening in the shipping industry and to understand how the stakeholders interpret what they see in the business environment. In light of this, the scenario that best describes where the industry stands with regards to biofuels could be identified. Following this, the emerged themes also highlighted what the desirable scenarios are the unlock an effective implementation of biofuels.

Figure 11 shows that Scenario 1 is where the shipping industry currently stands with regards to biofuels. Scenario 1 explores the situation where there are no mitigation policies that are applied beyond those that are already in force or/ and planned; and where world population increases – which leads to higher food demand and the need for more international trade / shipping. In fact, the data collected from literature review, PESTLE analysis and interviews commonly show that there are no policies or measures being planned beyond those that are already in place. Plus, the literature review predicted an increase in world population and in shipping in the future. For an effective implementation of biofuels in the shipping industry, the desirable scenario is Scenario 4 where regulations get stricter, both on the international and national levels; and where there is an equilibrium for food demand and supply. In line with Theme 3, Scenario 4 has been identified as the desirable scenario because legal framework and policy-makers play a crucial role in facilitating the implementation of biofuels, through sanctions, incentives and subsidies. Similarly, regulations and policies are an essential tool to oversee the interference of biofuels production with food production – which ultimately can lead to finding an equilibrium between food demand and supply.

Figure 12 shows that Scenario 7 is also where the shipping industry stands. Scenario 7 demonstrates the situation where shipping companies prefer other fuel alternatives (e.g. LNG) over biofuels and there is a lack of investments towards the production of biofuels. Although Theme 1 of the findings states that there is an overall positive outlook for biofuels, their implementation still holds a range of challenges. For instance, Theme Two explains the different social and environmental challenges associated with the production of biofuels. Similarly, the low levels of investments allocated to the production of biofuels have an impact on their affordability, availability and compatibility with ships. In this matrix, the desirable scenario is Scenario 6, where there is sufficient R & D in biofuels which would lead to a higher level of preference for biofuels. The higher level of preference would mainly be attributed to the cost-effectiveness of biofuels.

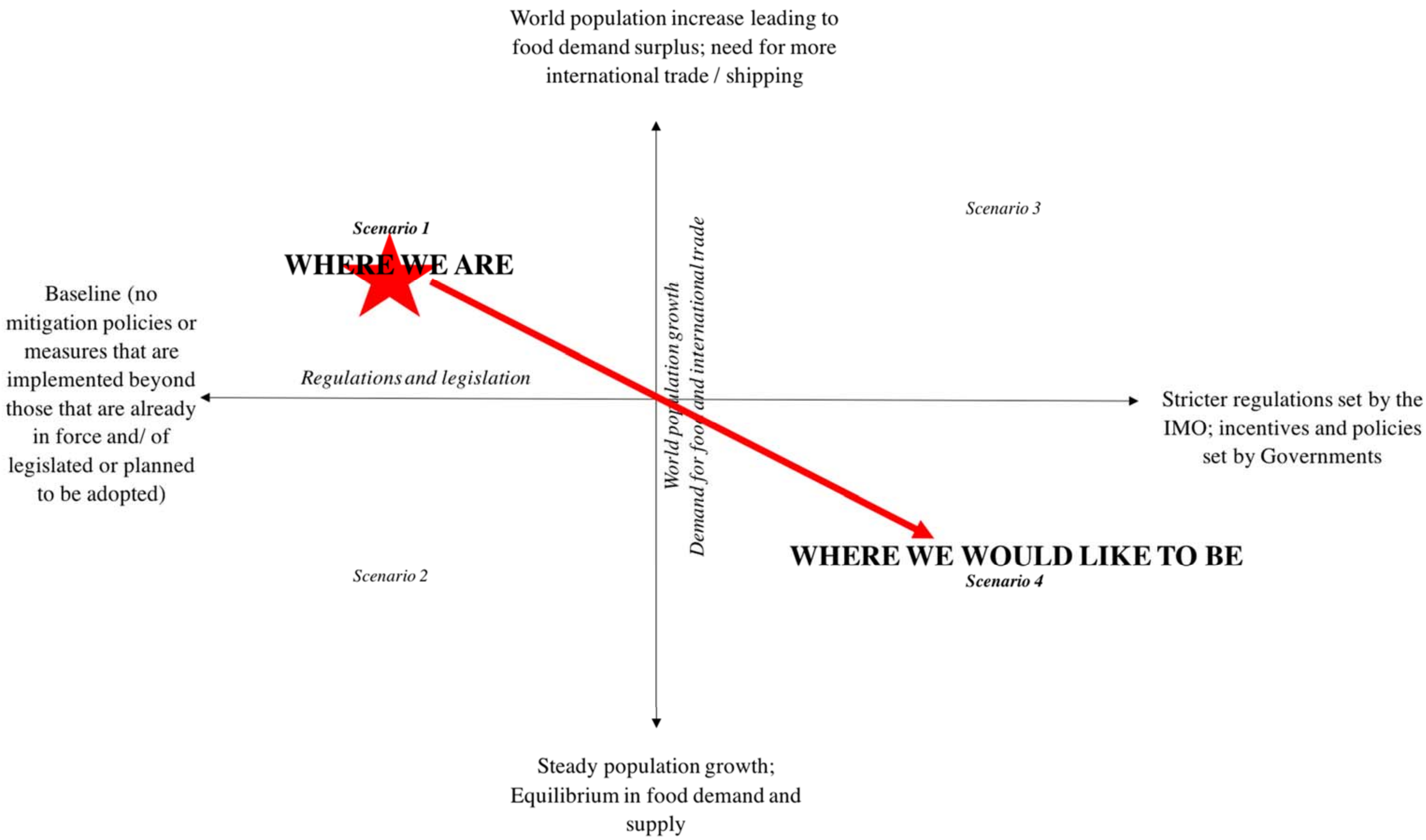


Figure 11: Scenario Analysis 1. Compiled by Author

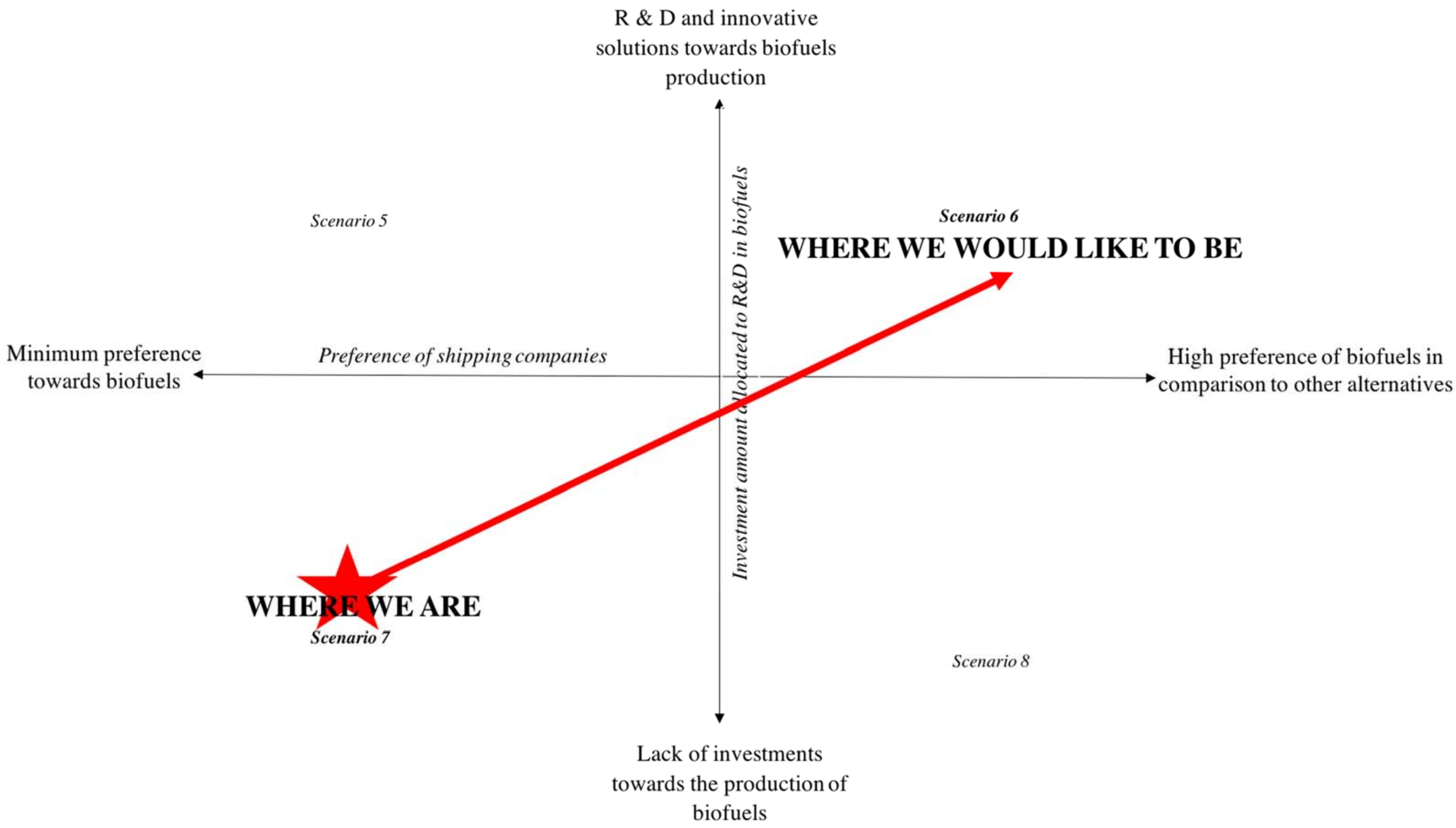


Figure 12: Scenario Analysis 2. Compiled by Author

5. CONCLUSIONS, RECOMMENDATIONS AND FUTURE RESEARCH

The aim of this dissertation was to identify the most influential factors that would enable the effective implementation of biofuels by shipping companies. The commonalities between the findings of the literature review, the PESTLE analysis and the interviews were compiled into themes. These themes can serve as answers to the research questions. First, the overall outlook of biofuels in the shipping industry can be attributed to the several economic, environmental and social advantages that their use generates. Nonetheless, the implementation of biofuels does not come without challenges which are primarily linked to land, food production and poverty as well as environmental externalities. For this reason, Figure 13 describes that a rigorous legal framework plays a crucial role in the implementation of biofuels in regulating biofuels production and consumption as well as in creating incentives for research and development. This latter will unlock innovation that will drive down production costs of biofuels. Similarly, a rigorous legal framework would tackle social and environmental challenges associated with biofuels production, including land grabbing, food production and other environmental externalities. Ultimately, this will lead to an enhanced brand image for shipping companies. The themes were also used to identify the scenarios where the shipping industry currently stands and the desirable scenarios where the situation would facilitate the effective implementation of biofuels.

To reach the desirable scenarios, the following recommendations can be implemented:

- ⇨ Governments and policy makers need to develop a regulatory framework that are tailor-made to each country's social and economic context. For instance, biomass producing countries need to implement legislation regarding land, as the local population mostly rely on agriculture for their livelihoods. In developed countries, where the technology is available, policy makers need to create incentives in order to encourage the adoption of biofuels.
- ⇨ Tax incentives need to be applied both on the producer and consumer's sides in the shipping industry.

- ⇨ Foreign companies that outsource to developing countries need to gear towards supporting local communities and employment. For this reason, they are encouraged to develop local talents in order to increase national employability and therefore improve living standards; which ultimately leads to alleviating poverty.
- ⇨ To preserve biodiversity, constantly look for innovative processing technologies that have the minimal impact on the environment and livelihoods.

For future research purposes, it would be essential to establish strategies on how to apply the above suggested recommendations.

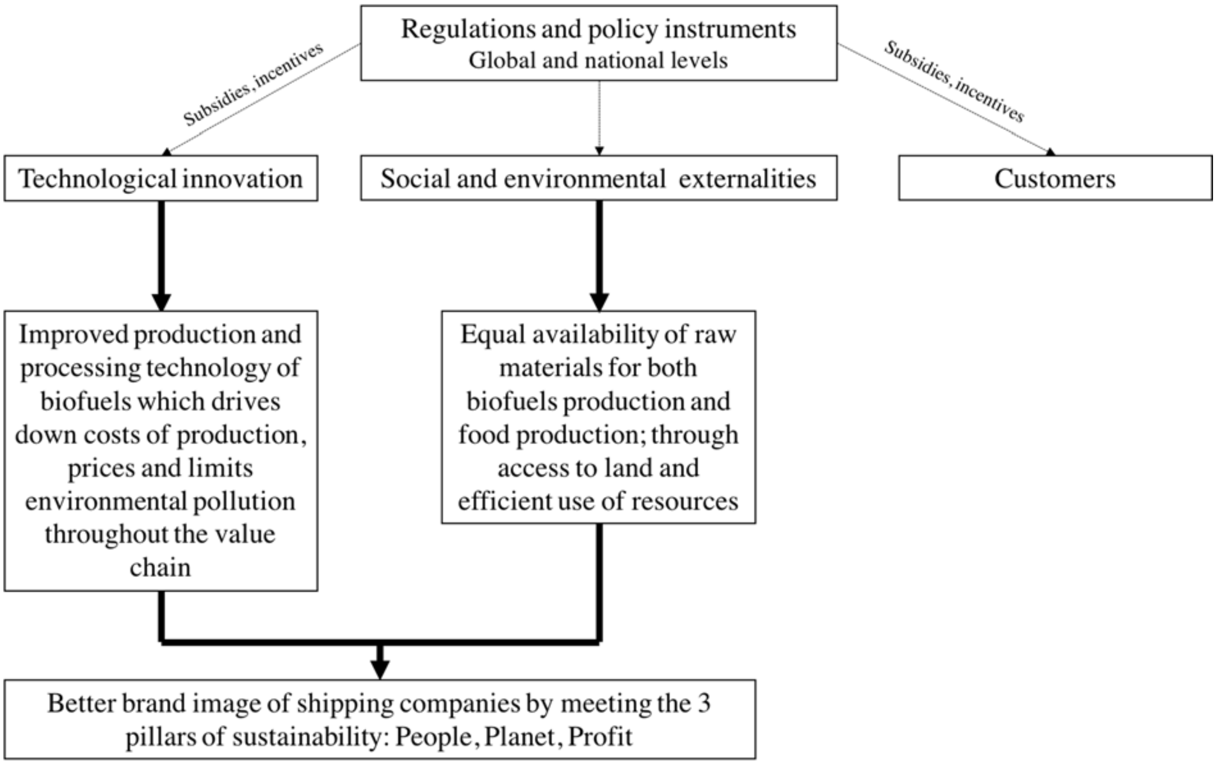


Figure 13: Framework enabling the effective implementation of biofuels. Compiled by Author.

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Appendix A

INTERVIEW QUESTIONS

<u>BACKGROUND</u>: The international regulating body of the shipping industry is the International Maritime Organisation (IMO). Being one of the most polluting industries in the world, the shipping industry is currently under pressure to meet the social and environmental targets including: Paris Climate Change Agreement, IMO 2020 (sulphur cap of 0.5%), IMO 2050 (50% reduction of CO_2 by 2050). One of the options for adaptation is the use of alternative fuels, namely biofuels. The following interview consists of collecting opinions from relevant stakeholders in order to assess the feasibility of the implementation of biofuels in the maritime transportation sector.

I. <u>Level of acceptance</u>

1. What do you think the level of acceptance towards biofuels in the maritime transportation industry?
2. How does demand for other alternatives affect demand for biofuels?

II. <u>Economic</u>

Among the following criteria which influence the implementation of biofuels, please rate them in order of importance:

- Affordability
- Availability
- Compatibility with current infrastructure and engine
- Legal compliance
- Reduction of ecological footprint
- Others

III. <u>Social</u>

1. What is your opinion on the social acceptance levels of biofuels in developing countries i.e. land grabbing, conflict with food security, enhancing world hunger
2. Do you think the predicted increase in demand for maritime transportation has an influence on the adoption of biofuels in the shipping industry? Why?

IV. Technology

1. In your opinion, are there enough efforts made towards the implementation of biofuels?
2. If not, what do you think should be changed?

V. Environmental

1. To what extent do you think biofuels contribute to the reduction of CO_2?

VI. Legal

1. How does the current mitigation policies affect the implementation of biofuels?
2. Do you think international institutions are doing enough to reinforce / meet GHG reduction goals?
3. In your opinion, are the current regulations strict enough to push for the implementation of biofuels